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Remedial Investigation/Feasibility Study for Comprehensive Environmental Response, Compensation, and Liability Act Oak Ridge Reservation Waste Disposal Oak Ridge, Tennessee

This document is approved for public release per review by:

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Contributed to the preparation of this document and should not be considered an eligible contractor for its review.

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Date Issued – March 2016

Prepared by
Professional Project Services, Inc. (Pro2Serve®)
Oak Ridge, Tennessee

Prepared for the
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Office of Environmental Management

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ACRONYMS

ALARA	as low as reasonably achievable
ALR	action leakage rate
ARAP	Aquatic Resources Alteration Permit
ARAR	applicable or relevant and appropriate requirement
ARRA	American Recovery and Reinvestment Act of 2009
ASA	Auditable Safety Analysis
AWQC	ambient water quality criteria
BCV	Bear Creek Valley
BCBG	Bear Creek Burial Grounds
BHHRA	Baseline Human Health Risk Assessment
BMP	best management practice
BNSF	Burlington Northern Santa Fe
BV	Bethel Valley
BY/BY	Boneyard/Burnyard
CARAR	Capacity Assurance Remedial Action Report
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR	Code of Federal Regulations
COPC	contaminant of potential concern
CWA	Clean Water Act of 1977
D&D	deactivation and decommissioning
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DQO	data quality objectives
DU	depleted uranium
EBCV	East Bear Creek Valley
ELCR	Excess Lifetime Cancer Risk
EM	Office of Environmental Management
EMDF	Environmental Management Disposal Facility
EMWMF	Environmental Management Waste Management Facility
EPA	U.S. Environmental Protection Agency
ETTP	East Tennessee Technology Park
FFA	Federal Facility Agreement
FFS	Focused Feasibility Study
FS	Feasibility Study
FWD	Federal Waste Disposal

FY	Fiscal Year
GCL	geosynthetic clay liner
HCDA	Hazardous Chemical Disposal Area
HDPE	high-density polyethylene
HI	Hazard Index
IFDP	Integrated Facility Disposition Program
IHB	Indiana Harbor Belt
IWM	Integrated Water Management
K	hydraulic conductivity
LCRS	leachate collection and removal system
LDR	land disposal restriction
LDRS	leak detection and removal system
LFRG	Low-Level Waste Disposal Facility Federal Review Group
LLW	low-level waste
LLWDDD	Low-Level Waste Disposal Development and Demonstration
M	million
MCC	Modular Concrete Canister
MCL	Maximum Contaminant Level
MEI	maximum exposed individual
MLLW	mixed low-level waste
MV	Melton Valley
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEPA	National Environmental Policy Act of 1969
NNSA	National Nuclear Security Administration
NNSS	Nevada National Security Site
NRC	Nuclear Regulatory Commission
NT	Northern Tributary
OMB	Office of Management and Budget
OREM	Oak Ridge Office of Environmental Management
ORERP	Oak Ridge Environmental Research Park
ORNL	Oak Ridge National Laboratory
ORO	Oak Ridge Office
ORR	Oak Ridge Reservation
ORSSAB	Oak Ridge Site Specific Advisory Board
OSHA	Occupational Safety and Health Administration
PCB	polychlorinated biphenyl
PCCR	Phased Construction Completion Report

PM	particulate matter
PPE	personal protective equipment
PreWAC	preliminary Waste Acceptance Criteria
PWTC	Process Waste Treatment Complex
RAO	remedial action objective
RAWP	Remedial Action Work Plan
RCRA	Resource Conservation and Recovery Act of 1976
RDR	Remedial Design Report
RI	Remedial Investigation
ROD	Record of Decision
RWCM	Radioactive Waste Management Complex
S&M	surveillance and maintenance
SDWA	Safe Drinking Water Act of 1974
SPCC	safety and spill prevention, control, and countermeasures
SPSA	Southeastern Public Service Authority
SR	State Route
SRF	size reduction facility
T&E	threatened and endangered
TBC	to be considered
TCLP	toxicity characteristic leaching procedure
TDEC	Tennessee Department of Environment and Conservation
TRU	transuranic
TSCA	Toxic Substances Control Act of 1976
TSDRF	treatment, storage, disposal, and recycling facility
UCL	upper confidence limit
UEFPC	Upper East Fork Poplar Creek
UPF	Uranium Processing Facility
U.S.	United States
USGS	U.S. Geological Survey
VR	volume reduction
WAC	Waste Acceptance Criteria
WBCV	West Bear Creek Valley
WCS	Waste Control Specialists LLC
WGF	waste generation forecast
WIPP	Waste Isolation Pilot Plant
WL	waste lot
WMI	Waste Management, Inc.

WWSY	White Wing Scrap Yard
Y-12	Y-12 National Security Complex

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EXECUTIVE SUMMARY

This Remedial Investigation/Feasibility Study (RI/FS) report evaluates disposal alternatives for future waste generated by cleanup actions at the United States (U.S.) Department of Energy's (DOE) Oak Ridge Reservation (ORR) and associated sites. The report follows previous Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) evaluations, decisions, and actions that resulted in an existing on-site disposal facility, referred to as the Environmental Management Waste Management Facility (EMWMF). Because EMWMF will reach capacity before all estimated ORR cleanup waste has been generated and dispositioned, DOE has determined the need to evaluate disposal alternatives for future CERCLA waste.

As the lead agency for ORR cleanup, DOE is working with the other Federal Facility Agreement (FFA) parties (DOE 1992), the U.S. Environmental Protection Agency and the Tennessee Department of Environment and Conservation, to evaluate alternatives for disposal of low-level waste (LLW), mixed waste, and certain classified waste. Mixed waste has components of radiological and other regulated waste, such as Resource Conservation and Recovery Act of 1976 (RCRA) hazardous waste and/or Toxic Substances Control Act of 1976 (TSCA) regulated waste. In addition to satisfying CERCLA requirements, this RI/FS incorporates National Environmental Policy Act of 1969 (NEPA) values in accordance with the DOE's Secretarial Policy on NEPA (DOE 1994).

This report serves as the initial document supporting DOE's selection of a preferred alternative for CERCLA waste disposition post-EMWMF. The EMWMF RI/FS (DOE 1998) was the first document in the CERCLA process that led to the construction and operation of EMWMF. This RI/FS utilizes relevant information from the EMWMF RI/FS with revisions and updates to describe and analyze current conditions. Alternatives analyzed include:

1. **No Action Alternative:** No coordinated ORR effort would be implemented to manage wastes generated by future CERCLA actions.
2. **On-site Disposal Alternatives:** Consolidated disposal of most future waste in a newly-constructed, engineered waste disposal facility (i.e., landfill) on the ORR, referred to as the Environmental Management Disposal Facility (EMDF). Although referred to in much of the text as the On-site Disposal Alternative, this alternative is actually three independent alternatives with on-site disposal at different sites. The proposed EMDF sites are located in Bear Creek Valley, bounded to the west by State Route 95 and to the east by the Y-12 National Security Complex.
3. **Off-site Disposal Alternative:** Two options that consider transportation and disposal of future waste at approved, off-site disposal facilities using mechanical size reduction for one of the options.
4. **Hybrid Disposal Alternative:** A combination of 2 and 3 above, one small on-site landfill (EMDF) providing disposal for a limited volume of future waste using mechanical size reduction, with the remainder of the waste transported and disposed at approved, off-site disposal facilities.

RI/FS APPROACH

Unlike a typical remediation project, the purpose of this RI/FS is not to evaluate alternatives for cleaning up a contaminated site. The purpose of this RI/FS is to develop, screen, and evaluate the alternatives for waste disposal against CERCLA criteria designed to address statutory requirements and feasibility. The RI/FS provides support for an informed selection decision about disposal of CERCLA waste.

Remedial decisions for cleanup of individual sites are outside the scope of this evaluation; consequently, a conventional Baseline Human Health Risk Assessment is not relevant to the RI/FS evaluation. For the remediation projects that will generate future waste streams to be disposed after EMWMF reaches maximum capacity, the RI/FS lists the applicable existing CERCLA documents that contain risk evaluations and identifies the projects for which a CERCLA risk evaluation and decision document have yet to be completed.

The remedial action objectives (RAOs) for alternatives evaluated in this RI/FS are:

- Prevent exposure of human receptors to CERCLA waste (or contaminants released from the waste into the environment) that exceeds a human health risk of 10^{-4} to 10^{-6} Excess Lifetime Cancer Risk (ELCR) or Hazard Index (HI) of 1.
- Prevent adverse impacts to water resources or unacceptable exposure to ecological receptors from CERCLA waste contaminants through meeting chemical-, location- and action-specific applicable or relevant and appropriate requirements (ARARs), including RCRA waste disposal and management requirements, Clean Water Act Ambient Water Quality Criteria for surface water in Bear Creek, and Safe Drinking Water Act Maximum Contaminant Levels in waters that are a current or potential source of drinking water.

The development and analysis of alternatives for the RI/FS relies on the established RAOs and estimates of future waste volumes and characteristics.

WASTE VOLUMES AND CHARACTERIZATION

This RI/FS presents waste volume estimates for future CERCLA waste disposal, including generation rates and information about waste characteristics of future CERCLA waste streams. The waste volumes and characterization are used as the basis for development and analysis of the disposal alternatives.

For the RI/FS waste volume estimates, waste streams are delineated by both waste type (regulatory classifications) and material type (waste forms). Waste types are LLW and mixed waste with components of radiological and other regulated waste (LLW/RCRA, LLW/TSCA). Material types may consist of various forms of soil and debris. Soil includes soil, sediment, and sludge. Debris includes a mixture of various forms of construction and demolition debris. For the RI/FS evaluation, material types are defined as either soil or debris with no further definition of soil or debris type. This approach is consistent with many waste volume estimates for future projects that delineate material types as soil or debris only.

The "as-generated" waste volume estimate was developed by using existing Waste Generation Forecast data and modifying it for use in the RI/FS. Updated waste volume estimates for specific projects were used where available. Projects and corresponding waste volume estimates were sequenced based on an assumed funding scenario of $420 Million (M) per year for ORR cleanup projects, with ORR CERCLA waste generation occurring through Fiscal Year (FY) 2043.

The "as-generated" waste volume estimate was used to calculate the "as-disposed" waste volume estimate in order to predict when maximum EMWMF capacity would be reached. Cumulative CERCLA waste capacity demand estimates through FY 2043, including a 25% uncertainty allowance, show maximum capacity of EMWMF (2.18 M yd^3) is estimated to be reached in FY 2024. Based on these estimates, the On-site Disposal Alternatives assume a new CERCLA waste disposal facility is operational in FY 2022, providing up to a two-year overlap of the facilities to allow operational flexibility. In addition to uncertainty in future waste volume estimates, other factors such as funding, project sequencing, and contracting can impact project implementation plans and the RI/FS waste volume estimates. A lower annual funding scenario could delay EMWMF reaching maximum capacity and the operational start of a new facility. Likewise, a higher funding scenario could result in EMWMF reaching capacity sooner.

The approach used to estimate as-disposed waste volumes follows a methodology similar to calculations used to predict as-disposed volumes in the Capacity Assurance Remedial Action Report (now reported in the Phased Construction Completion Report) prepared annually for EMWMF. The capacity needed for disposal of future CERCLA waste depends on the as-generated waste volumes, the relative mix of debris waste and waste suitable for use as fill material, and volume reduction efforts such as waste sequencing. The conceptual design capacity of the proposed EMDF at the multiple sites in the On-site Disposal Alternatives ranges from 2.25 M yd^3 (for a two footprint/two Site Option) to 2.8 M yd^3.

The as-generated waste volume estimate used in the RI/FS for FY 2022 through FY 2043 (post-EMWMF) is approximately 1.95 M yd^3, including a 25% uncertainty allowance. Approximately 70% of the 1.95 M yd^3 is debris. This estimate is used as the basis for analyzing waste shipments in the Off-site Disposal Alternative. Calculation of the as-disposed volume (from the as-generated volume) for the On-site Disposal Alternatives indicates the capacity required to dispose of this waste on-site is 2.2 M yd^3. Volumes for the hybrid alternative consider as-generated volumes for the off-site disposal component and as-disposed volumes for the on-site disposal component.

Because detailed characterization data do not exist for many of the individual deactivation and decommissioning and remediation projects, characterization of future waste streams for this RI/FS is based on available data for waste disposed at EMWMF. This methodology relies on the assumption that available data for waste disposed at EMWMF approximately represent the waste characteristics of future waste streams with the exception of mercury-contaminated waste. Data sets of radionuclide contaminants were derived from EMWMF waste data to calculate transportation risk for the Hybrid, On-, and Off-site Disposal Alternatives and risk associated with natural phenomena (wind-borne [tornadic] contamination risk) for the On-site and Hybrid Disposal Alternatives.

Demolition of several large facilities at the Y-12 National Security Complex will result in large volumes of mercury-contaminated debris. This debris is assumed to be treated under the project scope (as opposed to the consolidated disposal scope of this RI/FS). Therefore, the cost to provide treatment is outside the scope of this remedy and assumptions are made regarding its treatment. All assumptions include full treatment of waste is to be provided by waste generators as necessary to meet all regulatory requirements.

REMEDIAL ALTERNATIVES

Multiple alternatives were developed and evaluated for this RI/FS: No Action Alternative, On-site Disposal Alternatives (three Site Options – all three representing independent alternatives), Off-site Disposal Alternative, and Hybrid Disposal Alternative.

Key assumptions regarding responsibilities of the waste generators are common to all of the action alternatives. The waste generators are considered to be responsible for removal of waste during cleanup actions; waste characterization and treatment as necessary to meet disposal facility WAC; and local transport to the EMDF (On-site Disposal and Hybrid Alternatives) or the ETTP transfer facility (Off-site Disposal and Hybrid Alternatives). Except for the cost to purchase waste containers for transport to off-site facilities, costs associated with generator responsibility elements are not included in the cost estimates.

No Action Alternative

The No Action Alternative provides a benchmark for comparison with the action alternatives, and is required under CERCLA. Unlike the typical No Action Alternative which assumes no cleanup actions are taken at a contaminated site, the No Action Alternative for this RI/FS is based on the assumption that a comprehensive, site-wide strategy to address the disposal of waste resulting from any future CERCLA remedial actions at ORR after EMWMF capacity is reached would not be implemented. Future waste streams from site cleanup that require disposal after EMWMF capacity is reached would be addressed at the project-specific level.

On-site Disposal Alternatives

The On-site Disposal Alternatives would provide consolidated disposal of most future-generated CERCLA waste exceeding the capacity of the existing EMWMF in a newly-constructed, engineered facility or facilities. These alternative includes designing and constructing a landfill(s) and support facilities similar to EMWMF; receiving waste that meets the facility's Waste Acceptance Criteria (WAC); and managing the waste and landfill during the construction, operations, closure, and post-closure periods. Three proposed sites were selected for further consideration utilizing a screening evaluation that included many sites identified in a previous 1996 study (DOE 1996), as well as other possible favorable locations/footprints. A thorough examination is presented herein that first considers 16 sites. Secondary screening narrows consideration to three Site Options for detailed analysis in this RI/FS. One of the three sites is a two footprint option. The three Site Options, all in Bear Creek Valley, are shown in Figure ES-1. Site Options are identified as:

- East Bear Creek Valley (EBCV) Site Option, a site just east of the existing EMWMF (Option 5 in Appendix D)
- West Bear Creek Valley (WBCV) Site Option, a site located approximately 2.5 miles west of the existing EMWMF (Option 14 in Appendix D)
- Dual Site Option, which includes a site beside and to the west of the existing EMWMF (Site 6b) and a second site (Site 7a)[1], located 1.5 miles west of the existing EMWMF (Options 6b/7a in Appendix D)

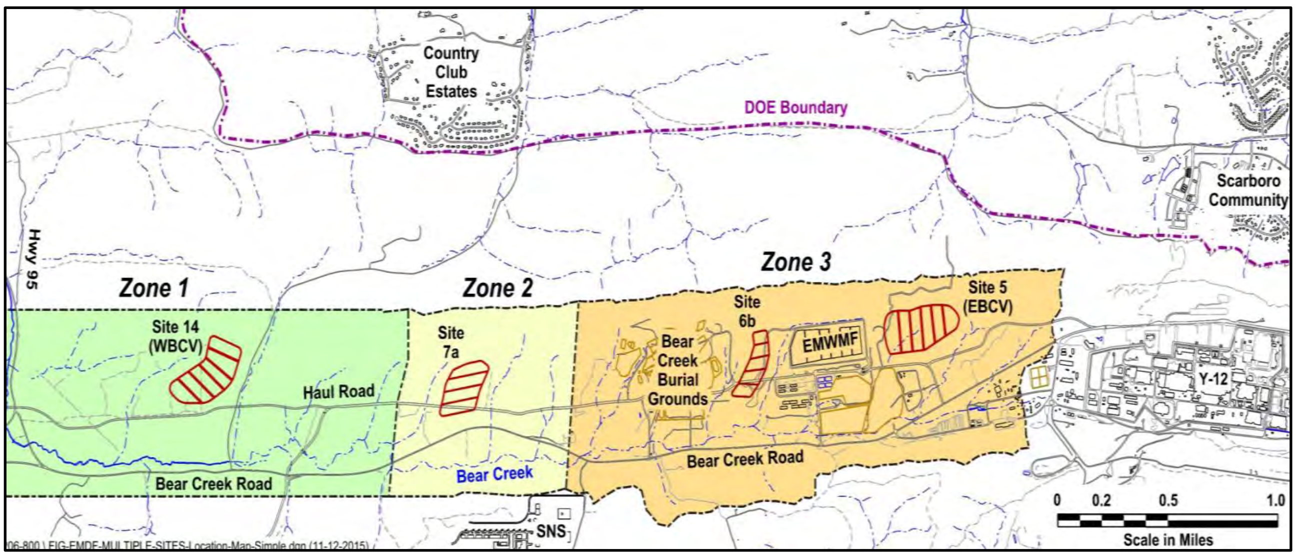

Figure ES-1. Bear Creek Valley Zones and Potential Sites for the Proposed EMDF in the On-site Disposal Alternative

This RI/FS provides results of fate and transport analyses, which demonstrate that analytic preliminary Waste Acceptance Criteria (PreWAC) for the proposed EMDF would meet applicable risk and dose criteria and be protective for the site modeled, EBCV. Based on these results, it can be concluded that most future CERCLA waste to be generated after EMWMF reaches maximum capacity would be able to be disposed at the proposed EMDF. It is acknowledged that the PreWAC identified in this RI/FS are a

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[1] Site 7a is part of a two site option evaluated in Appendix D as Option 7a/7b. In a comparison of small sites, Site 6b was determined to be the most suitable small footprint site, and a second site, to expand the available capacity to greater than 2 M yd^3 was needed. Site 7a was selected as this second site, but it is representative of either Site 7a or 7b, as the two sites are very comparable at the level of detail presented in this document. Should the Dual Site Option be selected, a more detailed analysis of the Site 7a/7b would be made to select the optimal footprint.

preliminary data set provided to show viability of land disposal at the proposed site modeled. While determination of PreWAC at other sites has not been completed, the limits would be expected to be similar to those determined for the EBCV Site Option. If on-site disposal is the selected remedy as determined by the CERCLA process, final WAC would be approved for the new facility by FFA parties prior to waste receipt and documented in a primary FFA document, the WAC Attainment (Compliance) Plan.

Site parameters, including the acreage required for operations and the acreage that would require permanent commitment of land (long-term impact) for the various On-site Disposal Alternatives considered in the RI/FS (as well as the on-site portion of the Hybrid Disposal Alternative), are given in Table ES-1.

Table ES-1. Summary of Characteristics of Proposed EMDF Sites[a]

Parameter	EBCV (Site 5)	WBCV (Site 14)	Dual Site (Sites 7a & 6b)	Hybrid (Site 6b only)
Capacity (yd^3)	up to 2.5 M	up to 2.8 M	up to 2.25 M	up to 1.4 M
Cells	6 Cells 3-5 acres each	6 Cells 4-5.5 acres each	9 Cells 2-5 acres each	4 Cells 4-5 acres each
Proposed Buildout (yd^3) (per RI/FS current waste volume estimate)	2.2 M 5 Cells	2.2 M 5 Cells	2.25 M 9 Cells	1.4 M 4 Cells
Acreage, extent of waste	30 acres	29 acres	32 acres	13 acres
Acreage, extent of cap	35 acres	34 acres	40 acres	17 acres
Acreage, development/operations	71 acres [b]	94 acres	135 acres [b]	53 acres [b]
Acreage, disposal facility (footprint)	48 acres	52 acres	68 acres	27 acres
Acreage, permanent commitment	70 acres	71 acres	109 acres	50 acres

[a] All acreage values given for facility capacity (not proposed buildout capacity). This applies only to EBCV and WBCV Sites. Reductions in acreage of approximately 12% (EBCV) and 18% (WBCV) if only five cells constructed.

[b] Acreage (21 acres) is already developed and in use by EMWMF; therefore acreage for development reported here (for Sites EBCV and Site 6b) does not include the 21 acres in the values reported.

Off-site Disposal Alternative

Under the Off-site Disposal Alternative, future CERCLA waste would be transported off-site for disposal at approved disposal facilities, primarily by rail transport. Representative routes are assumed for the cost estimate and risk evaluation. Two options are analyzed. In Option 1, approximately 92% of the waste (non-classified LLW and LLW/TSCA waste) would be shipped to the Nevada National Security Site (NNSS) in Nye County, Nevada, by rail transport from the East Tennessee Technology Park (ETTP) to a transfer facility in Arizona. Intermodal containers would then be transferred to trucks for the final leg of the shipment to NNSS. Mixed (LLW/RCRA) waste would be shipped for disposal by rail shipment from ETTP directly to Energy*Solutions*, Clive, Utah, or Waste Control Specialists (WCS), Andrews, Texas. Classified LLW waste would be shipped by truck to NNSS. In the second Option, all non-classified waste would be shipped by rail to Energy*Solutions* for disposal; the classified waste would be shipped to NNSS for disposal.

Hybrid Disposal Alternative

Hybrid disposal refers to significant disposal at both on-site and off-site disposal facilities using elements of both the On-site Disposal Alternative and Off-site Disposal Alternative. As with the other alternatives, the starting waste volume for the Hybrid Disposal Alternative is that waste volume produced by CERCLA actions on the ORR that could theoretically be disposed on-site. The Hybrid Disposal Alternative proposes consolidated disposal of future-generated CERCLA waste exceeding the capacity of the existing EMWMF in a newly-constructed, much smaller capacity, engineered waste disposal facility (i.e., landfill) on ORR. Waste volumes that exceed the capacity of the facility – regardless of whether those wastes meet the on-site disposal WAC – would be disposed off-site. A single on-site disposal option is analyzed (Site Option 6b, one of the two sites included in the Dual Site Option).

VOLUME REDUCTION

Volume reduction (VR) approaches and potential benefits for the alternatives are evaluated in this RI/FS. Sequencing of waste generation, as much as possible, is recommended for the on-site and hybrid alternatives to reduce the amount of clean fill required by utilizing soil waste as fill. Waste segregation is recommended for all alternatives, to maximize recycle or disposal of wastes in less costly industrial landfills. Both of these VR methods, sequencing and segregation, are implemented by generators. Size reduction by mechanical processing is recommended for the Off-site Disposal Alternative Option 1, where VR processing could result in an avoided shipping volume of over 160,000 yd^3 and a net estimated cost savings of up to $81M in 2012 dollars. It is not recommended for Off-site Disposal Alternative Option 2 because the transportation containers are weight limited, not volume limited. Size reduction by mechanical processing is recommended for the Hybrid Disposal Alternative (on-site portion only), where the processing results in an estimated cost savings of approximately $32.3M in avoided off-site transportation and disposal costs.

EVALUATION CRITERIA COMPARISON

Under the CERCLA process, alternatives for remedial action are assessed against nine evaluation criteria, which include two threshold criteria, five primary balancing criteria, and two modifying criteria.

The two final modifying criteria, state and community acceptance, will be addressed in the Proposed Plan and Record of Decision (ROD). This RI/FS version as submitted has not been reviewed by the state; therefore, information to evaluate state acceptance of this RI/FS version does not exist. While state input has been received on previous versions of this document, those comments are documented and addressed in separate records, the results of which have been incorporated into this RI/FS. State acceptance will be evaluated in the Proposed Plan. Likewise, while there has been much community discussion about the upcoming decision, formal public comments have not been received and sufficient information about community acceptance is not available for this RI/FS. Community acceptance will be addressed in the ROD.

The two threshold criteria are (1) protection of human health and the environment and (2) compliance with ARARs. Performance viability of the alternatives is addressed through the remaining criteria: (1) long-term effectiveness and permanence; (2) reductions in toxicity, mobility, or volume through treatment; (3) short-term effectiveness; (4) implementability; and (5) cost.

Protection of Human Health and the Environment and Compliance with ARARs (Threshold Criteria)

All action alternatives will be protective of human health and the environment. All ARARs will be complied with by the action alternatives. The no action alternative may not be protective of human health and the environment depending on the project-level decisions that are made. There are no ARARs for the no action alternative.

For the On-site Disposal Alternatives (and on-site portion of the Hybrid Disposal Alternative), the conceptual designs developed at each site will ensure protection of the public and environment and will meet all ARARs. Engineered features are designed to function for very long times, allowing many radioactive and organic contaminants to decay or degrade in place. Fate and transport modeling coupled with ground water modeling at the EBCV Site allows determination of facility PreWAC that limit the contaminants disposed, to ensure protection of human health and the environment according to RAOs for the compliance period. While only a single site has been modeled, all sites are located in Bear Creek Valley and share similar geological features; therefore, these site features will not result in significant differences between PreWAC for other sites. Hydrologic differences (e.g., distance to surface water, distance to karst features) would have minor impacts on determined PreWAC limits, as demonstrated in sensitivity analyses; however, all site PreWAC, despite these minor differences, are calculated based on meeting RAOs and thus would demonstrate protectiveness. A detailed analysis addressing the ability of each candidate site to remain protective and meet ARARs is included in the document.

The Off-site Disposal Alternative and the off-site portion of the Hybrid Disposal Alternative are protective of human health and the environment through the WAC, designs, site setting, and operational activities of the off-site disposal facilities. The features of these facilities ensure long-term protection of human health and the environment. There are short-term transportation issues but those are minimized through compliance with Department of Transportation requirements. There are very few ARARs for the Off-site Disposal Alternative and the off-site portion of the Hybrid Disposal Alternative as most actions are off-site. However, the on-site transportation and size reduction elements are covered by ARARs of which all are met.

Long-term Effectiveness and Permanence

Both on-site and off-site disposal, and therefore hybrid disposal, would be effective and permanent in the long-term. The No Action Alternative would likely be less protective if more wastes were managed in place at individual CERCLA sites rather than being consolidated in an engineered landfill. Engineered features, site characteristics, waste characteristics, and institutional controls for all action alternatives are relied on to prevent inadvertent intrusion and waste migration. Waste characteristics are controlled by WAC. The off-site facilities have WAC that have been demonstrated to be protective. This document demonstrates protectiveness provided by PreWAC for the EBCV Site. Other candidate sites would be expected to have similar PreWAC, and if selected as the preferred alternative, that site(s) would be modeled, to determine PreWAC limits that meet RAOs and thus demonstrate protection of the public and environment.

The greatest differentiator between disposal alternatives is the role site characteristics play in the effectiveness and permanence of an alternative. Off-site disposal of waste at Energy*Solutions*, WCS, and NNSS in the long-term would be more reliable at preventing exposure than on-site disposal on the ORR, because they are located in arid environments that reduce the likelihood of contaminant migration or exposure via ground water or surface water pathways. Fewer receptors exist in the vicinity of Energy*Solutions*, WCS, and NNSS than on the ORR.

For the On-site Disposal Alternatives and the on-site portion of the Hybrid Disposal Alternative, preventing exposure to contaminants placed in EMDF over the long term depends on success of the facility's engineered containment features and individual site characteristics. Conceptual designs at all sites include engineered multilayered cover and liner systems that are identical and provide the best protection that can technically be provided by current standards.

Individual site hydrology features are controlled by engineered subsurface and surface drainage systems included in the conceptual designs of the EMDF at all sites. The extent of those drainage systems differs, depending on site-specific hydrologic characteristics and topography. Underdrain engineered features maintain lowered ground water tables below geobuffer systems. Surface drainage features provide diversion of upgradient flow, reduce potential erosion and subsidence of the cover and promote stability, all of which will support the isolation of the waste from contact with water. All drainage systems are designed as passive systems with graded filtration and non-weathering materials to provide long-lived performance and protectiveness. Very detailed discussions of these features and individual site characteristics that influence them, as well as expected longevity are provided herein.

Reduction in Toxicity, Mobility, or Volume through Treatment

The No Action Alternative does not consider consolidated management of CERLCA generated wastes. Although the action alternatives evaluated do not directly establish waste treatment requirements, wastes would be treated as needed to meet WAC either before shipment or at the receiving facility (e.g., the Energy*Solutions* facility has treatment capabilities). Waste treatment is assumed to be the responsibility of the waste generator. Waste treatment by the generator or at the receiving facility could reduce the toxicity, mobility, and/or volume of waste, depending on the treatment applied. Option 1 of the Off-site Disposal Alternative includes mechanical VR, thus reducing transportation risk with fewer shipments. The Hybrid Disposal Alternative also include mechanical VR for the on-site disposal portion, providing about 17% more disposal capacity in the on-site disposal facility.

Short-term Effectiveness

In terms of short-term effectiveness, risk to human health is the most differentiating element. Under all the alternatives evaluated, risks to workers and the community from actions at the remediation sites and disposal facilities would be controlled to acceptable levels through compliance with regulatory requirements and health and safety plans. However, for the No Action Alternative, more wastes may be managed in place; less aggressive remediation would result in fewer short-term risks (e.g., less construction, transport of waste, etc.). For action alternatives, the most significant risk to human health would result from waste transportation. Off-site transportation carries a much higher risk to human health than does on-site transportation, due to the public roads/railroads travelled and the long distances involved (see Figure ES-2). The estimated risk increase varies depending on the receptor and whether the risk is radiological or vehicular, but can range from two times higher to as much as four orders of magnitude higher. Radiation exposure and vehicle-related risk would significantly increase if rail shipments in the Off-site Disposal Alternative were replaced by truck shipments (for Option 1 the majority of shipments evaluated in the Off-site Disposal Alternative are by rail to NNSS with a final short truck transport leg). Likewise, if the majority of waste were shipped to Energy*Solutions* in Utah (Option 2), the off-site risk would decrease by a factor of about three, but still significantly outweigh the on-site risk.

Implementability

Implementability for the No Action Alternative is not applicable. In terms of implementability of the action alternatives, availability of services and materials is most significant. Currently services and materials needed for pre-construction investigations, construction, and operation of the On-site Disposal Alternatives and on-site portion of the Hybrid Disposal Alternative, and transportation and disposal capacity for the Off-site and Hybrid Disposal Alternatives, are available. No impediments to future operation of the On-site Disposal Alternatives at any proposed site are likely to arise. State equity issues and reliance on off-site facilities introduce an element of uncertainty into the continued viability of off-site disposal during the anticipated operational period. Because CERCLA waste generation on the ORR is projected to continue through the year 2043, on-site disposal would provide much greater certainty that sufficient disposal capacity will be available at the time the wastes are generated.

Cost

The No Action Alternative does not have a direct cost; costs would reside within each project, and efficiencies that result from consolidation and economies of scale would not be achieved. Table ES-2 summarizes the costs for the various action alternatives presented in this document.

Table ES-3 is a summary of identified risks, with indications as to the extent the cost estimate would be affected, and indications as to the likelihood of the risk being realized.

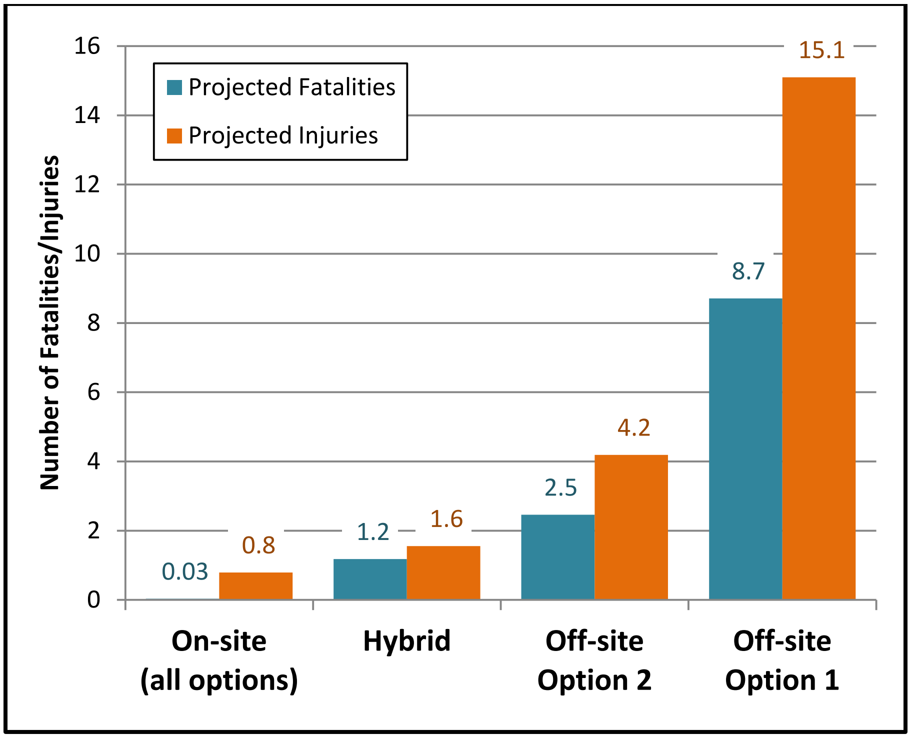

Figure ES-2. Transportation Risk (Vehicle Accidents/Emissions) for Action Alternatives

Table ES-2. Summary of Costs for On-site, Hybrid, and Off-site Disposal Alternatives

Description of Cost	On-site Disposal Alternatives			Hybrid Disposal Alternative	Off-site Disposal Alternative	
	EBCV Site Option	WBCV Site Option	Dual Site Option Site 6b & 7a	On-site (Site 6b) with Off-site Disposal	Option 1	Option 2
Annual Average Cost, Million \$ (computed on 22 years of active operations, for all alternatives)						
FY16 Dollars	\$32.6	\$33.3	\$40.9	\$62.3	\$81.8	\$71.2
Present Worth	\$24.7	\$25.3	\$30.7	\$52.0	\$67.9	\$59.8
Disposal Cost, \$/yd^3						
FY16 Dollars	\$368	\$376	\$462	\$703	\$923	\$804
Present Worth	\$279	\$286	\$347	\$587	\$767	\$675

Table ES-3. Risks and Cost Implications for Action Alternatives

Risk	Cost Implications	Probability of Occurrence
On-site and Hybrid Disposal Alternatives		
• Material and/or labor cost increases during construction or operation	Moderate cost	Moderate
• Waste not meeting facility WAC and requiring off-site disposal	Moderate cost	Unlikely
• Compliance issues/operational issues requiring corrective actions	Low cost	Unlikely
• Increased long-term surveillance and maintenance costs	Moderate cost	Moderate
• Disposal site shutdown during operations	High cost	Unlikely
• Post-closure, extreme maintenance issues	High cost	Unlikely
Off-site and Hybrid Disposal Alternatives		
• Delay of ORR Cleanup corresponding to Program annual appropriations that do not increase commensurate with increased annual disposal cost (off-site versus on-site)	Very high cost	Likely
• Public road travel from demolition site to rail transloading station located at ETTP in future	Moderate cost	Very likely
• Disposal of greater than Class A waste at NNSS in the Option 2 Off-site Disposal Alternative	Low to moderate cost	Very likely
• Debris size/weight, soil water content surcharges	Low to high cost	Very likely
• Shutdown of off-site facilities due to violations	Very high cost	Unlikely
• Unavailability of facilities due to state equity issues	Very high cost	Unlikely
• Multi-state travel; equity issues	Moderate to very high cost	Moderate
• Long-term DOE liability at an off-site location	Moderate to very high cost	Unlikely

1. INTRODUCTION

This document is a Remedial Investigation/Feasibility Study (RI/FS) to evaluate disposal alternatives for waste generated from cleanup actions implemented under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) at the United States (U.S.) Department of Energy's (DOE) Oak Ridge Reservation (ORR). The report follows previous CERCLA evaluations, decisions, and actions that resulted in an existing on-site disposal facility, referred to as the Environmental Management Waste Management Facility (EMWMF). Because the EMWMF is predicted to reach capacity before all estimated ORR cleanup waste has been generated and dispositioned, DOE has determined the need to evaluate disposal alternatives for future CERCLA waste. This RI/FS evaluation will also support the DOE strategic plan for reducing the ORR's cold war legacy footprint and dispositioning resultant waste materials (DOE 2011c).

1.1 BACKGROUND

DOE is responsible for site-wide waste management and environmental restoration activities at the ORR under its Office of Environmental Management (EM) Program at the national level, and locally under the Oak Ridge Office of Environmental Management (OREM) Program. The OREM Program is responsible for minimizing potential hazards to human health and the environment associated with contamination from past DOE practices and addressing the waste management and disposal needs of the ORR. Under the requirements of the ORR Federal Facility Agreement (FFA) (DOE 1992) established between DOE, the U.S. Environmental Protection Agency (EPA), and the Tennessee Department of Environment and Conservation (TDEC), all environmental restoration activities on the ORR are performed in accordance with CERCLA.

The 33,542-acre ORR is mostly within the city limits of Oak Ridge, Tennessee, which is approximately 12.5 miles west-northwest of Knoxville in Roane and Anderson counties (see Figure 1-1). The figure includes a map of the three major industrial research and production installations on the ORR managed by DOE and originally constructed as part of the World War II-era Manhattan Project: East Tennessee Technology Park (ETTP), formerly the K-25 Site; Oak Ridge National Laboratory (ORNL); and Y-12 National Security Complex (Y-12). Figure 1-1 also shows the location of the existing EMWMF Site as well as several sites for a potential new facility referred to as the Environmental Management Disposal Facility (EMDF) evaluated in this RI/FS.

The OREM Program's major focus has been CERCLA remediation of facilities within the installations that are contaminated by historical Manhattan Project and Cold War activities. This cleanup mission is projected to take the next three decades to complete and result in large volumes of radioactive, hazardous, and mixed waste requiring disposal.

The principal mission of ETTP was uranium enrichment, which has been completed, and the facilities and site are undergoing deactivation and decommissioning (D&D)[2] and remediation under CERCLA. ORNL currently and historically has hosted a variety of research and development facilities and nuclear reactors under DOE. Y-12 has served several missions: uranium enrichment, lithium refining, nuclear weapons component manufacturing, and weapons disassembly, and continues to perform in some of these capacities under direction of the National Nuclear Security Administration (NNSA). Over the past several years, DOE, NNSA, and their contractors have made significant cleanup progress at all three sites.

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[2] The acronym D&D encompasses a range of disposition activities, including transition, stabilization, deactivation, cleanout, decontamination, decommissioning, demolition, and restoration.

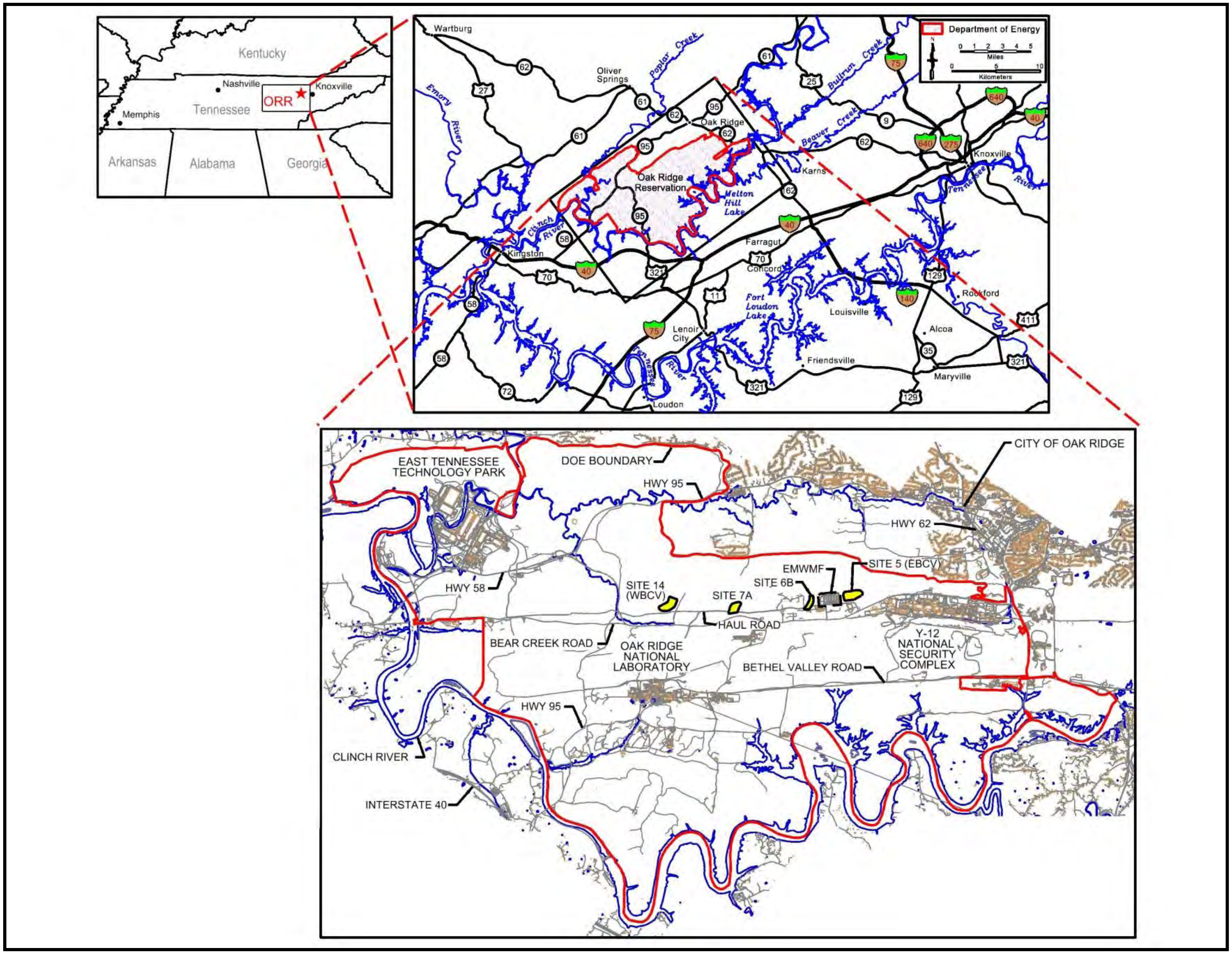

Figure 1-1. Oak Ridge Reservation, EMWMF, and Proposed EMDF Site Locations

A 1999 Record of Decision (ROD) (DOE 1999) authorized construction of a facility located on the ORR to provide permanent disposal for radioactive, hazardous, and mixed wastes that present unacceptable risks to human health and the environment in their current setting at ORR and associated sites. This facility, EMWMF, has been constructed and is accepting CERCLA cleanup wastes. The capacity of EMWMF is 2.2 Million (M) cubic yards (yd^3) as authorized by the ROD and a subsequent Explanation of Significant Difference (DOE 2010).

A widening of the scope of the OREM Program has occurred since the original waste estimates were made in the RI/FS that led to the construction of EMWMF (referred to herein as the EMWMF RI/FS) (DOE 1998). Extensive, new cleanup actions identified in the Integrated Facility Disposition Program (IFDP) were added by a major modification to the FFA in 2009 (DOE 2009). Some of the actions progressed into projects, which were performed under the American Recovery and Reinvestment Act of 2009 (ARRA). The added cleanup actions, recently completed under ARRA and forecasted to occur over the next three decades, significantly increase the volume of CERCLA waste projected to be generated. The EMWMF ROD (DOE 1999) estimated a waste volume[3] of 280,000 yd^3 would require disposal. Currently, a projected waste volume[4] of 1.4 M yd^3 will be disposed in EMWMF at the time of its closure. Approximately 1.6 M yd^3 of additional CERCLA waste[4] is expected to be generated and require disposal after EMWMF has reached capacity.

1.2 PURPOSE

The purpose of this RI/FS is to evaluate alternatives for disposal of CERCLA waste (after EMWMF capacity is reached) that will be generated from cleanup of portions of the ORR, including local sites outside the ORR boundary, but within OREM's domain of responsibility. As lead agency for ORR cleanup, DOE is working with the other FFA parties, EPA and TDEC, to evaluate alternatives for disposal of low-level waste (LLW); hazardous waste regulated under the Resource Conservation and Recovery Act of 1976 (RCRA) and/or hazardous waste regulated under the Toxic Substances Control Act of 1976 (TSCA) that may also be LLW (mixed waste); and certain classified waste. This RI/FS was prepared in accordance with CERCLA requirements and incorporates National Environmental Policy Act of 1969 (NEPA) values in accordance with the DOE's Secretarial Policy on NEPA (DOE 1994) and DOE Order (O) 451.1B (DOE 2012a).

This report will serve as the initial document supporting the selection of a preferred alternative for CERCLA waste disposition post-EMWMF. This report will be followed by a Proposed Plan that presents the preferred alternative to the public, and subsequently by a ROD that documents the selected alternative and addresses public comments on the Proposed Plan. The ROD will address a comprehensive decision for disposal of waste resulting from the implementation of remedial actions that are specified in separate existing and future CERCLA decisions.

1.3 SCOPE AND ORGANIZATION OF REPORT

The EMWMF RI/FS was the first document in the CERCLA process that led to the construction and operation of the EMWMF. As a follow-on to that process, this RI/FS utilizes relevant information from the EMWMF RI/FS with revisions and updates to describe and analyze current conditions. This RI/FS analyzes four alternatives: no action, on-site disposal in a newly constructed facility on the ORR at

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[3] The volumes given are waste debris and soils only (as-generated); does not include additional fill material used in land disposing of waste, nor does it include any uncertainty.

several locations[4], off-site disposal at permitted and licensed facilities, and a combination of on-site disposal using a smaller landfill footprint with the remainder of waste disposed off-site, which will be referred to as the Hybrid Disposal Alternative. The EMWMF RI/FS analyzed three siting options under the On-site Disposal Alternative:

- East Bear Creek Valley (EBCV), the site that was ultimately selected for the EMWMF
- West Bear Creek Valley (WBCV)
- White Wing Scrap Yard (WWSY)

A thorough analysis of many candidate sites was completed as part of this RI/FS, and is presented in Appendix D and Chapter 5, along with the rational for down-selecting to the site Options ultimately analyzed using the CERCLA criteria in Chapter 7. This RI/FS analyzes three site Options under the On-site Disposal Alternative as shown in Figure 1-2:

- EBCV Site Option, a site just east of the existing EMWMF (Option 5 in Appendix D)
- WBCV Site Option, a site located approximately 2.5 miles west of the existing EMWMF (Option 14 in Appendix D)
- Dual Site Option, which includes a site beside and to the west of the existing EMWMF (6b) and a second site (7a)[5], located 1.5 miles west of the existing EMWMF (Options 6b/7a in Appendix D)

These three sites are all equally independent On-site Disposal Alternatives, although throughout this document the On-site Disposal Alternative is given as a singular noun form, and capitalized ‘Option(s)’ is used when denoting a separate proposed site(s). The fourth alternative, the Hybrid Alternative, analyzes waste disposal using only one of the two site options from the Dual Site Option (Site 6b) in combination with off-site disposal.

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[4] Due to revision of this RI/FS from draft to draft final to final and to minimize changes to the document in this process, the on-site alternatives are referred to in this RI/FS in the singular form. The on-site alternatives are, however, considered and evaluated against the CERCLA criteria individually. Please note that wherever the document says “On-site Alternative” to refer to the on-site alternatives, generally, this should be read in the plural form.

[5] Site 7a is part of a two site option evaluated in Appendix D as Site 7a/7b. In a comparison of small sites, Site 6b was determined to be the most suitable small footprint site, and a second site, to expand the available capacity to greater than 2 M yd^3 was needed. Site 7a was selected as this second site, but is representative of either Site 7a or 7b, as the two sites are very comparable at the level of detail presented in this document. Should the Dual Site Option be selected, a more detailed analysis of the Site 7a/7b would be made to select the most appropriate location.

This document consists of eight chapters and supporting appendices as listed in Table 1-1 and described below.

Table 1-1. Outline of RI/FS Document Content

Chapter	Chapter Title
1	*Introduction*
2	*Waste Volume Estimates and Waste Characterization*
3	*Risk Evaluations*
4	*Remedial Action Objectives*
5	*Technology Screening and Alternatives Assembly*
6	*Alternatives Descriptions*
7	*Detailed Analysis of Alternatives*
8	*References*
Appendix	**Appendix Title**
A	*Waste Volume Estimates and Waste Characterization Data*
B	*Waste Volume Reduction*
C	*Treatment and Disposal Options for Mercury-contaminated Waste*
D	*On-site Disposal Alternative Site Screening*
E	*Detailed Site Descriptions and Characterizations*
F	*Alternatives Risk Assessment and Fugitive Emissions Modeling*
G	*Applicable or Relevant and Appropriate Requirements (ARARs)*
H	*On-site Disposal Facility Preliminary Waste Acceptance Criteria*
I	*Cost Estimates for On-site and Off-site Disposal Alternatives*

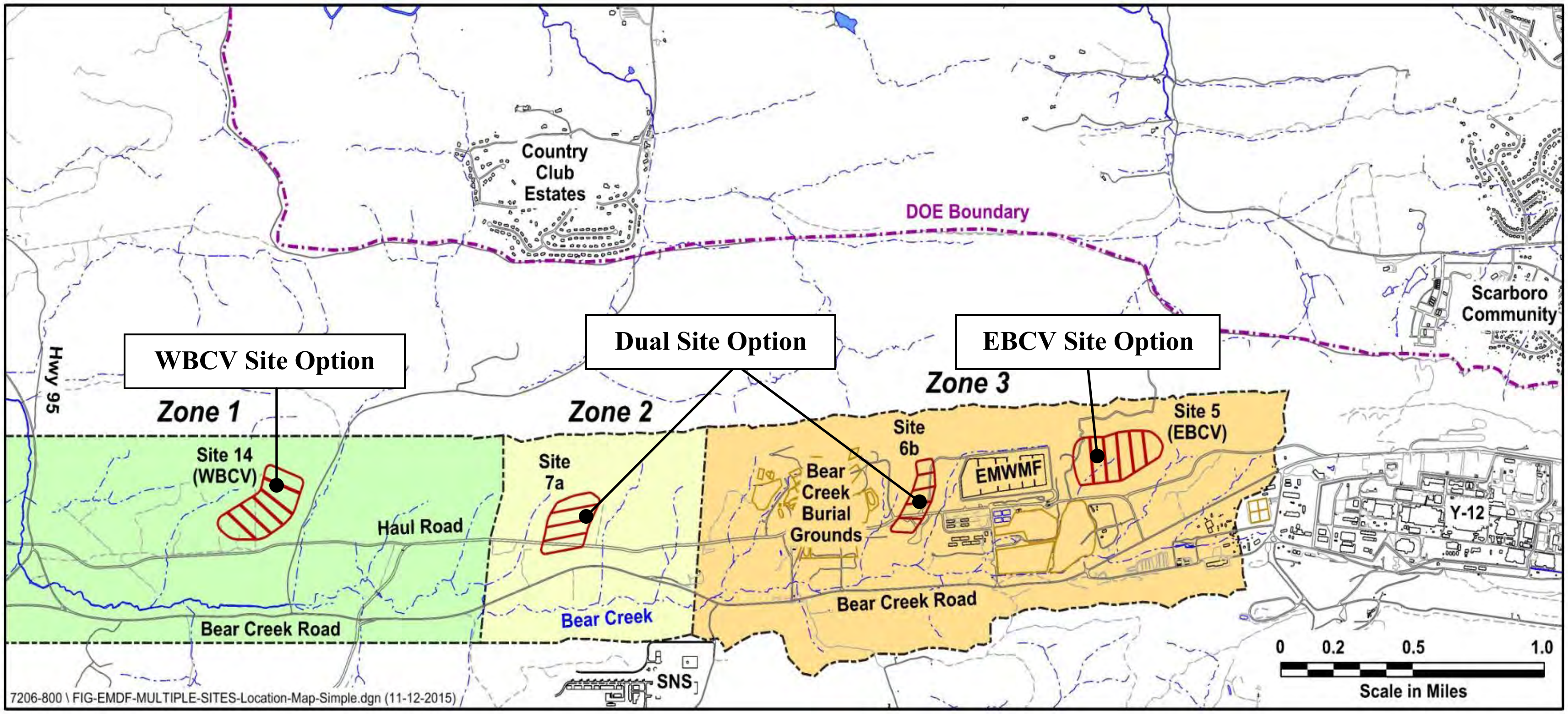

Figure 1-2. Three On-site Disposal Alternative Site Options

Chapter 2 of this RI/FS, *Waste Volume Estimates and Waste Characterization* corresponds to the "nature and extent of contamination" discussion found in RI/FS documents that addresses individual contaminated sites. While the EMWMF RI/FS relied on estimates of waste volumes and characteristics based on a limited set of existing data for individual sites expected to be remediated, this RI/FS uses information available for the ORR CERCLA cleanup that has been conducted over the last decade, including characteristics of waste disposed and operational experience at the EMWMF.

The EMWMF RI/FS provided an evaluation of baseline risk for the cleanup projects identified at that time. For the remediation projects that will generate candidate waste streams evaluated in this RI/FS, Chapter 3, *Risk Evaluations,* lists the applicable existing CERCLA documents that contain risk evaluations and planned future remediation projects for which a CERCLA risk evaluation and decision document have yet to be completed. Additionally, this Chapter addresses the preliminary risk evaluation of the on-site alternative, and addresses how that risk evaluation will evolve through the CERCLA process.

The remedial action objectives (RAOs) for alternatives evaluated in this RI/FS are specified in Chapter 4.

Chapter 5 of the RI/FS, *Technology Screening and Alternatives Assembly*, is based largely on the general response actions, technology types, and process options that were presented in the EMWMF RI/FS, supplemented with new information and lessons learned from ORR cleanup actions and the EMWMF.

Chapters 6 and 7 of the RI/FS describe the alternatives and provide a detailed analysis of alternatives, respectively. Chapter 8 provides references for supporting documents used and cited in the preparation of this report.

Appendices A through I contain supporting data and information.

Appendix A provides supporting waste volume and characterization data for Chapter 2, *Waste Volume Estimates and Waste Characterization*

Appendix B, *Waste Volume Reduction*, contains an evaluation of different potential approaches for reducing the volume of CERCLA waste to be disposed.

Appendix C is an evaluation of various treatment and disposal methods for mercury-contaminated debris.

Appendix D examines multiple on-site disposal locations on the ORR, and evaluates them through a multi-stage screening process to ultimately down-select to several proposed sites for the EMDF.

Appendix E provides applicable information about the region, and the proposed EMDF sites. Site-specific characterization data, completed under a limited Phase I characterization effort for the EBCV Site Option, is incorporated in this appendix as well. The EMWMF RI/FS is a reference for additional information about the regional environmental setting.

Appendix F presents the methodology and results of risk assessments for the On-site and Off-site Disposal Alternatives.

Appendix G provides a discussion and listing of ARARs for the On-site and Off-site Disposal Alternatives.

The EMWMF RI/FS contained preliminary analytic Waste Acceptance Criteria (WAC) derived from a risk assessment model. The EMWMF preliminary Waste Acceptance Criteria (PreWAC) was later finalized and approved in the WAC Attainment Plan (DOE 2001b). Appendix H of this RI/FS, *On-site Disposal Facility Preliminary Waste Acceptance Criteria*, provides PreWAC for one of the proposed

EMDF site Options, the EBCV Site Option, developed using fate and transport analysis to meet applicable risk and dose criteria. The analysis provides the basis for demonstrating that waste disposed in a potential new disposal facility would be protective and a viable disposal option for most CERCLA waste. PreWAC for those sites not specifically analyzed would be expected to be similar to those developed for the EBCV Option.

Appendix I provides summary cost estimate information and supporting assumptions for the On-site, Off-site, and Hybrid Disposal Alternatives.

2. WASTE VOLUME ESTIMATES AND WASTE CHARACTERIZATION

This section corresponds to the "nature and extent of contamination" discussion found in RI/FS documents that address individual contaminated sites. It defines CERCLA waste and material types, presents a waste volume estimate for future CERCLA waste disposal, including generation rates, and provides information about waste characteristics of future CERCLA waste streams. The waste volumes and characterization are used as the basis for development and analysis of the On-site and Off-site Disposal Alternatives for this RI/FS as shown in Table 2-1.

The RI/FS and a number of other CERCLA documents for the existing EMWMF were prepared over a decade ago. The environmental cleanup program on the ORR has progressed in a number of ways since that time, including:

- Approval of multiple CERCLA documents which delineate selected remedies for cleanup (e.g., RODs) and describe remedy implementations (e.g., Remedial Action Work Plans).
- Development of project-specific waste generation forecasts (WGFs) that are updated regularly.
- Accumulation of operational experience and knowledge from waste disposal practices at the EMWMF, including:
  - An approved WAC and WAC attainment/compliance process.
  - Approved waste profiles with waste characterization data for CERCLA waste streams.
  - An annual *Phased Construction Completion Report for the Oak Ridge Reservation Environmental Management Waste Management Facility* (PCCR), formerly the Annual Capacity Assurance Remedial Action Reports (CARARs), that includes a prediction of disposal capacity needs.

The approach to waste volume estimates and waste characterization in this RI/FS takes into account substantial additional information available for ORR CERCLA cleanup. However, the specific volumes and composition of waste that will be generated from the implementation of future CERCLA actions cannot be fully defined at this time. Development of waste volume estimates and characterization for this RI/FS relies on reasonable assumptions for proposed future remedial actions. Uncertainty is accounted for in the waste volume estimates based on a modified approach to that taken in the Fiscal Year (FY) 2014 PCCR. Uncertainty for this analysis is added as a straight percentage (increase only, to be conservative) to the annual predicted volumes. Uncertainty/sensitivity assumptions are not applied to waste characterization since it serves mainly as an input to risk calculations for on-site versus off-site alternatives (refer to Table 2-1), and that comparison may be made using only a deterministic data set. Looking at variability in that data set would not alter the comparison conclusions.

Table 2-1. RI/FS Alternative Components Supported by Waste Volume Estimates and Waste Characterization

RI/FS Alternative	Alternative Component	Location in RI/FS	Items Determined By Waste Volume Estimates	Items Determined By Waste Characterization
On-Site Disposal	**Conceptual Design and Cost Estimate**	**Chapter 6 and Appendix I**	Disposal capacity for new disposal facility (Based on "as-disposed" waste volume estimate)	
	Schedule	**Chapter 2 and Appendix I**	When maximum EMWMF capacity is reached and operation of new disposal facility begins (Based on "as-disposed" waste volume estimate) When capacity of cells in new disposal facility are reached (Based on "as-disposed" waste volume estimate)	
	Risk (Natural Phenomenon)	**Appendix F**		Waste contamination released by a tornado strike
	Risk (Transportation)	**Appendix F**	Number, waste type, and material type of waste shipments (Based on "as-generated" waste volume estimate)	Waste contaminants in waste shipments
	Preliminary WAC Evaluation	**Appendix H**		Preliminary WAC allows most future CERCLA waste to be disposed Proposed conceptual design provides adequate assurance that disposed contaminants would pose acceptable risks
Off-site Disposal	**Conceptual Design and Cost Estimate**	**Chapter 6 and Appendix I**	Number, waste type, and material type of waste shipments (Based on "as-generated" waste volume estimate)	
	Risk (Transportation)	**Appendix F**	Number, waste type, and material type of waste shipments (Based on "as-generated" waste volume estimate)	Waste contaminants in waste shipments

The volume and characterization estimate processes are outlined below.

Waste Volume Estimates

The RI/FS waste volume estimates of future CERCLA waste were developed based on an individual project basis, as reported in WGF[6] data. The data were modified based on ongoing planning and estimating efforts. Sequencing of waste volumes for this RI/FS was based on the latest information for OREM baseline planning efforts (March 2014). This sequencing has resulted in a slightly different annual waste volume profile from that reported in the FY 2014 PCCR (DOE 2014). Additionally, some project volumes were adjusted based on more recent information (e.g., waste volume for K-31 demolition was updated – the original baseline estimate was replaced with the contractor's estimate and Alpha-4 waste volume was corrected) which resulted in a slightly lower total forecasted waste volume than is reported in the FY 2014 PCCR (~10% lower). A more detailed discussion of the waste volume estimates used in this document is given in Section 2.2.

Waste Characterization

Representative radioactive contaminant concentrations for a unit of waste were determined based on waste characterization profiles, volumes, and weight data for waste disposed through FY 2011 at EMWMF. This source term is used in the transportation and natural disaster risk analysis. Hazardous contaminant concentrations were likewise determined. As mentioned, no uncertainty is applied to these data. A full discussion of waste characterization is given in Section 2.3.

2.1 CERCLA WASTE DEFINITION

Multiple waste and material types are expected to be encountered during future CERCLA actions. Wastes that are excluded from consideration in the RI/FS evaluation are described below. Waste and material types evaluated in this RI/FS are also described below.

2.1.1 Exclusions

Several waste types generated on the ORR are excluded from consideration in the RI/FS because they are not acceptable at an on-site facility from a WAC standpoint, are limited to disposal at very specific locations (e.g., DOE transuranic [TRU] waste must be disposed at the Waste Isolation Pilot Plant [WIPP]), or because disposition will be addressed by other established programs or by projects generating the waste. Additionally, many of those waste types are expected to be small volumes (e.g., listed waste) and costs to include them in an on-site facility would far outweigh the cost of individually sending them off-site. Excluded wastes include the following:

- Waste generated by DOE activities that are not CERCLA clean-up actions (e.g., RCRA waste from ongoing operations) is excluded because it is outside the scope of this RI/FS.
- RCRA waste defined as listed waste or that contains a listed waste is excluded (these volumes [listed waste] are projected to be very small, and accommodating them in an on-site alternative would incur on-site costs that exceed the cost of sending the waste off-site).
- RCRA waste that is not land disposal restriction (LDR) compliant is excluded.
- Liquid and gaseous wastes are excluded.
- High-level waste, Atomic Energy Act 11(e)2 by-product waste, and spent fuel rods are excluded.
- Fissionable materials that have the potential to become critical are excluded.
- Greater than Class C LLW materials are excluded.

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[6] WGF download September 2014.

- TRU waste is excluded because it will be treated on-site at the TRU Waste Processing Center for disposal at the WIPP.
- Industrial/sanitary (non-regulated) waste is excluded because there are less expensive options for disposal (i.e., ORR Landfills at Y-12).
- Recycle/reuse wastes are excluded because they will be returned to useful services or recycled through commercial vendors.
- No path for disposal wastes, an anticipated small volume of waste with no currently defined path for disposal, are excluded from the RI/FS waste volume estimates, but are qualitatively addressed in Chapter 7.

The current EMWMF WAC Attainment Plan (DOE 2001b) provides additional details regarding excluded materials and conditions of acceptance. Development of a future on-site facility WAC (including exclusions) is addressed in Section 6.2.3.

2.1.2 Waste Types and Material Types

For volume estimates to support the RI/FS, waste streams are delineated by both waste type (regulatory classification) and material type (waste form). Waste types are LLW and mixed waste. Mixed waste has components of radiological and RCRA hazardous waste as defined in 40 Code of Federal Regulations (CFR) 261 Subpart D. Material types may consist of various forms of soil and debris. Soil includes soil, sediment, and sludge. Debris includes a mixture of various forms of construction and demolition debris, including, but not limited to, the following:

- Reinforced concrete, block, brick, and shield walls
- Thick plate steel, structural steel, large piping, heavy tanks, and bridge cranes
- Glove boxes, fume hoods, ventilation ductwork, small piping, and conduit
- Insulation, floor tiles, siding materials, and transite
- Small buildings, small cooling towers, wood framing, and interior and exterior finishes
- Asphalt shingles, low-slope built-up roofs, vapor barrier, insulation, roof vents, flashing, and felt
- Containers, furniture, trash, and personal protective equipment (PPE)

For the RI/FS evaluation, material types are defined as either soil or debris with no further definition of soil or debris type. This approach is consistent with many waste volume estimates for future projects that delineate material types as soil or debris only.

There is often a lower level of confidence in waste type and material type volume estimates for future projects due to a lack of characterization data, and because detailed planning has not yet occurred. More definitive estimates are made when a project receives funding. For example, the determination of whether the waste type is a RCRA listed waste as identified in 40 CFR 261 Subpart D is part of waste characterization for disposition. Only a few, small volume solid waste streams (<6,000 yd^3) projected to contain RCRA "listed wastes" are identified in the OREM program WGF; these are projected for off-site disposal. Future potential sources of listed waste on the ORR include soil contaminated with a listed ground water plume (e.g., F039) that may be determined to require remediation. Further definition of soil quantities requiring remediation and a determination of whether the soil contains listed waste would occur when project characterization funding is received; however, listed waste will be excluded from disposal in an on-site disposal facility.

2.1.3 Wastes that do not Meet Disposal Facility WAC

An evaluation of ORR CERCLA waste disposal practices since FY 2002 shows that between 1% and 4% of total CERCLA waste generated annually (excluding waste sent to the ORR landfills) was packaged, shipped, and disposed at approved off-site facilities. The waste was shipped off-site because it did not meet the EMWMF WAC or because of other project-specific factors. As discussed in Section 2.3 and Appendix H, two points are made: (1) The characteristics of future CERCLA waste are anticipated to be similar to CERCLA waste generated since EMWMF began operating in FY 2002, with the exception of the introduction of mercury-contaminated waste expected from Y-12 cleanup projects. Small amounts of ORNL and Y-12 demolition and remediation waste have been received at EMWMF, and have introduced a broader variety of isotopes than ETTP waste alone. It is expected that with ORNL contributing a higher volume of waste in the future facility those isotopic concentrations will increase, but the representative isotopes are accounted for in the current EMWMF waste profile. (2) PreWAC at a new on-site disposal facility would allow most CERCLA waste to be disposed.

Based on the evaluation of CERCLA disposal practices to date and assumptions about similarities in current and future CERCLA waste generation, a small percentage of future total CERCLA waste generated annually is assumed to require shipment off-site. Because it is not a differentiator between the On-site and Off-site Disposal Alternatives, this small percentage of waste is excluded from the RI/FS waste volume estimate information (for both alternatives) and is addressed qualitatively in the alternatives analysis (Chapter 7).

The RI/FS waste volume estimate information below includes only those waste volumes that are projected to meet on-site disposal facility WAC and be either:

- Disposed at a new on-site CERCLA waste disposal facility (following closure of EMWMF) under the On-site Disposal Alternative or Hybrid Alternative, or
- Shipped for off-site disposal at an approved facility under the Off-site Disposal Alternative or Hybrid Alternative.

2.2 RI/FS WASTE VOLUME ESTIMATES

The waste volume estimates included in this RI/FS are limited to future CERCLA waste that will be generated from facility D&D and environmental restoration activities on the ORR. Development of waste volume estimates for this RI/FS relies on waste disposal practices and experiences on the ORR to date and reasonable assumptions about planned future D&D and remedial action activities.

Starting in 2013, reporting of anticipated disposal capacity needs on the ORR is given in the annual *Phased Construction Completion Reports for the Oak Ridge Reservation Environmental Management Waste Management Facility,* rather than the CARARs as has been done in the past. The waste definitions and general reporting approach have not changed with the change of report title. Similar to the definitions in the CARAR (DOE 2011a, 2012b), there are two types of quantitative waste volume estimates used in this RI/FS, "As-generated" and "As-disposed," as described below:

- "As-generated" waste volumes:
  - Volume estimate based upon excavated bulk volumes of soils/sediments and demolished building debris that includes void space.
  - As-generated volumes are roughly equivalent to the volumes expected to be shipped (i.e., used for Off-site Disposal Alternative).
  - Includes higher amount of void space and has lower density than as-disposed volumes because as-disposed volumes reflect compaction of the waste in the landfill.

The as-generated volumes are used in project planning to determine the number of truckloads and associated cost and duration necessary to move wastes from the work site to the disposal facility (on-site or off-site).

EMWMF disposal experience has allowed for development of formulas that are used to determine the amount of landfill space (volume) required for a given volume of as-generated waste material. The PCCR uses these formulas, including density conversion factors, to estimate total occupied or as-disposed volume after compaction in the landfill. Estimates of compacted waste and required fill material (fill material is used to fill voids, provide structural stability, and conduct operations; e.g., provide dump ramps) are used to convert as-generated volume to an as-disposed volume in order to predict future landfill space requirements.

- "As-disposed" waste volumes:
  - Volume estimate of waste after disposal in the disposal facility, at which point debris wastes, waste (soil) suitable for use as fill, and clean (additional) fill have been mixed and processed to meet compaction, void space, and operational requirements (i.e., used to determine the volume required for an on-site disposal facility).
  - Physically equivalent to survey results taken quarterly to estimate disposal facility airspace utilized.
  - Includes lower amount of void space than as-generated waste volumes because voids have been filled and it reflects compaction of the waste in the landfill.

The as-disposed waste volume estimate is used to predict when the EWMMF capacity will be reached, a key factor in evaluating post-EMWMF disposal alternatives. The as-disposed waste volume estimate is also used as the basis for determining the required capacity of a new disposal facility for the On-site Disposal Alternative.

As-generated and as-disposed waste volume estimates were developed for the RI/FS as described in the following two sections.

2.2.1 As-generated Waste Volume Estimate

The base as-generated waste volume estimate was developed using the most recent existing contractor and planning package WGF data[7] and modifying it for use in the RI/FS as follows:

- Waste to be disposed at facilities other than EMWMF was excluded from the total.
- A correction to the waste volume estimate for Building 9201-4 (Alpha-4) demolition was used, which reduced the waste debris volume for this facility by about 27,000 yd^3 from the previous RI/FS version.
- Waste soil sequencing was adjusted to better represent actual planning for Y-12 Upper East Fork Poplar Creek (UEFPC) remediation work.
- A revision to all assumed mercury-contaminated building debris, to split the debris into two volumes: LLW and mixed LLW, although the volume of debris given as mixed LLW is assumed to be treated to meet LDRs at the project level (thus rendering them non-hazardous or only LLW) for any on-site alternative (cost for treatment is thus not included in the on-site alteratives). In terms of off-site alternatives, although the mixed LLW may be treated off-site, the cost of that treatment is assumed to be covered in the demolition contractor scope (at the project level) and thus the mercury-contaminated debris cost included is no different from non-mercury bearing

[7] WGF download September 2014.

debris cost. The schedule for ORR cleanup projects and associated waste generation used to develop the WGF is based on an assumed \$385M - \$420M funding scenario[8] for ORR cleanup projects from FY 2015 through FY 2047, with ORR CERCLA waste generation occurring through FY 2043.

The base as-generated waste volume estimate covers the FY 2014 through FY 2043 timeframe and does not include applied uncertainty. The annual estimate for base as-generated waste volumes ranges from about 2,400 yd^3 per year to 150,000 yd^3 per year as shown in Figure 2-1. These projected volumes are quite variable, and are a result of planned project scheduling and sequencing. Planning this far in advance does not take into account details regarding staging and movement/placement of waste. It is expected that actual execution and operation would "smooth" the profile shown in the figure.

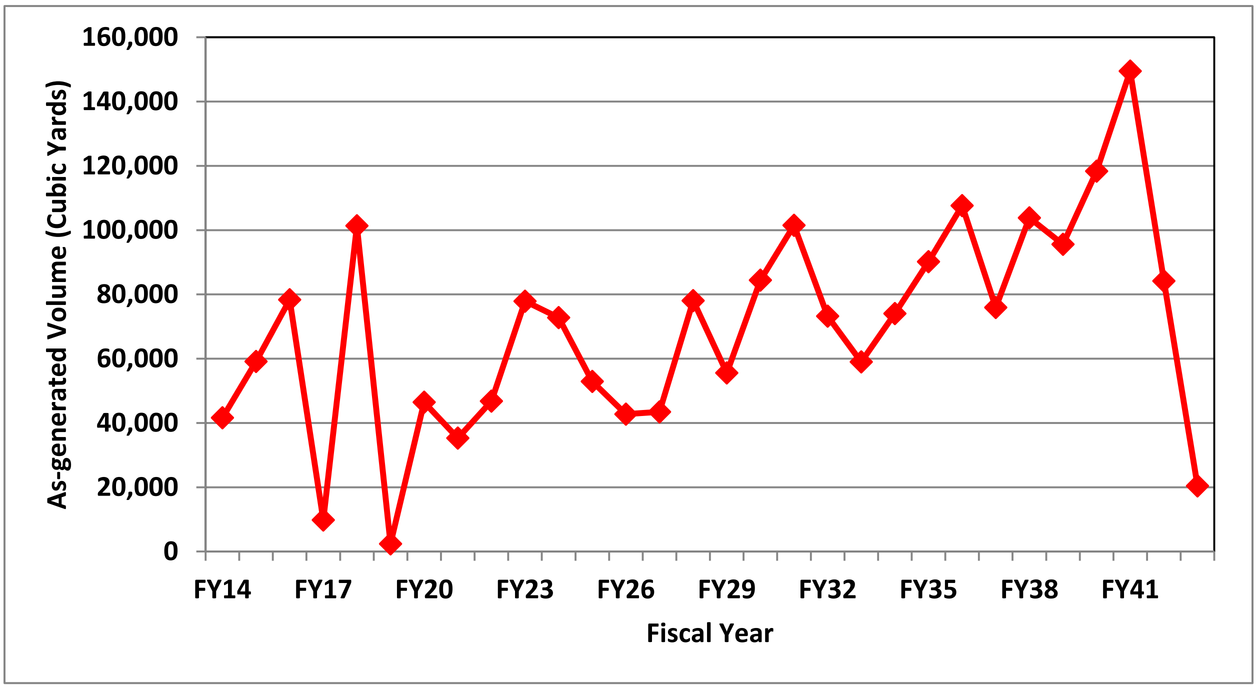

Figure 2-1. Annual, As-generated Waste Volume Estimates without Uncertainty

A calculated average of 69,410 yd^3 of waste per year is well within the EMWMF annual operational range of waste processed thus far (approximately 40,000 up to 150,000 yd^3 per year, which is rather variable).

Using the modified PCCR approach and assumptions about uncertainty to calculate the as-disposed volume described in Section 2.2.2, it is estimated, for the purposes of this RI/FS, that EMWMF will be filled to capacity in FY 2024. Any accelerated waste generation during the FY 2014 to FY 2024 timeframe would require a significantly large increase in funding, and while this is highly unlikely given the current and foreseeable economic situation, such a large funding increase would also provide for corresponding acceleration in the planning and construction of an on-site facility.

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[8] The RI/FS waste volume estimate and WGF download is based on an approximation of project sequencing for a scenario that assumes funding of \$385M in FY 2015, annual funding of \$420M for FY 2016 through FY 2018, and annual funding of \$420M escalated each year through the end of the program (FY 2047).

The new facility will begin receiving waste in FY 2022; therefore, an overlap of approximately two years is built into the schedule for a new facility. The new facility portion of the as-generated waste volume estimate (FY 2022 - FY 2043) is used in the disposal alternatives as follows:

- To calculate the as-disposed volume estimate used to predict: (1) the required disposal facility capacity needed for the On-site Disposal Alternative and (2) when individual cells of the new disposal facility would be filled.
- To analyze waste shipments in the Off-site Disposal Alternative.
- To analyze waste disposed in a small on-site facility and volume remaining to be shipped off-site in the Hybrid Disposal Alternative.

A summary of the post-EMWMF base as-generated waste volume estimate by material type and waste type is presented in Table 2-2. Note that the waste form, LLW/TSCA, is included with LLW. The waste volumes are summarized in this way to aid the off-site analysis, because LLW/TSCA waste can be disposed off-site at the Nevada National Security Site (NNSS) as LLW, while mixed waste that may require treatment is disposed at Energy*Solutions* or Waste Control Specialists LLC (WCS). Appendix A provides detailed as-generated waste volume estimates by project and year.

Table 2-2. Post-EMWMF Base As-generated Waste Volume Estimate (FY 2022 - FY 2043) without Uncertainty

Material Type	Waste Type		TOTAL by Material Type (yd^3)	% by Material Type
	LLW (includes LLW/TSCA)	Mixed (LLW/RCRA, LLW/RCRA/TSCA)		
Debris	921,152	119,534	1,040,686	67%
Debris/Classified[a]	28,489	3,697	32,186	2%[a]
Soil	432,092	53,882	485,974	31%
Total	1,381,734	177,113	**1,558,846**	
% by Waste Type	89%	11%		

[a] Some percentage of debris waste is expected to be classified, but is currently not specified as such in the Waste Generation Forecast. Three percent of generated debris is assumed to be classified for purposes of off-site disposal evaluation (based on 3% of waste from ETTP considered classified in the WGF).

2.2.2 As-disposed Waste Volume Estimate (On-site Disposal Alternative)

The approach used to estimate as-disposed waste volumes follows a methodology similar to calculations used to predict as-disposed volumes in the FY 2014 PCCR (DOE 2014) and the CARARs that had been previously prepared annually for the EMWMF. The capacity needed for disposal of future CERCLA waste depends on the as-generated waste volumes, the relative mix of debris waste and waste suitable for use as fill material (e.g., soil), the volume of clean fill needed for filling voids and for operational purposes, and the compaction of the combined materials. The optimum fill material is contaminated soil or soil-like material from a remediation project that can be mixed with the debris or be placed around or among containers. When contaminated fill is not available, clean fill must be used. Sequencing of waste soil and debris to take advantage of this optimization is carried out to the extent possible at the disposal cell. Sequencing projects to take advantage of the waste soil/debris optimization is discussed further in Appendix B, *Waste Volume Reduction*.

The PCCR and previous CARARs utilize density conversion factors that reflect compaction of waste in the landfill for many different waste material types to predict as-disposed waste volumes from as-generated waste volumes. A formal Monte Carlo uncertainty analysis is performed for the PCCR and a calculated 95% upper confidence limit (UCL) uncertainty allowance is added to the total waste volume (debris, soil waste, and clean fill) to account for uncertainty in waste volume estimates and fill demand projections. The UCL-95 uncertainty allowance is applied to future volumes. For purposes of this RI/FS analysis, it was conservatively assumed that volume uncertainty would result in increased rather than decreased need for landfill space. A straight 25% uncertainty on waste volumes is assumed in this document.

Prediction of as-disposed volumes for the RI/FS uses a simplified methodology from that of the PCCR, as described in general in the bullets below (detailed calculations are given in Appendix A):

- Start with the base as-generated waste volume estimate as described in Section 2.2.1 and summarized in Table 2-2.
- Use the simplifying assumption of two waste material types (soil and construction debris) and corresponding density conversion factors (per the FY 2013 PCCR [DOE 2013]) to calculate as-disposed volumes of debris and soil that reflect compaction of waste in the landfill.
- Establish total fill needed using a multiplication factor of 2.26 applied to the as-disposed debris volume. The factor 2.26 is based on a field-determined ratio of total fill density to as-disposed debris density (DOE 2004).
- Take the total fill volume and subtract the as-disposed soil waste volume (which is used as fill) to calculate the volume of clean fill soil required. (Note: excess soil waste fill could potentially occur when more waste soil fill is generated than is needed for void space management; however, this does not occur in the current volume analysis).
- Add the assumed uncertainty allowance to get future volumes of total waste (debris, soil waste, and clean fill).

Table 2-3 provides as-disposed volumes of debris and soil based on the as-generated volumes given in Table 2-2 and calculated per the above described method. Density conversion factors (from the PCCR, DOE 2004) are given for the as-disposed volume determinations. These as-disposed volumes include the soil fill (made up of soil waste and clean fill). As much as possible, projects are sequenced to take advantage of using soil waste as fill (see Figure 2-2 and Appendix B).

Table 2-3. As-Disposed Waste Volume Determination

Waste Type	Volume (yd^3)	Basis
AD Debris (compacted)	533,011 (A)	AG debris volume divided by 2.01 (as defined in Appendix A)
AD Waste Soil (compacted)	365,612 (B)	AG waste soil volume divided by 1.30 (as defined in Appendix A)
Total Fill	1,204,606	AD debris volume multiplied by 2.26 (as defined in Appendix A for filling void space and for operational needs)
Clean Fill	838,994 (C)	AD Waste Soil subtracted from Total Fill
Total AD Volume	1,737,617	Add values A, B, and C
Excess Waste Soil (compacted)	8,812	This is the calculated excess waste soil that occurs under the sequencing scenario
Total AD Volume includes excess waste soil	1,746,430	This is the total volume required (no uncertainty)

AD = As-disposed; AG = As-generated

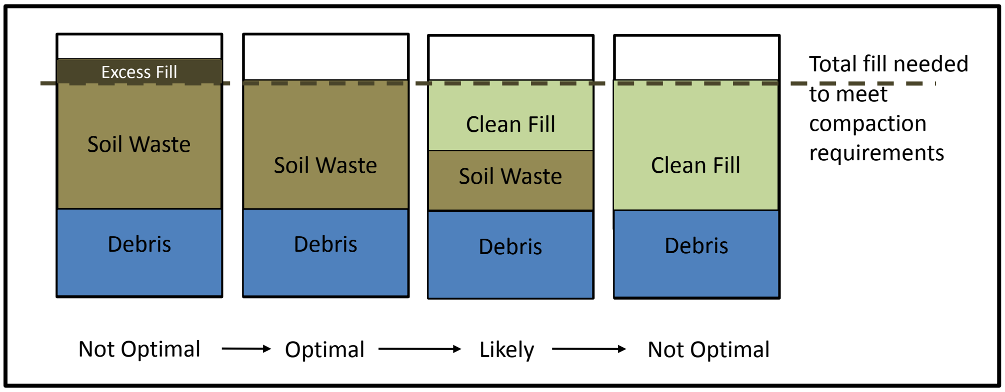

Figure 2-2. Scenarios for Total Fill in Landfill

If soil waste exceeds the total fill required, it is labeled excess fill. Proper sequencing of soil remediation and demolition projects allows maximizing the use of soil waste as fill (the likely situation in Figure 2-2). The optimal situation is not likely simply because soil remediation volumes are not that large, and clean fill must make up the rest of the fill required for compaction and stability requirements in the landfill.

Using the as-disposed volume (1,746,430 yd^3) as shown in both Table 2-3 and Table 2-4, an allowance of 25% uncertainty is applied and results in a needed ~2.2 M yd^3 of additional capacity over the current EMWMF facility's capacity. This is about 15% less than the 2.5 M yd^3 provided by the landfill conceptual design for the EBCV Option. Likewise, the WBCV Option conceptual design is 2.8 M yd^3, allowing for expansion/finalization of design capacities. The difference between 2.2 and 2.5/2.8 M yd^3 will allow for final design changes (e.g., slope recalculations, cut/fill changes, height of waste, etc.) for these two options, or to provide additional capacity in the future should it be required. Total volume provided by the Dual Site Option is 2.25 M yd^3. All costs and comparisons throughout the document are based on buildout of facilities that accommodate approximately 2.2 M yd^3 of waste, which corresponds to five cell buildouts for EBCV and WBCV Options, and complete buildout of the Dual Site Option. The 2.5 and 2.8 M yd^3 maximum design capacities are not factored into any further discussions within this document. The capacity required including a 25% contingency (2.2 M yd^3) is supported by the waste volume uncertainty analysis presented in Table 2-5, which gives a capacity range needed of between 1.2 and 2.5 M yd^3.

The *Fiscal Year 2014 Phased Construction Completion Report for the Oak Ridge Reservation Environmental Management Facility* (DOE 2014) predicts that a total CERCLA waste volume of 4.1 M yd^3 is required at the 95% UCL. Subtracting 2.18 M yd^3 (capacity of the EMWMF) leaves 1.92 M yd^3 additional disposal capacity needed. The difference between the two estimates, 2.2 M yd^3 needed per this RI/FS and 1.92 M yd^3 needed per the FY 2014 PCCR, is a result of the following:

- A greater uncertainty is assumed and applied to volumes in this RI/FS (25% versus the 95% UCL in the PCCR).
- A 4% difference in waste generation estimates in the RI/FS versus the PCCR (mainly attributed to a correction in the Alpha-4 waste volume and a re-estimate of the K-31 waste volume).

In addition to the differences in needed disposal capacity, the FY 2014 PCCR predicts the EMWMF reaches capacity in 2022, whereas this analysis predicts that date is 2024 due to the overlap of available disposal (e.g., with EMDF accepting waste beginning in 2022, the life of EMWMF is extended).

Table 2-4. Uncertainty (Contingency) and Corresponding Projected Disposal Capacity Need

Contingency	Projected Disposal Capacity Need (yd^3)	Description	EBCV Option, Cells Filled	WBCV Option, Cells Filled	Dual Option, Cells Filled
0	1,746,430	As-disposed waste volume estimate, no uncertainty	Cells 1-4 (1.77M yd^3)	Cells 1-4 (1.52 M yd^3)	Site 6b, Cells 1-5 (0.85 M yd^3) Site 7a, Cells 1-3 (0.93 M yd^3)
25%	2,183,037	As-disposed waste volume estimate plus 25% contingency to accommodate uncertainty	Cells 1-5 (2.18M yd^3)	Cells 1-5 (2.20 M yd^3)	Site 6b, Cells 1-5 (0.85 M yd^3) Site 7a, Cells 1-4 (1.4 M yd^3) [2.25 M yd^3 tot]
		Conceptual design facility capacity; will be adjusted in final design	+ Optional Cell 6 (2.5M yd^3)	+ Optional Cell 6 (2.8M yd^3)	No additional capacity

Table 2-5. Analyzed Uncertainties in Determining On-site Disposal Capacity Needs

Waste volumes for disposal (see Appendix A) from the Waste Generation Forecast (WGF)			Detailed uncertainty analysis that could Decrease or Increase the capacity required			
			Uncertainty explanation	As-disposed volume		Detailed assumptions
WGF	As-generated volume (yd^3)	As-disposed volume (yd^3)		Decrease (yd^3)	Increase (yd^3)	
Debris (LLW/TSCA)	949,641	472,458				
Debris (Mixed)	123,231	60,553	Treatment of mercury-contaminated debris	183,445	200,697	Treatment of mercury-contaminated debris will not achieve the in-place volume reduction that is achieved with other debris. Lower value is 100% demolition site macro, higher value is 100% in-cell macro.
Soil (LLW/TSCA)	432,092	332,378	Bear Creek Burial Grounds (BCBG) Remediation		105,000	Assume partial excavation, 21,000 yd^3 waste to be grouted with a 4:1 ratio of grout to waste per BCBG FFS. (DOE 2008) (Note: this cannot be used as fill).
			Chestnut Ridge Remediation		9,962	90 x 394 ft area; 12,950 yd^3 soil.
Soil (Mixed)	53,882	42,047	UEFPC Mercury-contaminated soils		21,023	Assume 50% increase in soil volume requiring treatment. Note this cannot be used as fill.
Other: Fill		838,994	Other: Fill : AD-debris ratio adjustment	(410,240)		Assume the 2.26 fill:debris ratio is 1.7.
			Additional fill needed due to poor sequencing		187,213	Assume 1/2 of soil waste can't be used as fill.
			Leachate treatment, secondary waste	1,694	1,694	Secondary waste generated by leachate treatment facility, 22 years of operation (22 - B25 boxes per year).
			Affects of EMWMF uncertainties:			
			Additional capacity achieved	(200,000)		Thinning of EMWMF cap increases capacity of EMWMF landfill.
			UPF soils/debris (new)	20,119	20,119	Newly identified waste for disposal at EMWMF.
			Inaccuracies		125,141	Current EMWMF air survey (FY 2015) showing 125,141 yd^3 less available capacity than is demonstrated by mass balance.
			Fill:AD-debris ratio adjustment	(140,935)		Assume the 2.26 fill:debris ratio is 1.7.
			Additional fill needed due to poor sequencing		47,711	Assume 1/2 of soil waste can't be used as fill.
SUBTOTAL	**1,558,846**	**1,746,430**	**Calculated uncertainties**	(545,918)	718,560	Apply these calculated uncertainties to as-disposed volume from the WGF (e.g., 1,746,430)
25% uncertainty	389,712	436,608				
TOTAL	**1,948,558**	**2,183,038**				
Volume (capacity) required with calculated uncertainties realized:				**1,200,512**	**2,464,990**	**(Low and high capacities required for on-site disposal)**

If an On-site Disposal Alternative is selected as the remedy, the footprint capacity will be further optimized for efficiency and land utilization considering topographic and hydrogeologic features in the detailed design. A phased construction of the landfill would allow adjustment of cell construction as needed to accommodate potential lower waste volumes (e.g., construction of Phase III could be eliminated if capacity is not needed).

Figure 2-3(a) shows the cumulative CERCLA waste capacity demand estimate through FY 2043 including the 25% uncertainty allowance for future volumes. Figure 2-3(a) also shows the maximum capacity of EMWMF (2.18 M yd^3) is estimated to be reached in FY 2024 based on 25% uncertainty in future volumes. A cumulative volume graphic for the new facility alone is also shown (Figure 2-3[b]). Based on this estimate, the On-site Disposal Alternative assumes a new CERCLA waste disposal facility is operational in FY 2022.[9] Details regarding the calculations may be found in Appendix A.

In addition to uncertainty in future waste volume estimates, other factors such as funding, project sequencing, and contracting can impact project implementation plans and the RI/FS waste volume estimates. For example, annual funding lower than the $420M funding scenario assumed (see Section 2.2.1) could delay EMWMF reaching maximum capacity and the operational start of a new facility. A higher funding scenario could result in EMWMF reaching capacity sooner.

2.2.3 Volume for Off-site Disposal Alternative

Completion of the Off-site Disposal Alternative analysis requires the total volume of waste to be shipped. This volume is the as-generated waste volume (see Table 2-2). In addition, those volumes are adjusted by the same uncertainty used in the On-site Disposal Alternative (e.g., 25%).

Table 2-6 gives the as-generated waste volumes with 25% uncertainty, which are used in the Off-site Alternative Analysis.

Table 2-6. Post-EMWMF As-generated Waste Volume Estimate (FY 2022 - FY 2043) with 25% Uncertainty

Material Type	Waste Type		TOTAL by Material Type (yd^3)
	LLW (includes LLW/TSCA)	Mixed (LLW/RCRA, LLW/RCRA/TSCA)	
25% Uncertainty applied to As-generated Estimates			
Debris	1,151,440	149,418	1,300,858
Debris/Classified[a]	35,612	4,621	40,233
Soil	540,115	67,353	607,468
Total	**1,727,167**	**221,391**	**1,948,558**

[a] Some percentage of debris waste is expected to be classified, but is currently not specified as such in the Waste Generation Forecast. Three percent of generated debris is assumed to be classified for purposes of off-site disposal evaluation (based on 3% of waste from ETTP considered classified in the WGF).

[9] Operational start-up of a new facility is assumed to begin approximately two years prior to reaching capacity at EMWMF.

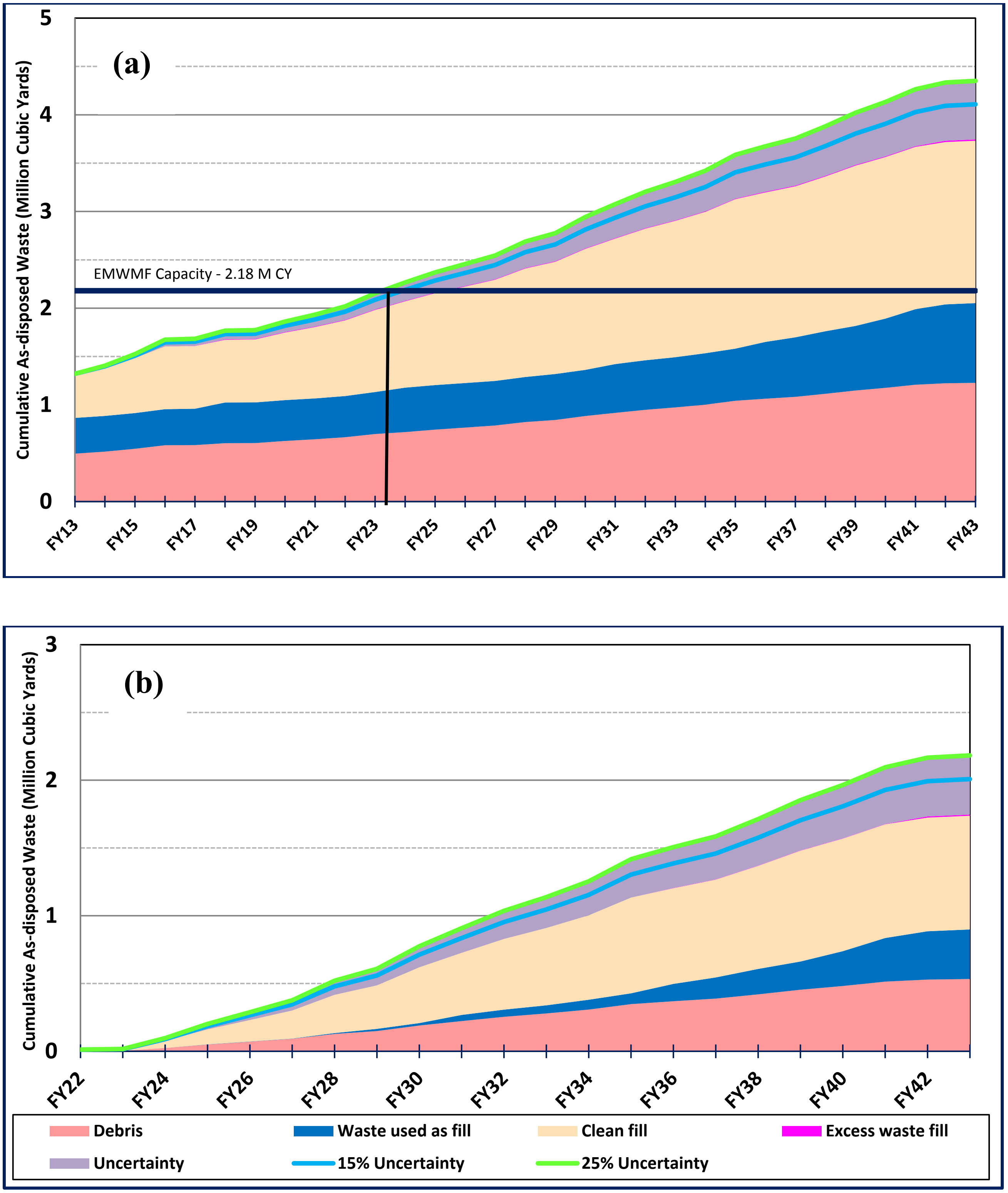

Figure 2-3. (a) Cumulative CERCLA Waste Capacity Demand Estimate (b) Cumulative CERCLA Waste Capacity Demand Estimate for New EMDF

2.2.4 Volumes for Hybrid Disposal Alternative

The hybrid alternative, a combination of on-site and off-site disposal that combines volume reduction (VR) for waste disposed on-site, allows for a portion of waste to be disposed in a small on-site facility while the remainder of waste is disposed off-site. This analysis was performed assuming Site 6b would be the on-site option location based on the proximity to existing infrastructure, minimal need for construction of underdrains compared to other small sites (e.g., Site 7a, 7b, and 6a), and future land use location (DOE industrial use). More detailed explanation regarding the selection of this site for the Hybrid Disposal Alternative is given in Chapter 6, Section 6.4.

This site provides approximately 850,000 yd^3 of disposal capacity. Because operation of a landfill of this limited capacity would likely entail some annual combination of on-site and off-site disposal of CERCLA waste, an assumption was made that 10% of the debris would be disposed off-site during the operational phase of the on-site facility; this resulted in a volume distribution (on/off-site) as indicated in Table 2-7. Note that on-site volumes are given for as-generated and as-disposed, while off-site volumes are as-generated. Volume reduction capacity preserved was calculated based on Appendix B results. More information is provided in Section 6.4.

Table 2-7. Hybrid Alternative Waste Volumes

Material Type	On-site Volumes by Material Type		Off-site Volumes by Material Type (As-generated, yd^3)
	(As-generated, yd^3)	(As-disposed, yd^3)	
Debris	490,706	244,132	582,166
Soil	77,566	59,666	408,409
Fill		492,073	(not applicable)
Volume preserved through VR		-144,838	
25% uncertainty		**198,968**	**247,644**
Total		**850,001**	**1,238,219**

Sum of as-generated volumes (490,706 + 77,566 + 582,166 +408,409 equals 1,558,846) as given in Table 2-2.

2.3 RI/FS WASTE CHARACTERIZATION

This section discusses characterization of future generated CERCLA waste streams. Because detailed characterization data do not exist for many of the individual D&D and remediation projects, characterization of future waste streams is based on available data for waste disposed at EMWMF to establish contaminants of potential concern (COPCs) and estimate contaminant concentrations. This methodology relies on the assumption that available data for waste disposed at EMWMF approximately represent the waste characteristics of future waste streams. Use of characterization data for waste disposed at EMWMF is limited in the RI/FS to serving as a basis for the transportation risk and natural phenomena risk calculations. Additionally, these transportation and natural phenomenon risk analyses consider the risk posed by release of radioactively contaminated waste as far exceeding the risk posed to the public by any contained chemical hazards, and therefore only the radioactive portion of the waste is considered in those assessments.

The EMWMF waste characterization results were used to develop a derived data set of radionuclide contaminants as discussed in Section 2.3.1 below. The data set forms the basis for calculating transportation risk for the On- and Off-site Disposal Alternatives, and risk associated with natural phenomena (wind-borne [tornadic] contamination risk) for the On-site Disposal Alternative (see Table 2-1). Risk calculations are discussed in Appendix F. Because chemical contaminants contribute relatively minimal transportation and natural phenomenon risk, relevant non-radiological contaminant information provided in this RI/FS is limited to a discussion of the anticipated chemical constituents in Section 2.3.2.

PreWAC have been developed based on contaminant pathway analysis modeling for the proposed on-site disposal facility conceptual design. As shown in Table 2-1, the PreWAC evaluation is used to determine the following:

- Does the PreWAC allow most future CERCLA waste to be disposed?
- Does the proposed conceptual design provide adequate assurance that disposed contaminants would pose acceptable risks?

The projection that waste characteristics of future waste will be similar to waste disposed to date at the EMWMF, specifically those disposed from cleanups at Y-12 and ORNL, is a key assumption in the analysis.

2.3.1 Radionuclide Characterization

The derived data set of radionuclide COPCs and estimated radionuclide contaminant concentrations are designed to provide a reasonable range of contaminant parameters for waste expected to be generated from future D&D and remedial action projects, especially as they are used only in a relative sense, to compare on-site and off-site alternative risks. It is recognized that radionuclide COPCs from future cleanup projects may differ in concentrations; however, the list of radionuclides received at EMWMF (includes waste received from all three ORR facilities) and on which this analysis is based is extensive and reflects the nuclides expected in future waste lots. The process used to develop the contaminant data set of mass-weighted average radionuclide concentrations for use in natural phenomenon risk and transportation risk evaluation consisted of the following steps:

- Data collection
- Data set development exceptions
- Development of data set used for risk evaluation

A summary of the process is provided below. A more detailed description of the process steps and calculations is provided in Appendix A.

2.3.1.1 Data Collection

The data collection process is summarized as follows:

- Waste lots (WLs) for waste disposed at EMWMF were identified using a Waste Transportation Management System[10] EMWMF Disposition Summary Report.
- Radionuclide COPC concentration data for identified WLs were obtained from a Waste Acceptance Criteria Forecast Analysis Capability System[11] output report or waste profile data. The expected value concentrations of radionuclide COPCs reported in the individual waste WL data sets were identified.
- Net weight data for identified WLs were collected.

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[10] Waste Transportation Management System is a web-based tool that provides a central source for manually compiling and printing shipping documents required for the transport of waste and materials generated by the OREM contractor.

[11] Waste Acceptance Criteria Forecast Analysis Capability System is the primary tool used to ensure analytic WAC compliance at the EMWMF.

2.3.1.2 Development of Data Set for Risk Evaluation

A mass-weighted average concentration for each radionuclide was derived for use as input for the transportation risk and natural phenomenon risk evaluation as summarized below:

- Calculate the activity in pCi of each radionuclide contaminant reported in each WL using the reported concentration of each radionuclide in the WL and the net weight of all shipments for the WL.
- Calculate the average concentration in pCi/g for each radionuclide contaminant in the WL data set by summing the activities calculated above and dividing by the sum of net weights of all shipments for all WL in the data set with a reported value for the radionuclide.

The mass-weighted average concentration in pCi/g calculated for each radionuclide contaminant shown in Table 2-8 forms the data set used for transportation and natural phenomena risk evaluation.

2.3.1.3 Data Collection and Data Set Development Exceptions

Exceptions to the data collection and data set development process summarized above were made for WLs that were merged or split out from the original approved WL profile and therefore shipped under a different WL number. Details about the exceptions are provided in Appendix A.

2.3.2 Chemical Characterization

As stated previously, the chemical contaminants for future waste streams to be disposed at EMDF are assumed to be similar to those of waste disposed at the EMWMF. Because chemical contaminants contribute relatively minimal transportation and natural phenomenon risk, the chemical contaminant information provided in the RI/FS is not analyzed in those scenarios. The methodology explained for radionuclide data collection and average concentration calculations (Sections 2.3.1.1–2.3.1.2) was followed to obtain estimated chemical concentrations as well. A complete list of the chemical constituents identified in the EMWMF WAC and the chemical constituents which have historically been found in the waste disposed at EMWMF (BJC 2008) is provided in Table 2-9.

2.3.3 Mercury-contaminated Waste

One exception to the similarity in chemical contaminants for EMWMF waste compared to future CERCLA waste is mercury. Future Y-12 CERCLA waste will include media and debris generated during demolition and remediation of mercury-contaminated sources in the Y-12 main plant area. This mercury-contaminated waste will include debris and soils/sediments that are characteristically hazardous (carry the D009 hazardous waste code) due to elevated mercury levels based on the toxicity characteristic leaching procedure (TCLP) as well as waste that, although it contains mercury, passes TCLP and is therefore not hazardous. As the mercury concentrations in these future waste lots are expected to vary significantly, an average mercury concentration is not given in Table 2-9.

Past determinations have shown the mercury-contaminated waste, which will be generated upon demolition of the four Y-12 facilities and associated ancillary facilities, as well as the soils and sediments to be generated during remediation, would not carry the U-151 listed waste code (code for discarded elemental mercury product, off-specification metallic mercury product, and container or spill residues thereof). An extensive review of the subject was completed and communicated to regulators (DOE 2005), and the recent and thorough characterization work completed on the Alpha-5 facility also addressed this topic, confirming that the waste would not be U-151 listed (DOE 2012c).

Table 2-8. Radionuclide Data Set for Natural Phenomena and Transportation Risk Evaluation

Isotope	Mass Weighted Average (pCi/g)	Isotope	Mass Weighted Average (pCi/g)	Isotope	Mass Weighted Average (pCi/g)
Ag-110m	4.76E-01	Fe-59	1.49E+00	Pu-244	3.22E-02
Am-241	9.18E+00	H-3	1.91E+02	Ra-226	9.10E-01
Am-243	5.77E-01	I-129	1.79E+00	Ra-228	7.95E-01
Bi-214	3.89E-01	K-40	4.21E+00	Ru-106	6.27E+04
C-14	2.91E+01	Kr-85	1.04E+02	Sr-90	9.73E+03
Cm-242	1.63E-01	Mn-54	8.47E-01	Tc-99	3.67E+01
Cm-243	6.69E+00	Nb-94	7.93E-02	Th-228	4.27E-01
Cm-244	1.14E+04	Ni-59	4.04E+01	Th-229	4.00E-03
Cm-245	1.39E-01	Ni-63	1.05E+02	Th-230	1.55E+00
Cm-246	5.41E+00	Np-237	2.91E-01	Th-232	1.69E+00
Cm-247	9.55E-03	Pb-210	2.50E+00	U-232	1.65E+00
Co-57	1.48E-01	Pb-214	4.02E-01	U-233	8.13E+01
Co-60	5.05E+02	Pm-147	1.00E+01	U-234	2.69E+02
Cs-134	2.48E+04	Pu-238	5.69E+01	U-235	1.63E+01
Cs-137	5.83E+03	Pu-239	1.17E+01	U-236	1.14E+01
Eu-152	6.43E+03	Pu-240	1.74E+02	U-238	1.60E+02
Eu-154	4.85E+03	Pu-241	2.01E+02	Zn-65	1.46E+00
Eu-155	1.41E+03	Pu-242	3.79E-01		

According to RCRA LDRs[12], mercury-contaminated (D009) waste must be treated prior to land disposal unless another alternate regulatory approach is invoked. Optional technical and regulatory approaches for the treatment and disposal of mercury-contaminated debris are described in Appendix C. RCRA hazardous waste that is disposed in an on-site facility will be required to meet LDRs prior to disposal, as is the practice at EMWMF per that facility's administrative WAC. The PreWAC analysis identifies additional risk- and dose-based chemical limits for constituents that may be present in the waste, and analytic WAC will be finalized for a future facility (see Section 6.2.3).

[12] The purpose of LDR requirements is to reduce the toxicity and/or the mobility of the hazardous constituents in the environment. In particular, LDRs are aimed at reducing the likelihood that hazardous constituents will leach into ground water and/or surface water. Under LDRs, specific constituent levels (i.e., treatment standards) must be achieved before the hazardous waste can be land disposed. Alternate regulatory approaches that achieve certain criteria may be used if approved by regulators.

Table 2-9. Chemical Constituents

Chemical	CASN	Mass-average (mg/kg)
(1,1-Dimethylethyl)benzene	98-06-6	
(1-Methylpropyl)benzene	135-98-8	0.0
1,1,1-Trichloroethane	71-55-6	
1,1-Dichloroethane	75-34-3	
1,1-Dichloroethene (Dichloroethylene)	75-35-4	
1,1,2-Trichloroethane	79-00-5	
1,1,2-Trichloro-1,2,2-Trifloroethane	76-13-1	
1,2,4-Trichlorobenzene	120-82-1	
1,2,4-Trimethylbenzene	95-63-6	0.03
1,2-Dichlorobenzene	95-50-1	0.0
1,2-Dimethylbenzene	95-47-6	0.01
1,2-Dichloroethane	107-06-2	
1,2-Dichloroethene	156-59-2	
1,3,5-Trimethylbenzene	108-67-8	
1,3-Dichlorobenzene	541-73-1	0.0
1,4-Dichlorobenzene	106-46-7	0.0
1-Methyl-4-(1-methylethyl)benzene	99-87-6	
2,3,4,6-Tetrachlorophenol	58-90-2	0.23
2,3,7,8-Tetrachlorodibenzo-p-dioxin	1746-01-6	
2,4-Dimethylphenol	105-67-9	0.01
2,4-Dinitrophenol	51-28-5	
2,4,5-Trichlorophenol	95-95-4	
2-Butanone (also known as Methyl Ethyl Ketone)	78-93-3	
2-Chlorophenol	95-57-8	
2-Chloronaphthalene	91-58-7	
2-Hexanone	591-78-6	
2-Methylnaphthalene	91-57-6	
2-methylphenol (o-cresol)	95-48-7	
3-3'-Dichlorobenzidine	91-94-1	
3-methylphenol (m-cresol)	108-39-4	
2-Nitroaniline (O-Nitroaniline) IP-Nitroaniline)	88-74-4	
4,4'-DDD	53-19-0	0.2
4,4'-DDE	72-55-9	1.2

Chemical	CASN	Mass-average (mg/kg)
4,6-Dinitro-2-methylphenol	534-52-1	
4-Chloro-3-Methylphenol	59-50-7	
4-Methyl-2-Pentanone (MIBK)	108-10-1	
4-methylphenol (p-cresol)	106-44-5	
Acenaphthene	83-32-9	26.41
Acenaphthylene	208-96-8	0.55
Acetone	67-64-1	0.44
Acetophenone	98-86-2	0.1
Aldrin	309-00-2	0.09
Alpha-BHC	319-84-6	0.0
alpha-Chlordane	5103-71-9	
Aluminum	7429-90-5	
Anthracene	120-12-7	
Antimony	7440-36-0	12.1
Arsenic	7440-38-2	
Asbestos	1332-21-4	
Barium	7440-39-3	256.3
Benzo(a)anthracene	56-55-3	
Benzene	71-43-2	0.0
Benzenemethanol	100-51-6	
Benzo(a)pyrene	50-32-8	
Benzo(b)fluranthene	205-99-2	
Benzo(g,h,i)perylene	191-24-2	
Benzo(k)fluoranthene	207-08-9	
Benzoic Acid	65-85-0	24.3
Beryllium	7440-41-7	
Beta-BHC	319-85-7	0.0
Bis(2-ethylhexyl)phthalate	117-81-7	
Boron	7440-42-8	30.82
Butylbenzylphthalate	85-68-7	
Cadmium	7440-43-9	
Calcium	7440-70-2	
Carbazole	86-74-8	47.44

Table 2-9. Chemical Constituents (Continued)

Chemical	CASN	Mass-average (mg/kg)	Chemical	CASN	Mass-average (mg/kg)
Carbon disulfide	75-15-0	0.0	Lead	7439-92-1	637
Carbon tetrachloride	56-23-5	0.0	Lithium	7439-93-2	0.0
Chlordane	57-74-9	0.04	Magnesium	7439-95-4	
Chlorobenzene	108-90-7	0.0	Manganese	7439-96-5	38,143
Chloroethane	75-00-3		Mercury	7439-97-6	varies
Chloroform	67-66-3	0.0	Methoxychlor	72-43-5	
Chromium	7440-47-3	932	Methylcyclohexane	108-87-2	0.0
Chrysene	218-01-9		Methylene Chloride	75-09-2	0.02
cis-1,2-Dichloroethene	156-59-2		Molybdenum	7439-98-7	34.5
Cobalt	7440-48-4		n-Nitroso-di-n-propylamine	621-64-7	0.0
Copper	7440-50-8		Naphthalene	91-20-3	46.2
Cumene	98-82-8	0.02	Nickel	7440-02-0	
Cyanide	57-12-5	0.6	Polychlorinated biphenyl (PCB), Total	1336-36-3	
Delta-BHC	319-86-8	0.0	Pentachlorophenol	87-86-5	
Dibenz(a,h)anthracene	53-70-3		Phenanthrene	85-01-8	
Dibenzofuran	132-64-9		Phenol	108-95-2	0.45
Dieldrin	60-57-1	0.18	Potassium	7440-09-7	
Diethylphthalate	84-66-2	8.13	Propylbenzene	103-65-1	0.0
Dimethylphthalate	131-11-3	3.99	Pyrene	129-00-0	
Di-n-butyl phthalate	84-74-2	5.02	Selenium	7782-49-2	118
Di-n-octylphthalate	117-84-0		Silver	7440-22-4	
Endosulfan I	959-98-8	0.18	Sodium	7440-23-5	
Endosulfan II	33213-65-9		Strontium	7440-24-6	178
Endosulfan Sulfate	1031-07-8		Tetrachloroethene (PCE)	127-18-4	0.0
Endrin	72-20-8	0.18	Thallium	7440-28-0	
Endrin Aldehyde	7421-93-4	0.18	Tin	7440-31-5	81.9
Ethylbenzene	100-41-4	0.06	Titanium	7440-32-6	
Fluoranthene	206-44-0		Toluene	108-88-3	0.04
Fluorene	86-73-7		Trichloroethene (TCE)	79-01-6	0.02
gamma-Chlordane	5103-74-2	0.04	Uranium	7440-61-1	
Heptachlor Epoxide	1024-57-3	0.02	Vanadium	7440-62-2	39.9
Hexachlorobutadiene	87-68-3	0.0	Vinyl Chloride	75-01-4	0.0
Hydrogen fluoride (released from UF_6)	7664-39-3		Xylenes	1330-20-7	0.04
Indeno(1,2,3-cd)Pyrene	193-39-5		Zinc	7440-66-6	
Iron	7439-89-6		Zirconium	7440-67-7	
Isophorone	78-59-1	0.05			

3. RISK EVALUATIONS

This chapter discusses evaluations of risk for the four alternatives: no action, on-site disposal, off-site disposal, and hybrid disposal considered in this RI/FS. These evaluations were prepared in general accordance with the principles outlined in Risk Assessment Guidance for Superfund Parts A and C (EPA 1989; EPA 1991a).

3.1 EVALUATION OF BASELINE RISK (NO ACTION ALTERNATIVE)

CERCLA requires that the No Action Alternative be considered as a baseline for comparison against action alternatives. For a typical CERCLA evaluation, the No Action Alternative is based on the assumption that no cleanup actions or other measures are taken to mitigate existing or potential future impacts to human health or the environment posed by a contaminated site. For a typical No Action Alternative:

- Current and future baseline risks are estimated to (1) determine whether remediation of a contaminated site is required and (2) evaluate risk reduction that would result from implementation of remedial actions.
- Baseline Human Health Risk Assessments (BHHRAs) are performed in accordance with EPA guidance to provide estimates for both carcinogenic (cancer) risk and systemic toxicity (non-carcinogenic effects) from contaminant exposure.
- The receptor scenario (e.g., residential, industrial, or recreational use) is determined by considering current and potential future land use.

Unlike an RI/FS for a typical remediation project, the purpose of this RI/FS is not to evaluate alternatives for cleaning up a contaminated site. The purpose of this RI/FS is to evaluate alternatives for disposal of CERCLA waste generated from cleanup of various contaminated sites on the ORR and associated sites under an action alternative that provides a consolidated, central method for disposal versus a no action that does not provide a central and consolidated disposal path for that waste. Decisions about cleaning up those sites have already been made in existing CERCLA decision documents or will be made in future CERCLA decision documents. Remediation of the sites is expected to generate radiological and/or hazardous wastes that will require disposal at an approved facility.

Remediation projects for contaminated sites are connected to the evaluation of disposal alternatives in this RI/FS only by the candidate waste streams to be generated that require disposal. The baseline risk evaluations for contaminated sites in existing and future CERCLA documents are otherwise separate and distinct from this CERCLA evaluation of disposal alternatives for waste streams. Likewise, remedial actions to be conducted at contaminated sites are determined by CERCLA decisions that are separate from this RI/FS evaluation.

For the remediation projects that will generate candidate waste streams evaluated in this RI/FS, Table 3-1 contains a list of the applicable existing CERCLA documents that contain risk evaluations (including BHHRAs) and corresponding existing CERCLA decision documents. Future remediation projects for which a CERCLA risk evaluation and decision document have yet to be completed are also identified.[13]

Unlike the No Action Alternative for a typical RI/FS which assumes no cleanup actions are taken at a contaminated site, the No Action Alternative for this RI/FS is based on the assumption that disposal of future waste streams from site cleanup would be addressed at the project-specific level. No coordinated ORR effort would be implemented to manage wastes generated by future CERCLA actions after EMWMF capacity is reached.

[13] For these future remediation projects, selected remedies and candidate waste streams have been assumed for planning purposes only and do not preclude the outcome of a future CERCLA evaluation process.

Table 3-1. Risk Evaluation and Decision Documents for Remediation Projects

Site	Subproject	Risk Evaluation Document	Decision Document*	Project
ETTP	**Remaining Facilities D&D**	*Engineering Evaluation/Cost Analysis for the K-25 Auxiliary Facilities Demolition Project Group II Buildings at East Tennessee Technology Park, Oak Ridge, Tennessee (DOE/OR/01-1765&D4)*	*Action Memorandum for the Remaining Facilities Demolition Project at East Tennessee Technology Park, Oak Ridge, Tennessee* (DOE/OR/01-2049&D2-R)	Central Neutralization Facility
				K-1037 and K-1037-C
				Poplar Creek Facilities
				TSCA Incinerator Facilities
	Site Wide	*Final Sitewide Remedial Investigation and Feasibility Study for East Tennessee Technology Park, Oak Ridge, Tennessee* (DOE/OR/01-2279&D3)	**Record of Decision for Site Wide Remedial Actions**	Site Wide Remedial Actions
	Zone 2	*Focused Feasibility Study for Zone 2 Soils and Buried Waste, East Tennessee Technology Park, Oak Ridge, Tennessee* (DOE/OR/01-2079&D1/R1)	*Record of Decision for Soil, Buried Waste, and Subsurface Structure Actions in Zone 2, East Tennessee Technology Park, Oak Ridge, Tennessee* (DOE/OR/01-2161&D2)	Zone 2 Remedial Actions
ORNL	**Melton Valley (MV)**	**To Be Determined**	**MV Reactors and Other Facilities Record of Decision**	EGCR Complex
				HPRR Complex
				MV LGWO Complex
				MV Waste Storage Facilities
				MV HRE Facility
				TWPC Complex

Table 3-1. Risk Evaluation and Decision Documents for Remediation Projects (Continued)

Site	Subproject	Risk Evaluation Document	Decision Document*	Project
ORNL (cont)	**Bethel Valley (BV)**	*Remedial Investigation/Feasibility Study for Bethel Valley Watershed at Oak Ridge National Laboratory, Oak Ridge, Tennessee, Volume 1. Main Text* (DOE/OR/01-1748&D3)	*Record of Decision for Interim Actions in Bethel Valley, Oak Ridge, Tennessee* (DOE/OR/01-1862&D4)	BV Chemical Development Lab Facilities
				BV Isotope Area Facilities
				BV Reactor Area Facilities
				BV Tank Area Facilities
				BV Remaining Slabs and Soils
				ORNL Non- Hydrofracture Well P&A
				ORNL Remaining Non-Hydrofracture Well P&A
				ORNL Soils and Sediments
				BV Inactive Tanks and Pipelines
				BV Remaining Inactive Tanks and Pipelines
			Notice of Non-Significant Change to the Record of Decision for Interim Actions in Bethel Valley: Addition of Hot Storage Garden (3597)	Hot Storage Garden
			Notice of Non-Significant Change to the Record of Decision for Interim Actions in Bethel Valley, Oak Ridge, Tennessee (IFDP and ARRA Buildings)	2026 Complex
				2528 Complex
				3019A Complex
				3525 Complex
				3544 Complex
				3608 Complex
				4501/4505 Complex
				5505 Building
				6010 and East BV Complex
				Central Stack East Hot Cell Complex
				Central Stack West Hot Cell Complex
				Fire Station Complex
				LLLW Complex

Table 3-1. Risk Evaluation and Decision Documents for Remediation Projects (Continued)

Site	Subproject	Risk Evaluation Document	Decision Document*	Project
ORNL (cont)	**Bethel Valley (cont)**	*Remedial Investigation/Feasibility Study for Bethel Valley Watershed at Oak Ridge National Laboratory, Oak Ridge, Tennessee, Volume 1. Main Text* (DOE/OR/01-1748&D3)	*Notice of Non-Significant Change to the Record of Decision for Interim Actions in Bethel Valley, Oak Ridge, Tennessee (IFDP and ARRA Buildings)*	Southeast Lab Support Complex
				Southeast Services Group Complex
				Sewage Treatment Plant Complex
Y-12	**Upper East Fork Poplar Creek (UEFPC)**	*Engineering Evaluation/Cost Analysis for the Y-12 Facilities Deactivation/Demolition Project, Oak Ridge, Tennessee* (DOE/OR/01-2424&D2)	*Action Memorandum for the Y-12 Facilities Deactivation/Demolition Project, Oak Ridge, Tennessee* (DOE/OR/01-2462&D1)	9206 Complex
				9206 Complex LMD
				9212 Complex
				9212 Complex LMD
				Alpha-2 Complex
				Alpha-2 Complex LMD
				Alpha-3 Complex
				Alpha-3 Complex LMD
				Alpha-4 Complex
				Alpha-5 Complex
				Beta-1 Complex
				Beta-1 Complex LMD
				Beta-3 Complex LMD
				Beta-4 Complex
				Biology Complex
				Beta-3 Deactivation Only
				9731 LMD
				Steam Plant Complex LMD
				9213 and 9401-2 Demolition
				Tank Facilities Demolition

Table 3-1. Risk Evaluation and Decision Documents for Remediation Projects (Continued)

Site	Subproject	Risk Evaluation Document	Decision Document*	Project
Y-12 (cont)	**Upper East Fork Poplar Creek (cont)**	*Remedial Investigation of the Upper East Fork Poplar Creek Characterization Area at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, Volume 1* (DOE/OR/01-1641/V1&D2)	*Record of Decision for Phase I Interim Source Control Actions in the Upper East Fork Poplar Creek Characterization Area, Oak Ridge, Tennessee* (DOE/OR/01-1951&D3) (BJC 2002)	UEFPC Sediments - Streambed and Lake Reality
			Explanation of Significant Differences for the ROD for Phase I Interim Source Control Actions in the UEFPC Characterization Area, Oak Ridge, Tennessee (DOE/OR/01-2539&D2)	UEFPC Soils 81-10 Area
		Upper East Fork Poplar Creek Soil and Scrapyard Focused Feasibility Study (DOE/OR/01-2083&D2)	*Record of Decision for Phase II Interim Remedial Actions for Contaminated Soils and Scrapyard in Upper East Fork Poplar Creek, Oak Ridge, Tennessee* (DOE/OR/01-2229&D3) (BJC 2006)	UEFPC Remaining Slabs and Soils
				UEFPC Soils
	Bear Creek Valley (BCV)	**To Be Determined**	**Bear Creek Valley White Wing Scrap Yard Record of Decision**	BCV White Wing Scrap Yard Remedial Action
		Remedial Investigation of Bear Creek Valley at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, Volume 1 (DOE/OR/01-1455/V1&D2)	**Bear Creek Valley Burial Grounds (Phase II) Record of Decision**	BCV Burial Grounds Remedial Action
			Record of Decision for the Phase I Activities in Bear Creek Valley at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee (DOE/OR/01-1750&D4)	BCV S-3 Ponds
				BCV DARA Facility Remedial Action

***Bold Red Text** Denotes a Future CERCLA Evaluation or Decision

BCV	Bear Creek Valley
BV	Bethel Valley
EGCR	Experimental Gas Cooled Reactor
HPRR	Health Physics Research Reactor
LGWO	Liquid Gaseous Waste Operations
LMD	Legacy Material Disposition
MV	Melton Valley
P&A	plugging and abandonment
TWPC	Transuranic Waste Processing Center
UEFPC	Upper East Fork Poplar Creek

The No Action Alternative leaves decisions on how/where to dispose of a project's CERCLA waste to the individual project/contractor completing that single cleanup (e.g., one building or group of buildings). This process would then be repeated by all projects (some 100 demolition and remediation projects), leading to great inefficiencies through repetition - more expenses through repetition and individual contracting and trucking of waste as opposed to transporting by rail or disposing on-site; increased likelihood of waste storage as opposed to disposal; and greatly increased short-term risk involved in packaging and transporting waste to off-site disposal by truck when compared to on-site disposal or consolidated rail movement (the action alternatives). Long-term risk could be greater due to more in situ management of waste as well. Due to higher costs, extension of cleanup schedules for projects as well as the entire ORR (in excess of 10 years) poses greater risk to both human health and the environment as well as to the cleanup completion as a whole. Section 6.1 provides further discussion of the No Action Alternative.

3.2 EVALUATION OF RISK FOR THE ON-SITE ALTERNATIVE

Risks associated with the On-site Disposal Alternative (regardless of the proposed landfill location within Bear Creek Valley) include short-term risks (risk associated with transport of the waste to an on-site disposal facility as well as risk associated with construction and operation of the facility) and long-term risks (residual health risk posed by the disposed waste, and permanence – that is the ability of the alternative to ensure protectiveness over time) (EPA 1991a).

Short-term risks associated with the On-site Disposal Alternative are evaluated in Appendix F, and include morbidity (non-fatal) and mortality (fatal) risks posed by transporting the waste on-site. Risk arises from radiological exposure during routine and accident scenarios, to both the maximum exposed individual (MEI) and collective populations, as well as risk due to vehicular-related occurrences, which include those due to emissions and those due to the location/miles travelled. Other short-term risks include those posed to human health by occurrences of natural phenomena events, and risk to human health via possible fugitive dust emissions during construction activities. These short-term risks are summarized in Table 3-2 and evaluated for the on-site alternative as part of the CERCLA short-term effectiveness criteria discussed in Section 7.3.4. Detailed calculations and results are given in Appendix F.

For the On-site Disposal Alternative, long-term risk evaluation is a much more involved process. Residual risk can only be estimated in the early "feasibility" stage of this remedy, as the waste is not yet in place, and the types and amounts of contaminants are not yet fully known. However, this estimated risk represents the highest possible risk, as it is determined in terms of maximum limits (the PreWAC) for disposal of each COPC based on contaminant fate and transport analyses at points of exposure for an MEI. These PreWAC limits (along with other limits and a compliance approach to meeting those limits – see Section 6.2.3) determine whether or not each waste lot proposed for disposal may be accepted. As the remedy is further advanced through the design and eventually implementation and closure stages, a more quantitative approach to verifying that risk can be applied. Figure 3-1 is an illustration of the stages of this remedy with their associated inputs, processes applied, and resulting outputs.

Table 3-2. Short-term Risks Associated with the On-site Disposal Alternative (all Site Options) [a]

Scenario		Morbidity (Non-fatal)	Mortality (Fatal)
Transportation of Waste to an On-site Location			
Radiological Exposure (due to routine travel, all shipments)	MEI (single shipment) [b]	6.65E-08	4.99E-08
	Collective population	2.13E-13 to 8.47E-05	1.60E-13 to 6.35E-05
Vehicular-related incidents (due to emissions and miles travelled)		7.94E-01	3.31E-02
Natural Phenomena Risk in On-site Disposal of Waste at an On-site Location			
Aggregate human health risk due to tornado strike: 3.71E-07			
Fugitive Dust Emissions PM_{10} Values During Construction of an On-site Facility			
Range from 106 to 150 µg/m^3 for various construction activities			

[a] See Appendix F for details and calculations.
[b] No exposure to MEIs, for on-site disposal, for multiple shipments. The MEI is a worker for on-site disposal and under a worker protection plan. No residents live along the on-site disposal route. Single shipment risk is given here.

As stated, residual risk is the human health risk posed by the waste disposed in the facility. At this RI/FS stage, (feasibility stage in the figure) that risk can only be estimated, but it is conservatively estimated based on maximum contaminant limits for future waste. Appendix H of this document provides an evaluation of contaminant concentration (upper) limits that would be applied to determine acceptance of the waste, the analytic PreWAC. As the figure illustrates, several inputs are required to determine the PreWAC, including the facility conceptual design, the waste generation estimate (volumes), expected contaminants, etc. PreWAC are determined based on meeting the RAOs that specify the acceptable risk, and meeting ARARs, for example, the Maximum Contaminant Levels (MCLs). PreWAC are comparable to CERCLA preliminary remediation goals. The modeling for PreWAC that is presented in Appendix H is based on meeting defined risk goals and therefore serves as a risk evaluation.

During the second stage, the design stage, the WAC Attainment (Compliance) Plan, a primary FFA document, will be developed that will address the final analytic WAC as determined through the design processes, as well as other WAC (e.g., administrative, safety basis-controlled, and physical WAC, see Section 6.2.3). Final analytic WAC will be documented as part of the WAC Attainment (Compliance) Plan development. Demonstration of final WAC attaining the prescribed risk goals (RAOs) and ARARs will be included in the WAC Attainment (Compliance) Plan or accompanying analyses.

The implementation (operating) stage of the on-site facility will focus on evaluating waste lot information, determining if waste lots are acceptable for disposal (per the WAC Attainment (Compliance) Plan), and continuing to meet RAOs and ARARs.

Completion of the remedy and closure of the on-site disposal facility would result in a final cumulative risk, based on the final disposal facility inventory per the WAC attainment/compliance process, which would ensure the risk will not exceed the maximum allowable risk. Additionally, long-term, post-closure monitoring is implemented, as well as institutional controls, and continues to ensure the protectiveness of the action.

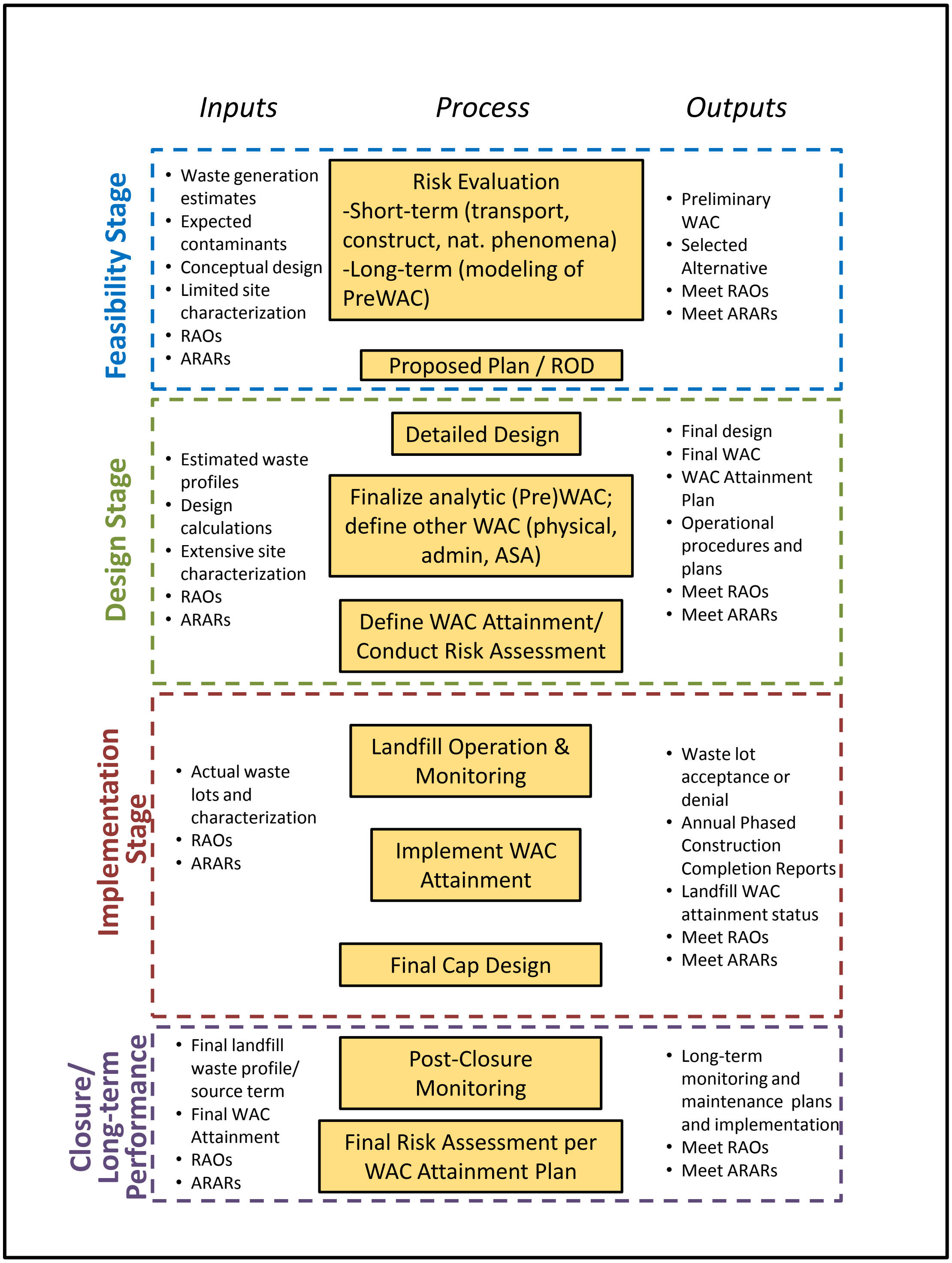

Figure 3-1. Illustration of the Stages of an On-site Disposal Action and Resulting Risk Determinations

3.3 EVALUATION OF RISK FOR THE OFF-SITE ALTERNATIVE

Risk associated with the Off-site Disposal Alternative includes only short-term risk, risks associated with transport of the waste to an off-site disposal facility. Short-term risks associated with the Off-site Disposal Alternative are evaluated in Appendix F, and include risk of injury (morbidity) and/or death (mortality) posed by transporting the waste off-site. These risks are summarized in Table 3-3 and evaluated for the off-site alternative as part of the CERCLA short-term effectiveness criteria discussed in Section 7.3.4. Note that Table 3-3 risks are for rail transport of wastes off-site (see also Tables F-4 and F-5 in Appendix F), and that these risks increase by a factor of about ten if wastes are transported solely by truck.

Chapter 7 provides a detailed analysis of alternatives according to CERCLA evaluation criteria and NEPA values. Evaluations in Chapter 7 of overall protection of human health and the environment (a CERCLA threshold criterion), short-term effectiveness, and long-term effectiveness use risk assessment information from Appendix F and Appendix H.

Table 3-3. Short-term Risks Associated with the Off-site Disposal Alternative[a]

Scenario		Morbidity (Non-fatal)	Mortality (Fatal)
Radiological Exposure (due to routine travel, all shipments)	MEIs	6.07E-05 to 7.21E-03	4.56E-05 to 5.41E-03
	Collective population	1.96E-03 to 9.13E-02	1.47E-03 to 6.84E-02
Vehicular-related incidents (emissions and miles travelled)		15.1 (NNSS, Option 1) 4.2 (Energy*Solutions,* Option 2)	8.7 (NNSS Option 1) 2.5 (Energy*Solutions,* Option 2)

[a] See Appendix F for details and calculations.

3.4 EVALUATION OF RISK FOR THE HYBRID ALTERNATIVE

Risk associated with the hybrid alternative is a combination of those risks associated with on-site and off-site disposal. Although a smaller on-site facility is assumed, the short-term risk posed to human health by occurrences of natural phenomena events and risk to human health via possible fugitive dust emissions during construction activities are independent of the size of the facility, so those results remain the same as for the On-site Disposal Alternative. Short-term risks are summarized for the Hybrid Disposal Alternative in Table 3-4 and evaluated as part of the CERCLA short-term effectiveness criteria discussed in Chapter 7.

Disposal of a portion of waste on-site in the Hybrid Disposal Alternative results in long-term risk (residual health risk posed by the disposed waste, and permanence – that is the ability of the alternative to ensure protectiveness over time) (EPA 1991a). This risk is similar to the long-term risk and evaluation made for the On-site Disposal Alternative discussed above in Section 3.2. However, as the hybrid alternative assumes a smaller on-site facility is constructed, the residual risk will be proportionally smaller for this alternative. Discussion and comparisons of long-term effectiveness for the various alternatives are presented in the comparative analysis in Chapter 7.

Table 3-4. Short-term Risks Associated with the Hybrid Disposal Alternative[a]

Scenario		Morbidity (Non-fatal)	Mortality (Fatal)
Radiological Exposure (due to routine travel, all shipments)	MEIs	2.11E-05 to 7.89E-04	1.58E-05 to 5.92E-04
	Collective population	3.09E-05 to 5.93E-02	2.31E-05 to 4.45E-02
Vehicular-related incidents (emissions and miles travelled)		1.6 (On-site disposal with off-site disposal at Energy*Solutions*)	1.2 (On-site disposal with off-site disposal at Energy*Solutions*)
Natural Phenomena Risk in On-site Disposal of Waste at an On-site Location			
Aggregate human health risk due to tornado strike: 3.71E-07			
Fugitive Dust Emissions PM_{10} Values During Construction of an On-site Facility			
Range from 106 to 150 μg/m^3 for various construction activities			

[a] See Appendix F for details and calculations.

4. REMEDIAL ACTION OBJECTIVES

CERCLA guidance defines RAOs as "medium-specific or operable-unit specific goals for protecting human health and the environment" (EPA 1988). According to the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), (40 CFR 300.430[e][2][i]), RAOs should specify the media involved, contaminants of concern, potential exposure pathways, and remediation goals. The scope of this RI/FS is limited to evaluating alternatives for the disposition of future-generated CERCLA waste resulting from CERCLA cleanup actions on the ORR and associated sites after the capacity of the existing landfill (i.e., EMWMF) is reached. Remediation goals for those cleanup actions are established at the project-specific level in existing CERCLA decision documents, or will be made in future CERCLA decision documents. For this RI/FS, the actions being evaluated are designed to provide for the disposition and containment of various waste types, so rather than establishing remediation goals for medium-specific cleanup, two types goals are established for this waste disposal response action. The first type of goal is the RAOs (which define protectiveness of the remedy), and the second goal supports the RAOs, but does not define protectiveness. The second goal is to develop and utilize WAC, further described at the end of this section.

COPCs for the On-site Disposal, Off-site Disposal, and Hybrid Disposal Alternatives include those present in various waste types derived from a wide range of sources and activities that would be disposed either on-site, off-site, or a combination of the two. A full description of those wastes and COPCs with estimated average concentrations based on wastes accepted at EMWMF to date (see Table 2-8 for radionuclides and Table 2-9 for chemicals) was given in Chapter 2.

As specified in Chapter 2, wastes that contain chemical contaminants that are RCRA hazardous must be treated to meet LDRs for any alternative (see Appendix G for the applicable or relevant and appropriate requirements that are specified for an on-site remedy). These wastes will have therefore met the specific constituent treatment standards required for land disposal that ensure protectiveness in terms of toxicity and/or mobility of the particular hazardous contaminant in a land disposal environment. In addition to meeting LDRs, hazardous COPCs as well as radioactive COPCs are addressed in this document through the establishment of PreWAC for an on-site facility, and subsequently through application of a final WAC (should either the On-site or Hybrid Disposal Alternative be selected as the remedy).

Two RAOs are defined for alternatives evaluated in this RI/FS:

1. Prevent exposure of human receptors to CERCLA waste (or contaminants released from the waste into the environment) that exceeds a human health risk of 10^{-4} to 10^{-6} Excess Lifetime Cancer Risk (ELCR) or Hazard Index (HI) of 1.
2. Prevent adverse impacts to water resources or unacceptable exposure to ecological receptors from CERCLA waste contaminants through meeting chemical-, location- and action-specific ARARs, including RCRA waste disposal and management requirements, Clean Water Act (CWA) Ambient Water Quality Criteria (AWQC) for surface water in Bear Creek, and Safe Drinking Water Act (SDWA) MCLs in waters that are a current or potential source of drinking water.

RAOs one and two are partially satisfied for the On-site Disposal Alternative through meeting ARAR location and siting requirements, design and construction requirements, monitoring requirements, and closure/post-closure requirements as summarized in Appendix G. Specifically, these requirements include but are not limited to the following:

- Avoidance of floodplains; wetlands; archaeological resources; and endangered, threatened or rare species. Where avoidance is not possible, mitigation measures will be taken.

- Siting requirements (some of which will require waivers that are justified in this document) regarding seismic stability; soil properties; hydrogeologic conditions; presence of natural resources; and capability of the site to be monitored.
- Design requirements regarding the liner system; leachate detection, collection/storage, and treatment systems; geologic buffer system; run-on/run-off control systems; and final cover systems.
- Construction requirements regarding installation and quality assurance of components as well as management of storm water.
- Operational requirements concerning the acceptance and receipt of waste (form, characterization, etc.); emplacement of waste in the landfill; transportation of waste; security systems; storm water management; inspections; training; contingency planning; inventory and record keeping; inspections; and sampling and monitoring of leachate, ground water, and surface water.
- Closure requirements regarding manner of closure; monitoring; security and land use control; and final cover functioning and design.
- Post-closure requirements including institutional controls; maintenance; monitoring; and general care.

RAO attainment for both radiological and conventional contaminants is also supported by limiting the concentration of waste that can be disposed in the facility. These concentration limits (WAC or PreWAC) are developed through fate and transport modeling of a representative on-site facility based on certain assumptions.[14] **NOTE**: The assumptions, such as the exposure point and maximum exposed individual, used for developing WAC or PreWAC concentration limits are used *only* to develop these allowable concentrations for waste to be disposed. In the event that there is a release from the waste disposal unit, the RAOs, whether they are ARAR- or risk-based, will be met as defined for the specific medium. For example, releases to ground water will be addressed consistent with RCRA Subpart F at the waste management unit boundary.

These PreWAC waste concentration limits are determined based on demonstrating the following goals are met during the 1,000 year compliance period:

- 10^{-5} ELCR and HI of 1 based on a human receptor's (direct) ingestion of ground water from a drinking water well and (indirect) uptake of surface water for the compliance period (to 1,000 years) using a resident farmer scenario, and 10^{-4} ELCR and HI of 3 at times exceeding 1,000 year compliance period. (More information may be found in Appendix H.)
- Appropriate AWQC for chemicals (risk-based discharge levels for radionuclides in Bear Creek and tributary surface water are per the Integrated Water Management Focused Feasibility Study, UCOR 2016).
- MCLs in ground water present in the drinking water well of the resident farmer scenario.

Under the Off-site Disposal Alternative, waste is shipped for permanent disposal at existing permitted off-site facilities. All off-site facilities presented and proposed for use under the Off-site Disposal Alternative in this RI/FS have been vetted through the CERCLA off-site rule, Section 121(d)(3) of the

[14] Non-carcinogenic contaminant exposure is modeled to determine PreWAC limits based on an HI equal or less than 1.0 for the compliance period, up to 1,000 years. With increased uncertainty in modeling results past 1,000 years, the target HI is increased to 3.0 beyond the compliance period. Likewise, the target ELCR is set at the high end of the risk range, 10^{-4}, for the post-compliance time period for carcinogenic contaminant fate and transport modeling. More detail may be found in Appendix H.

NCP 40 CFR 300.440, and as such have been approved for disposal of CERCLA wastes. Thus the Off-site Disposal Alternative meets RAOs one and two.

The Hybrid Disposal Alternative, as a combination of the On-site and Off-site Disposal Alternatives, satisfies RAOs one and two as discussed above.

As described in Chapter 3, the No Action Alternative provides no coordinated ORR effort to manage waste generated by future CERCLA actions after EMWMF capacity is reached; therefore, the RAOs are not directly applicable to the No Action Alternative. Overall protectiveness of human health and the environment and risk reduction would have to be addressed by CERCLA decisions at the individual sites without the benefit of a comprehensive disposal strategy.

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5. TECHNOLOGY SCREENING AND ALTERNATIVES ASSEMBLY

Technologies and process options are identified and screened in this chapter to determine representative process options that best support the disposal of candidate waste streams identified in Chapter 2. The representative process options are assembled into disposal alternatives that satisfy the RAOs developed in Chapter 4.

The selected disposal alternatives are further developed and evaluated against the CERCLA criteria to build a basis for choosing one that is the most likely to provide an effective, implementable, and economical solution. The alternatives are developed in detail in Chapter 6, and evaluated in Chapter 7.

5.1 IDENTIFICATION OF TECHNOLOGIES AND PROCESS OPTIONS

RAOs are met through implementation of general response actions, which are intended to protect human and ecological receptors from exposure to contamination in sources or environmental media. This section of the RI/FS draws from the general response actions, technology types, and process options that were presented in the EMWMF RI/FS and includes updates and modifications as necessary to address the present state of conditions. Applicable new information and lessons learned from construction and operation of the EMWMF are presented and applied throughout the screening process.

As specified in EPA RI/FS guidance (EPA 1988), a wide range of applicable technologies are evaluated to select a smaller number of process options for alternatives analysis. In the initial screening step, each process option is evaluated to determine its technical applicability to provide/support a potential solution. Next, the retained process options for each general response action and technology type are evaluated based on effectiveness, implementability, and relative cost to select final representative process options to retain for further development. Selection of representative process options for the development of alternatives does not eliminate other process options from future consideration.

The following general response actions apply to development of waste disposal alternatives for ORR CERCLA wastes:

- No action
- On-site disposal
- Off-site disposal
- Treatment of mercury-contaminated debris
- Volume reduction (VR)
- Waste packaging and transport
- Institutional controls

Potential applicable technology types and process options that apply to each general response action are identified, evaluated, and screened to narrow the selections to those that are most likely to be feasible. Following the initial screening, the process options retained are evaluated for relative effectiveness, implementability, and cost. Process options that best satisfy these criteria are carried forward as the representative process options that are assembled into remediation alternatives. Assembled remediation alternatives of the same technology type may use significantly different process options that could provide a unique advantage. In such a case, both alternatives of the same technology type may be carried forward for further development.

Selection of representative process options for the development of alternatives does not eliminate other process options from future consideration. Process options not retained may be reconsidered or new options may be added during development of the Proposed Plan, the ROD, or during the final design, equipment and vendor selection, or implementation.

Table 5-1 identifies and summarizes technologies and process options for each general response action, and identifies options that are retained or eliminated with comments regarding the basis for the screening decision. Process options are evaluated with respect to technical applicability and a smaller number of options are selected to retain for further study as recommended by EPA (EPA 1988). The evaluation process also documents the justification for eliminating options from further consideration. Process options or technology types that do not pass the initial screening step are not considered further. The following subsections provide general descriptions of process options considered for each of the seven general response actions.

5.1.1 No Action

The No Action Alternative is considered in accordance with CERCLA and NEPA requirements as required by the NCP as a basis for comparison with other general response actions. For this alternative, there would be no CERCLA action or work scope to consider for this project. Management of CERCLA waste after EMWMF capacity is reached would be addressed by the individual projects, rather than on an integrated ORR-wide basis.

Unlike the No Action Alternative for a typical feasibility study which assumes no cleanup actions are taken at a contaminated site, the No Action Alternative in this case is based on the assumption that no coordinated ORR effort would be implemented to manage wastes generated by future CERCLA actions after EMWMF capacity is reached. No assumptions are made under this alternative regarding the implementation of remedial strategies or specific actions for the individual sites, or at the watershed or ORR program-wide level.

Project-specific remedial decisions, including those concerning on-site, off-site, or in-situ waste disposal, would be made under the No Action Alternative without the benefit of an ORR site-wide disposal strategy or infrastructure. While protective remedies would be implemented, the lack of a coordinated disposal program has potential cost and protectiveness impacts as discussed in Section 7.2.1 and Section 7.3.

5.1.2 On-site Disposal

On-site disposal technologies considered include new facilities and existing land disposal facilities. To be considered applicable, a facility would have to accept the anticipated candidate waste streams (unclassified or classified LLW and mixed solid waste types with RCRA and/or TSCA components). Facilities were screened out if they could not accept some or all of these wastes or are not acceptable for other reasons. Some candidate waste streams could be treated to remove or segregate contaminants and the uncontaminated portion of the waste stream could be disposed of in another approved manner.

5.1.2.1 New Facilities

Concrete vaults: Concrete vaults are large, reinforced concrete, multi-celled structures constructed above- or below-grade facilities. The floors, ceilings, and exterior walls of concrete vaults may be up to 2 ft (0.6 m) thick. Concrete vaults are typically used to dispose of containerized LLW. Once these cells are filled with waste containers, the void spaces are filled with sand or grout and the filled vault is covered with a concrete lid. Vaults can be designed to allow for waste removal if necessary. Although vaults are structurally stable, concrete is more permeable than clay and as a result, disposal of leachable material within a vault would require an additional low-permeability lining of clay or other material for long-term containment of the waste. The requisite liners and multilayer cap can be used in conjunction with vaults for disposal of LLW and MLLW.

Table 5-1. Technology Descriptions, Screening, Evaluations, and Selection of Representative Process Options

General Response Action	Technology Type	Process Option	Description	Effectiveness	Implementability	Relative Cost	Selection
No Action	None	No actions	No coordinated CERCLA disposal capability is developed for the ORR. CERCLA cleanup projects arrange for disposal at the project level.	Ineffective as an ORR-wide disposal effort	Disposal is independently implemented by CERCLA cleanup projects.	Collective costs for project level waste management could be very high.	Retained as required by the NCP
On-site Disposal	New facilities	Below-grade facilities	Disposal of waste in silos, concrete vaults, engineered cells, or other facilities placed entirely below grade.	Effective for long-term disposal of LLW	Insufficient land available; ground water is too shallow	Very High	Eliminated due to shallow ground water concerns
		Sanitary landfill	A sanitary or construction/demolition landfill similar to an engineered disposal facility but with fewer isolation features incorporated into design.	Ineffective due to insufficient waste isolation systems	Prohibited from receiving LLW or MLLW	Low	Eliminated due to inability to receive projected waste
		Unlined trenches landfill	A trench or excavation with no bottom liner and a simple vegetative cover.	Ineffective due to insufficient waste isolation systems	Prohibited from receiving LLW or MLLW	Low	Eliminated due to inability to protect public and environment long-term
		Concrete vaults (above grade)	Large, reinforced, structurally stable, multi-celled structures designed for containerized waste. Allows for waste removal. Caps, liners, and leachate removal systems can be incorporated to meet requirements for LLW and mixed waste disposal.	Effective, but no more so than LLW landfill	Requires larger commitment of land than other new facility options	Very High	Eliminated due to very high costs and larger land commitments (cost expected to be similar to Tumulus facility, see below)
		Engineered disposal facility (landfill)	Facility that is partially below, at, or above grade and uses natural and man-made materials in embankments, cap, and liners. Caps, liners, and leachate removal system can be incorporated to meet requirements for LLW and mixed waste disposal.	Effective isolation of wastes; assumes treatment as required for land disposal	Superior: technology is mature and robust, materials, equipment, and contractors are available	Moderate	Retained
		Tumulus facility	Waste placed in concrete containers on a concrete pad. Caps, liners, and leachate removal system can be incorporated to meet requirements for LLW and mixed waste disposal.	Effective, but no more so than LLW landfill	Increased design and construction requirements relative to LLW landfill	Moderate to High	Eliminated due to high cost estimated at $4000 per cubic yard, escalated to 2015 dollars (Van Hoesen and Jones 1991)

Table 5-1. Technology Descriptions, Screening, Evaluations, and Selection of Representative Process Options (Continued)

General Response Action	Technology Type	Process Option	Description	Effectiveness	Implementability	Relative Cost	Selection
On-site Disposal (continued)	Existing facilities	Y-12 Industrial Landfill V	A Class II (TDEC) lined landfill designated to receive industrial, commercial, and institutional waste with little or no contamination.	Ineffective due to insufficient waste isolation systems	Prohibited from receiving LLW or MLLW	Low	Eliminated due to inability to receive projected waste
		Y-12 Construction/ Demolition Landfills VI/VII	Class IV (TDEC) unlined landfills designed to receive demolition wastes with little contamination for remodeling, repair, and construction.	Ineffective due to insufficient waste isolation systems	Prohibited from receiving LLW or MLLW	Low	Eliminated due to inability to receive projected waste
		Interim Waste Management Facility	Tumulus facility at SWSA 6 designed as a disposal facility for LLW generated at ORNL.	Not available	Closed under the Melton Valley Closure Project and not available for waste disposal	None	Eliminated, unavailable
		Long-term storage	Storage in containers in existing buildings until treatment or disposal capability is available.	Effective for limited waste volumes	May be used for interim storage of waste that may not meet disposal facility WAC, pending treatment and disposal options	Low	Retained as interim option
		EMWMF	Facility is partially below grade and uses natural and man-made materials in embankments, cap, and liners. Caps, liners, and leachate removal system incorporated to meet requirements for LLW and RCRA waste disposal.	Effective isolation of wastes; includes limited treatment as required for land disposal	Projected to be at capacity and unavailable	Moderate	Retained Anticipated to be in use until 2024 timeframe
Off-site Disposal	New facilities	New off-ORR engineered facility	An above- or below-ground engineered cell, concrete vault, or tumulus facility at an off-site location designed to receive LLW and MLLW.	Effective	No known plan for a new facility. Adequately represented by existing permitted DOE and commercial facilities	Very High	Eliminated, no planned facilities identified
	Existing LLW and mixed-waste facilities	Chem Nuclear	Commercial LLW disposal facility in Barnwell, South Carolina.	Effective	Available to limited states (TN is not in compact) Limited capacity	High	Eliminated, cannot receive waste from state of Tennessee

Table 5-1. Technology Descriptions, Screening, Evaluations, and Selection of Representative Process Options (Continued)

General Response Action	Technology Type	Process Option	Description	Effectiveness	Implementability	Relative Cost	Selection
Off-site Disposal (continued)	Existing LLW and mixed-waste facilities (continued)	Energy*Solutions* (formerly Envirocare)	Commercial LLW/mixed waste facility in Clive, Utah	Effective isolation of wastes; assumes treatment as required for land disposal. Treatment of LLW/RCRA waste to meet LDRs is available at facility	Available for non-classified LLW and MLLW. Incurs potential risk of transportation accident or shut-down	Very High due to transportation costs and disposal fees	Retained as representative commercial off-site disposal option for non-classified LLW and MLLW
		DOE NNSS (formerly Nevada Test Site)	DOE disposal facility near Las Vegas, Nevada	Effective isolation of wastes; provides disposal for LLW and MLLW that meets LDRs.	Available for non-classified and classified LLW and MLLW. Incurs potential risk of transportation accident or shut-down	Very High due to transportation costs	Retained as representative off-site disposal option for non-classified LLW and MLLW that meets LDRs.
		DOE Hanford Reservation	DOE storage/disposal facility near Richland Washington	Effective for LLW disposal, but lacks MLLW disposal capability	Hanford's CERCLA ROD does not allow receipt of MLLW from out-of-state	Very High due to transportation costs	Eliminated, cannot receive waste from state of Tennessee
		US Ecology-Hanford	Commercial LLW waste facility near Richland Washington	Effective for LLW disposal	Not available for ORR waste streams	Very High due to transportation costs	Eliminated, cannot receive waste from ORR
		Waste Control Specialists (WCS)	Commercial LLW/mixed waste facility in Andrews, Texas	Effective for LLW and MLLW treatment and disposal; limited to receiving containerized debris waste (soil waste may be bulk)	DOE recently entered into a contract with WCS; however, WCS has limitations on volumes of waste that can be received due to its size (~ 1 M yd^3)	Very High due to limitations on waste receipt (containers and volumes)	Retained as representative commercial off-site disposal option for non-classified LLW and MLLW
	Existing RCRA/TSCA facilities	WMI-Emelle	Commercial RCRA-Hazardous and TSCA waste disposal facility in Emelle, Alabama	Effective for RCRA/TSCA, not currently capable of receiving DOE LLW or MLLW	Not currently on approved active TSDRF list for ORR cleanup	High to Very High	Eliminated, not approved for receipt of ORR waste
		US Ecology-Beatty	Commercial RCRA-Hazardous and TSCA waste disposal facility in Beatty, Nevada				
		Clean Harbors, Deer Park	Commercial RCRA-Hazardous and TSCA waste disposal facility in Deer Park, Texas				
		Clean Harbors - Clive	Commercial RCRA-Hazardous and TSCA waste disposal facility in Clive, Utah				

Table 5-1. Technology Descriptions, Screening, Evaluations, and Selection of Representative Process Options (Continued)

General Response Action	Technology Type	Process Option	Description	Effectiveness	Implementability	Relative Cost	Selection
Volume Reduction (see Appendix B for detailed analyses)	Recycling and Reuse	Recycling/reuse	Recycle of commercially valuable materials	Effective for clean materials, but significant effort required for contaminated materials to render them suitable for recycle	Readily implemented for clean materials; difficult to implement for contaminated materials	Low for clean materials; high for contaminated materials	Eliminated; applicable at the Project level; assume all recycle completed prior to waste "entering" this RI/FS . DOE moratorium on recycling of CERCLA-generated scrap metal remains in force.
		Sequencing	Schedule sequencing to make use of waste soil as fill material for landfill operations	Effective for on-site and off-site disposal	Readily implemented during planning phase; significant management effort required maintain effective project sequencing ; more difficult to implement if stockpiling is required	Very low if stockpiling of soils is not required; low if stockpiling is required	Retained as a common practice for all options at the Project level (see details in Appendix B)
	Segregation	Characterize and Separate	Separation of clean or lightly contaminated materials for Subtitle D landfill disposal	Effective for on-site and off-site disposal	Routinely implemented during CERCLA actions; extensive characterization may allow further segregation (see Appendix B)	Moderate due to the cost of characterization activities	Eliminated; applicable at the Project level; assume all segregation completed prior to waste "entering" this RI/FS . (see details in Appendix B)
	Mechanical Size Reduction	Excavator Attachments	Primary size reduction of debris to meet transportation, packaging, and landfill placement requirements	Effective for large debris items	Readily implemented during demolition operations	Moderate due to the additional equipment and effort required	Retained as a common practice for all options at the Project Level (see Appendix B)
		Debris Processors	Additional size reduction using industrial processors to reduce debris void space	Effective for reducing off-site transportation costs for debris with low bulk density; not effective for on-site disposal (See Appendix B)	Complex and costly to implement	Costly to implement. Not cost effective for on-site disposal, but cost effective for off-site disposal (See Appendix B)	Retained for the Off-site Disposal Alternative only

Table 5-1. Technology Descriptions, Screening, Evaluations, and Selection of Representative Process Options (Continued)

General Response Action	Technology Type	Process Option	Description	Effectiveness	Implementability	Relative Cost	Selection
Waste Packaging and Transport	Packaging	Small containers	Small containers such as drums, B-25 boxes, or over- packs can be used to accumulate, store, or transport waste	Effective for small quantities, but not appropriate for much of the anticipated ORR CERCLA waste stream	Implementable for small waste streams generated over long periods, but not suitable for large waste volumes or for large items	Moderate to High	Retained as process option for certain wastes
		Large containers	Large containers such as roll-off bins, intermodal cargo or sealand containers can contain bulk waste or small containers	Effective and in current use for certain wastes; required for off-site transport	Intermodal containers are available. Intermodal containers are presently used for some off-site shipments originating on the ORR	Moderate	Retained for all waste streams as representative for comparative analysis of alternatives
		Bulk containers	Bulk containers such as Supersacks can contain bulk soil-like waste	Effective for some classes of waste; less effective than intermodals in maintaining containment in the event of an accident	Currently routinely used for bulk materials and waste disposal	Low	Retained as process option for certain wastes
	Transport	Barge	Transportation of bulk or packaged waste to DOE Hanford Reservation by barge via Tennessee River, Mississippi River, Gulf of Mexico, Panama Canal, Pacific Coast, Columbia River	Effective for large quantity bulk wastes	Cannot be implemented because Hanford CERCLA landfill is restricted to receiving wastes only from Hanford facilities	Moderate	Eliminated, cannot receive ORR waste
		Truck	Transportation of bulk waste on-site in dump trucks, or packaged waste to on-site and off-site disposal facilities by flatbed or other trucks	Effective for bulk and small-quantity waste packages (drums)	Implementable; roads, trucks, and contractors are available	Low to Moderate on a per ton/mile basis	Retained for off-site transportation of classified waste and for rail to truck transfer to NNSS Retained as representative for all on-site transportation
		Train	Transportation of bulk or packaged waste to off-site disposal facilities by railroad	Effective mode for off-site transportation of bulk wastes, intermodal containers, or small containers.	Implementable. A truck to train transfer facility is available at ETTP. Direct rail service is available from ETTP to ES in Clive, UT. NNSS can be accessed by using rail to truck transfer facility in Kingman, AZ, then truck transfer to NNSS.	Low to Moderate on a per ton/mile basis	Retained for off-site transportation of classified waste and for rail to truck transfer to NNSS, and for direct shipment of waste to ES

Table 5-1. Technology Descriptions, Screening, Evaluations, and Selection of Representative Process Options (Continued)

General Response Action	Technology Type	Process Option	Description	Effectiveness	Implementability	Relative Cost	Selection
Institutional Controls	Access and use restrictions	Physical barriers	Security fences, signs, buffer zones, and other barriers installed around potentially contaminated areas to limit access	Effective while maintained	Implementable. Materials and contractors are available	Low	Retained
		Administrative controls and security	Use of security (e.g., guards, surveillance, badges for access) or institutional requirements (e.g., training, standard operating procedures) to limit access to contaminated areas	Effective while maintained	Implementable	Low	Retained
		Covenants and deed restrictions	Restrictions on land use by licensed agreements, regulatory permits, code, zoning, stipulations on property deeds	Effective	Implementable	Low	Retained
	Maintenance and monitoring	Surveillance and maintenance (S&M)	Inspection of engineered and remedial actions and performance of preventive and or corrective measures to ensure proper operation of engineered controls	Effective while maintained; improves overall reliability	Implementable and required	Low to Moderate	Retained
		Environmental monitoring	Use of results from sampling and characterization of media before, during, and after remediation to predict and verify effectiveness of remedial actions	Effective while maintained; improves overall reliability	Implementable and required	Low to Moderate	Retained

Engineered Disposal Cell: An engineered disposal cell can be designed to accommodate a wide range of solid waste streams. A partially below-grade or above-grade engineered cell typically consists of a multilayer liner beneath the waste, lined embankments, and a multilayer final cover to completely encapsulate the waste. Engineered cells are constructed to satisfy the design requirements appropriate to the type of waste they contain.

In a cell engineered for LLW, the waste is placed on a bottom clay layer designed to impede the percolation of free water from the cell into the ground. The waste is then covered with a cap that includes an impermeable layer, a drainage layer, and a vegetative layer. The cell makes extensive use of natural materials and can be engineered to isolate wastes for long periods.

RCRA-hazardous waste is disposed of according to the requirements of 40 CFR 264 and 268 and more stringent state requirements, as applicable. In a cell with design components similar to those specified in 40 CFR 264.301, the waste is placed on a bottom liner system consisting of two leachate collection/removal layers, each above a low-permeability liner with appropriate characteristics for retarding contaminant migration. The final (top) cover on this type of cell must be equally or less permeable than the bottom liner and meet other performance requirements.

TSCA waste must be disposed of according to the requirements of 40 CFR 761. A facility designed to receive TSCA waste (i.e., PCBs) would be required to meet the facility specifications in 40 CFR 761.75. The liner consists of 3 to 4 ft (0.9-1.2 m) of soil and may also use a synthetic membrane liner. The bottom liner of the cell must be 50 ft (15 m) above ground water or provide equivalent or superior protection. A cell designed to accommodate LLW, RCRA, TSCA, and mixed low-level waste (MLLW) would incorporate design elements to meet all regulatory requirements. In general, landfills designed to meet RCRA requirements will meet or exceed TSCA requirements.

Tumulus Facility: A tumulus facility consists of an at-grade concrete pad, stabilized waste, and a cover designed to contain LLW. Concrete containers of stabilized waste are stacked on the pad. The concrete pad incorporates a leachate collection system; an impermeable liner may be added to contain other types of waste. Once the stabilized waste containers have been placed on the pad, a multilayer cap is placed over the stacked waste to limit the infiltration of water. Taken as a whole, the protective features of the containers, pad, liners, and cover allow the facility to receive LLW and MLLW.

5.1.2.2 Existing Facilities

EMWMF: While capacity is currently available and suitable, projections are that the landfill will be at capacity by 2024**.**

Interim Waste Management Facility: This is a tumulus facility at Solid Waste Storage Area 6 that has been used to dispose of ORNL-generated LLW. Facility construction is similar to that described in the preceding paragraph.

Long-term Storage: Storage capacity in existing buildings on the ORR could accommodate some candidate waste streams. As with the existing wastes in storage, this is only an interim solution pending the availability of treatment or permanent disposal options.

5.1.3 Off-site Disposal

Evaluated off-site disposal technologies include new facilities, existing LLW and mixed waste facilities, and existing RCRA/TSCA facilities. Off-site disposal requires the same approach as on-site disposal with regard to the priority of recycle, reuse, and the use of Subtitle D landfills before considering disposal off-site. The process includes selection of an approved disposal site, development of generator certification documentation, development of waste profiles that meet the disposal site WAC, waste packaging, transportation, and disposal.

5.1.3.1 Existing LLW and Mixed-Waste Facilities

Chem Nuclear Barnwell Facility: This facility is a LLW disposal facility located in Barnwell County, near the town of Snelling South Carolina. It accepts waste from three member compact states: Connecticut, New Jersey, and South Carolina only. Therefore, it was eliminated from consideration.

Energy*Solutions*: Energy*Solutions* is a commercial waste disposal facility in Clive, Utah, that has previously received ORR waste. Energy*Solutions* can receive LLW and MLLW that meets their WAC. Energy*Solutions* also has facilities and permits necessary to process and stabilize untreated MLLW for disposal. Wastes are disposed of in an engineered disposal cell located in a remote arid environment.

Nevada National Security Site: NNSS is located in Nye County, Nevada, 65 miles northwest of Las Vegas, Nevada. There is an ongoing DOE-EM mission at the NNSS that includes the Area 5 Radioactive Waste Management Complex (RWMC), a radioactive waste management and disposal facility where LLW and MLLW are safely and permanently disposed. The Area 5 RWMC is located in one of the most arid and least populated regions of the United States, which provides an ideal area for near-surface disposal of LLW. The NNSS has the unique capability of accepting U. S. Government classified waste materials for disposal.

The NNSS is authorized to receive DOE-generated LLW, as well as DOE-generated RCRA hazardous waste and RCRA MLLW (that meet LDRs). No treatment capability for mixed waste is provided at NNSS.

DOE Hanford Reservation: The DOE Hanford Reservation, near Richland, Washington, will accept out-of-state LLW for disposal, but cannot accept out-of-state MLLW for disposal.

US Ecology-Hanford: US Ecology operates a commercial LLW facility on the Hanford Reservation. US Ecology is currently accepting waste only from generators in the Northwest States waste compact.

Waste Control Specialists: WCS is a waste processing and disposal company that operates a permitted 1,338-acre treatment, storage and disposal facility near Andrews, Texas. WCS offers management of radioactive waste, hazardous waste, and mixed waste.

5.1.3.2 Existing RCRA/TSCA Facilities

There are a number of permitted commercial RCRA/TSCA disposal facilities available for ORR candidate waste streams. The following RCRA/TSCA facilities were considered in the technology screening process:

- WMI-Emelle in Emelle, Alabama
- US Ecology-Beatty in Beatty, Nevada
- Clean Harbors in Deer Park, Texas
- Clean Harbors in Clive, Utah

All of these facilities are similar in the types of waste that they receive for treatment and disposal and the services that they offer. The primary difference between them is transportation distance, with the WMI-Emelle facility the closest and US Ecology's Nevada facility the most distant. Off-site facilities in the western United States (e.g., Nevada, Utah, Texas, and Washington) tend to have more favorable hydrogeological conditions and lower local population densities than facilities in the more humid South (e.g., Alabama).

5.1.4 Treatment of Mercury-contaminated Debris

Mercury-contaminated (D009) waste will require treatment to render it non-hazardous and to meet LDRs. For soils contaminated with mercury, individual projects (remedial action projects) are assumed to provide this treatment (by sulfur polymer stabilization/solidification or similar process) prior to disposal (on-site or off-site), and therefore process option considerations for soils are not necessary in this RI/FS analysis. Likewise, for mercury-contaminated debris, the assumption in this RI/FS is made that treatment to meet LDRs will be the responsibility of the project/demolition contractor, and the cost for that treatment is incurred by the project. However, for characteristically hazardous debris (D009), RCRA allows for treatment of that debris to be accomplished as an integral part of disposal. This can be allowed under a RCRA Corrective Action Management Unit designation for an on-site facility; off-site facilities (e.g., Energy*Solutions* and WCS) also have regulatory authority to perform this treatment as an integral part of disposal. Appendix C introduces this topic for consideration and possible future incorporation into a final remedy. Therefore, under the assumption that the demolition project manages and covers the cost of treatment for mercury-contaminated debris regardless of where that treatment occurs or where the waste is disposed, no further consideration of this topic is given in this RI/FS beyond the introduction provided in Appendix C.

5.1.5 Volume Reduction

OREM follows a hierarchy for disposing of waste generated through cleanup projects to minimize disposition volumes and costs, and reduce needed landfill capacity. As shown in Figure 5-2, the foundation of the strategy is built on first evaluating waste materials for recycle or beneficial reuse. The second priority is to make use of on-site Subtitle D landfills for final disposal of waste. This RI/FS identifies process options for use after this step; that is, the recycle/reuse and use of ORR landfills through segregation is accomplished at the project level prior to waste entering consideration for management by the alternatives of this RI/FS; however, it is worth noting that these volume reduction methods are already part of the overall OREM strategy for waste management. This approach is common to all disposal actions. Mechanical size reduction processing requires additional evaluation to determine cost effectiveness and possible incorporation as a process option. Appendix B includes a detailed evaluation of volume reduction methods.

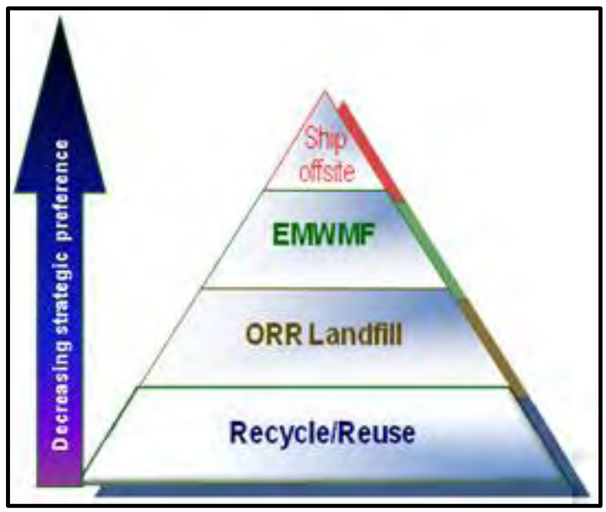

Figure 5-1. OREM Hierarchy for Waste Disposition

5.1.5.1 Recycle/Reuse

Recycle involves identifying materials from CERCLA actions that have value within DOE or in the marketplace as a resource for construction or for manufacturing other products. Examples include recycle of structural steel for the automobile industry or recycle of masonry rubble and concrete as aggregate for road construction. CERCLA remedial action projects that generate waste soil are evaluated as a potential source of fill material for demolition debris with significant void fraction. As indicated above, CERCLA actions are evaluated at the project/program level for potential recycling and reuse.

5.1.5.2 Segregation

Waste segregation is an important volume reduction option that is emphasized in planning of all DOE D&D projects. Significant effort and funding is provided for initial characterization activities in order to provide health and safety information for worker protection, to develop waste profile information for disposal, and to identify opportunities for separating clean and contaminated materials. Segregation involves the effort required to separate materials in order to divert suitable waste materials to a Subtitle D landfill such as the ORR Landfill. Again, while it is a pertinent element of OREM's waste disposition strategy, segregation is carried out at the project level. The possibility of more extensive characterization to enable more complete/extensive segregation is examined in Appendix B.

5.1.5.3 Mechanical Size Reduction Processing

Mechanical size reduction involves physical cutting, crushing, or compressing debris to reduce size for transporting, to meet physical criteria for landfill acceptance, and to reduce the void fraction of the material for disposal as well as ultimately reduce the volume of waste to be disposed. Reducing void space reduces the amount of fill material required to stabilize the landfill thus reducing overall size of the landfill, reduces pathways for water intrusion, and minimizes settling and associated damage to the final cover. The waste acceptance criteria for landfills include physical criteria that require size reduction actions to be performed prior to placement in the landfill. An example of this is the EMWMF physical WAC that requires debris items to sized to dimensions less than 6 ft long, 4 ft wide, and 4 ft deep. This is usually accomplished using excavators with shearing and cracker jaw attachments. This primary size reduction would be required regardless of the disposal method (on-site or off-site) in order to fit the materials into containers or to meet disposal criteria. Additional size reduction beyond the primary requirement involves the use of processing equipment such as industrial shredders, crushers, and shears designed for high-volume production facilities. Debris void space can be reduced, which in turn reduces the volume of material necessary to fill voids and stabilize the landfill. If implemented effectively, size reduction can reduce the landfill footprint. However, the benefits and challenges, cost and complexity of size reduction must be considered to determine any net results of the process. Appendix B provides an evaluation of all volume reduction options as applied to both on-site and off-site waste disposal, and weighs VR options against the CERCLA criteria.

5.1.6 Waste Packaging and Transport

Packaging technologies are used to ensure safe containment of waste during transport, storage, and disposal. Transport vehicles can be used in conjunction with packaging for relocation of waste to treatment or disposal facilities. Some transport vehicles can be equipped to provide containment without additional packaging.

5.1.6.1 Packaging

Small Containers: A number of small containers such as lab packs, B-12 and B-25 boxes, drums, and overpacks are designed to contain various waste forms (e.g., debris, solid, liquid, sludge, granular) and types (e.g., LLW, RCRA-corrosive). Small containers would be applicable to certain specific candidate waste streams. Small containers are typically disposed of with the waste rather than emptied and reused.

Large Containers: Large containers include roll off bins, intermodal containers, and other container types with various weight and volume capacities, loading capabilities (top-, side-, or end-loaded), and handling characteristics. Some containers can be moved by forklift, some by crane, and some can be winched directly onto a truck bed. Some truck-mounted containers can be unloaded directly by dumping from the truck, while other containers must be removed and unloaded with additional equipment. A variety of waste forms and types can be loaded into the containers. Large containers can usually be decontaminated and reused. Dedicated containers can be reused for similar waste streams with only external decontamination.

Bulk Containers: Bulk containers are single-use containers typically disposed of with the waste. A Supersack, a large reinforced bag, is an example of a bulk waste package that can be used to package soil-like waste material.

5.1.6.2 Transport

Truck: Truck transport is applicable to both local and long-distance waste transport. Trucks can transport bulk wastes either in approved containers or in covered beds. Waste being shipped off site by rail has to be transferred from trucks to railcars at a transload facility. All off-site disposal facilities are configured to receive waste directly via truck.

Rail: Rail transport would be viable only for long-distance waste transport. Railcars could be loaded from trucks at a transload facility. An existing transload facility at ETTP could accommodate containerized waste; however, additional waste transfer facilities would be needed to allow handling of bulk waste. Energy*Solution*s and WCS are configured to receive direct rail shipments. Shipment to other off-site disposal facilities would require either transloading to trucks for the last leg of the trip or construction of a rail spur from the nearest rail line to the disposal facility.

5.1.7 Institutional Controls

Access and use restrictions and maintenance and monitoring are institutional control technologies that can reduce the potential for exposure to waste that remains at a remediation site or is placed in a disposal facility. These technologies and the associated process options would be used in conjunction with on-site waste handling, storage, and disposal process options.

5.1.7.1 Access and Use Restrictions

Physical barriers: Fences, signs, buffer zones, or other barriers can be installed around potentially contaminated areas to limit access.

Administrative Controls and Security: Security (e.g., guards, surveillance, badges for access) or institutional requirements (e.g., training, standard operating procedures) can be used to limit access to contaminated areas.

Covenants and Deed Restrictions: License agreements, codes, zoning, or stipulations on a property deed can be used to prohibit unacceptable uses of a contaminated site that could put human or ecological receptors at risk.

5.1.7.2 Maintenance and Monitoring

Surveillance and Maintenance: Scheduled and special inspections of engineered facilities and implementation of preventive or corrective measures can be used to ensure the proper operation of engineered components.

Environmental Monitoring: Results of the sampling and characterization of environmental media before, during, and after remediation can be used to predict and verify the effectiveness of remedial actions.

5.2 RETAINING/ELIMINATING PROCESS OPTIONS

5.2.1 No Action

The "No Action" general response action is retained as required by the NCP to serve as a baseline for comparison to action-based alternatives. For this alternative, there would be no CERCLA action or work scope to consider for this project. Management of CERCLA waste after EMWMF capacity is reached would be addressed at each individual project level.

5.2.2 On-site Disposal

On-site disposal technology types considered include new and existing land disposal facilities. Three of the on-site disposal options were retained for further study based on effectiveness in isolation of the required waste types, the maturity of the technology, availability of commercial contracting capability, and moderate cost.

5.2.2.1 New Facilities

Sanitary and unlined trench landfills were eliminated from consideration because they are not applicable or suitable for candidate waste streams. Below-grade facilities, concrete vaults, and tumulus facilities were all eliminated due to higher costs, more difficult implementation, and/or physical limitations at the ORR.

The final representative process option retained for on-site disposal is the partially below-grade engineered disposal facility. This option is a proven concept currently demonstrated at the EMWMF and is expected to meet future requirements. It was selected based on equivalent or superior effectiveness, relative ease of implementation, and reduced cost compared to other process options.

5.2.2.2 Existing Facilities

With the exception of EMWMF and long-term interim storage facilities, existing facilities on the ORR were eliminated because none have WAC that allow for disposal of projected candidate waste streams. The EMWMF option is retained in order to provide effective near-term disposal capability. EMWMF is expected to be filled to capacity sometime in 2024. The long-term storage is retained as an interim option for waste that may not meet disposal facility WAC, pending identification of appropriate treatment and disposal options.

5.2.3 Off-site Disposal

Options considered for off-site disposal include new facilities, existing LLW and mixed waste facilities, and existing RCRA/TSCA facilities. Several of the existing off-site facilities would accommodate the anticipated waste volumes and types to be generated on the ORR; however, the cost of transportation is extremely high and the options incur the risk of transportation incidents with potential exposure of the general public to radiological hazards. Tipping fees at commercial facilities would also increase costs to the extent that these off-site facilities are used. Further, DOE would retain liability for remediation of these sites in the event that releases occur.

5.2.3.1 New Facilities

Consideration of the use of a new off-ORR engineered facility would require a plan for a new facility to be at some level of development/implementation. Since there are no new facilities being planned, this option was eliminated. However, there are existing permitted DOE and commercial off-site facilities that could adequately accommodate the ORR CERCLA waste types and volumes.

5.2.3.2 Existing LLW and Mixed-Waste Facilities

LLW and MLLW disposal sites evaluated included Energy*Solutions* in Clive, Utah; NNSS in Nye County, Nevada; Chem Nuclear's Barnwell South Carolina facility; the DOE Hanford Reservation near Richland, Washington; US Ecology-Hanford, and WCS in Andrews, Texas. All these sites would effectively isolate wastes that meet their respective WAC, but would incur high transportation/disposal costs as well as risk liabilities until waste reaches its destination. ORR wastes are currently being shipped to the Energy*Solutions* and NNSS facilities, and shipment and disposal at these sites is readily implementable. Chem Nuclear's Barnwell facility was eliminated since it does not accept waste from states outside of its compact. DOE Hanford and US Ecology-Hanford were eliminated from consideration due to limited ability to accept ORR waste. WCS is a potential process modification to the Off-site Disposal Alternative (see Section 6.3.5.10.1) if in the future the receipt of debris waste in bulk form is allowed (currently WCS requires debris waste to be containerized); however, their facility is currently not large enough (at just under 1 M yd^3) to take a majority of the future CERCLA waste. WCS is an option for MLLW receipt.

Energy*Solutions* was retained for disposal of non-classified LLW and MLLW. Treatment of MLLW waste to meet LDRs is also available at the Energy*Solutions* facility. The NNSS facility is retained for unclassified and classified LLW and MLLW disposal. However, treatment of LLW/RCRA waste prior to disposal is not available at NNSS. WCS is retained as a destination for MLLW, as they provide treatment to meet LDRs.

5.2.3.3 Existing RCRA/TSCA Facilities

The Waste Management, Inc. (WMI)-Emelle (Emelle, Alabama), US Ecology-Beatty (Beatty, Nevada), Clean Harbors (Deer Park, Texas), and Clean Harbors (Clive, Utah) facilities were identified as existing RCRA/TSCA facilities. All of the facilities are eliminated because the facilities are no longer on the approved active treatment, storage, disposal, and recycling facilities (TSDRFs) list for ORR cleanup. Non-radioactive RCRA/TSCA waste is a small percentage of CERCLA waste generated that does not meet the EMWMF WAC and is not a differentiator for the On-site and Off-site Disposal Alternatives. Non-radioactive RCRA/TSCA waste and other waste that would not meet an on-site disposal facility WAC are not included as candidate waste streams for quantitative analysis (see Section 2.1.3).

5.2.4 Volume Reduction

Recycle/reuse as a volume reduction process option is eliminated because it is performed at the project level prior to the waste being considered in this RI/FS (see explanation of OREM waste disposal strategy shown in Figure 5-1; additionally clean, recyclable material is not acceptable at an on-site disposal facility – see exclusions under Section 2.1.1). Therefore, any waste that may be recycled should be recycled by the project contractor generating the waste, regardless of whether the CERCLA waste alternative for disposal is on-site or off-site. A more detailed analysis is presented in Appendix B, Section 5.1.

Project sequencing (in order to maximize the use of soil waste as void fill) was retained because it is very effective, low in cost, and is currently implemented for conserving the EMWMF disposal capacity. It should be noted that planning to take advantage of project waste sequencing is accomplished outside the scope of this RI/FS; however, to the extent possible, sequencing of waste at an on-site facility should be accomplished.

Waste segregation was eliminated for the same reasons as recycle/reuse; waste that is capable of being disposed in ORR landfills should be disposed as such by the demolition project contractor, regardless of the CERCLA waste alternatives reviewed under this RI/FS analysis. However, a more detailed analysis is considered in Appendix B, and project-level cost benefit analyses of more detailed characterization to allow for further segregation are suggested (see Section 5.3 in Appendix B). Waste segregation is a current practice for CERCLA actions at the project level, and is effective in diverting clean materials from the EMWMF.

Mechanical size reduction processing of debris is evaluated in detail in Appendix B against the CERCLA criteria with the result that it is not recommended for combination with the On-site Disposal Alternative (see detailed evaluation in Appendix B, Section 5.4.4). However size reduction was retained for the Off-site Disposal Alternative because benefits outweigh the risks for off-site transport; it reduces transportation and disposal costs (fewer shipments) by increasing bulk density and the mass of waste material per shipment, and thereby also decreases risk to the public. For the Hybrid Disposal Alternative, because the on-site disposal capacity is severely limited, mechanical volume reduction is retained (see Section 6.4.1.3).

5.2.5 Waste Packaging and Transport

Packaging technologies are used to ensure safe containment of waste during transport, storage, and/or disposal. Transport vehicles can be used in conjunction with packaging for relocation of waste to treatment and disposal facilities. Some transport vehicles can be equipped to provide containment without additional packaging.

5.2.5.1 Packaging

The use of small containers (e.g., B-12 and B-25 boxes, drums, and over-packs) is retained because they are effective and implementable for specific candidate waste streams. They are typically disposed of with the waste rather than emptied and reused, and they can be placed in large containers for ease of shipment.

Use of large containers (e.g., roll-off bins, intermodal/sealand containers) for bulk waste and over-packs containing small containers are effective and implementable. They are commonly used on the ORR in a variety of sizes and configurations that provide for diverse loading and unloading scenarios. Large containers are retained for all waste streams as a necessary component of On-site and Off-site Disposal Alternatives.

Bulk containers such as Super Sacks® are inexpensive, single-use containers typically disposed of with the waste. Large volumes of waste in bulk containers can be transported on-site by truck. Some bulk waste can be transported off-site by truck or train, depending on the waste characteristics and the receiving facility's waste handling capabilities. Bulk waste containers can also be placed in large containers to minimize large container decontamination costs. Bulk containers are retained as a process option because they can be suitable for certain on-site wastes, such as asbestos.

5.2.5.2 Transport

Truck transport is applicable, effective, and implementable for both local and long-distance waste transport. Though the cost for long-distance transport is high, this process option is routinely used on the ORR for waste materials, and it is retained as a potential alternative.

Rail transport is retained as a viable long-distance waste transport method that could be more cost effective than truck transport for off-site disposal. An existing transload facility at ETTP can effectively accommodate transfer of containerized waste from truck to train for the expected waste volumes. Energy*Solutions* in Utah is configured to receive rail shipments of LLW and MLLW. Transport by rail to NNSS in Nevada currently requires transfer of the waste from railcars to trucks at a transload facility (assumed as Kingman, Arizona) for the last leg of the trip. The cost for rail transport, including the cost of transloading, would be lower than truck transport for very large waste volumes.

5.2.6 Institutional Controls

As shown in Table 5-1, all institutional controls process options were retained to be used in conjunction with other actions to ensure adequate security and long-term protectiveness.

5.3 ASSEMBLY OF ALTERNATIVES AND ABILITY TO MEET REMEDIAL ACTION OBJECTIVES

The general response actions, technology types, and representative process options carried forward for alternative development are shown in Table 5-2 where they have been assembled into four disposal alternatives: the No Action Alternative, the On-site Disposal Alternative, the Off-site Disposal Alternative, and the Hybrid Disposal Alternative. The alternatives presented in Table 5-2 are described in detail in Chapter 6 and fully evaluated in Chapter 7. Each alternative includes the necessary characteristics that satisfy RAOs for CERCLA waste disposal.

The No Action, On-site, Off-site, and Hybrid Disposal Alternatives satisfy the RAOs as described in the following:

- Prevent exposure of a human receptor to future-generated CERCLA waste or waste contaminants that exceeds a human health risk of 10^{-4} to 10^{-6} ELCR or HI of 1.
  - **No Action Alternative:** The No Action Alternative provides no coordinated ORR effort to manage waste generated by future CERCLA actions after EMWMF capacity is reached; therefore, the RAOs are not directly applicable to the No Action Alternative. Overall protectiveness of human health and the environment and risk reduction would have to be addressed by CERCLA decisions at the individual sites without the benefit of a comprehensive disposal strategy.
  - **On-site and Hybrid Disposal Alternatives:** The on-site disposal facility would meet this RAO by isolating the waste using appropriate engineered features and natural materials, complying with ARARs, and by establishing a facility WAC for constituents of concern given the potential exposure pathways based on the conceptual design. These WAC limits are set based on meeting the RAOs ($^{10-5}$ ELCR and HI=1 for the compliance period. If on-site or hybrid disposal is the selected remedy, the final WAC would require approval by all regulatory parties. Waste not meeting the on-site disposal facility WAC (or exceeding the on-site capacity) would be shipped to appropriate off-site disposal facilities or placed in interim storage with adequate waste isolation features and institutional controls pending the development of treatment or disposal capabilities.

    Appropriate controls at an on-site facility, including compliance with regulations (ARARs) and health and safety plans, would ensure that workers would not be exposed to the waste during handling, transport, or disposal operations.

    Isolation features at the on-site disposal facility would be maintained after closure for an indefinite period. Such isolation would be regularly verified by the regulatory agencies responsible for ensuring proper design and compliance with long-term closure, monitoring, and maintenance requirements. The containment afforded by the facility's design, as well as permanent restrictions (e.g., ROD land use controls) on land and ground water use, would ensure long-term protection of workers and the public.
  - **Off-site and Hybrid Disposal Alternatives:** The off-site facilities proposed for use under the Off-site and Hybrid Disposal Alternatives have been vetted through the CERCLA off-site rule, Section 121(d)(3) of the NCP [40 CFR 300.440], and have been approved for treatment and/or disposal of CERCLA wastes. As a result, this RAO is met through facility design and operating conditions for off-site facilities and compliance with established WAC.

- Prevent adverse impacts to water resources or unacceptable exposure to ecological receptors from CERCLA waste contaminants through meeting chemical-, location- and action-specific ARARs, including RCRA waste management and disposal requirements, CWA AWQC for surface water in Bear Creek, and SDWA MCLs in waters that are a current or potential source of drinking water.
  - **No Action Alternative:** The No Action Alternative provides no coordinated ORR effort to manage waste generated by future CERCLA actions after EMWMF capacity is reached; therefore, the RAOs are not directly applicable to the No Action Alternative. Overall protectiveness of human health and the environment and risk reduction would have to be addressed by CERCLA decisions at the individual sites without the benefit of a comprehensive disposal strategy.
  - **On-site and Hybrid Disposal Alternatives:** The engineered isolation features and natural materials of an on-site disposal facility would be designed to meet ARARs for protection of ecological receptors from contact with or exposure to the waste or waste constituents (e.g., within the cap, 2 ft of biointrusion rock below 5 ft of clay and overburden provides protection to burrowing animals). Candidate wastes would be contained during transport and disposal to prevent exposure to ecological receptors. Compliance with SDWA MCLs in potential future drinking water and CWA AWQC are demonstrated in modeling and determining PreWAC for the on-site facility for the compliance period, to demonstrate human health protectiveness. Protection of ecological receptors is thus demonstrated as well. While radiological limits are not included in the CWA AWQC, protection of human health places limits on radiological contaminants in the major water pathway to a degree that ecological receptors are protected. The soil pathway does not present a significant ecological risk.
  - **Off-site and Hybrid Disposal Alternatives:** The off-site facilities proposed for use under the Off-site and Hybrid Disposal Alternatives have been vetted through the CERCLA off-site rule, Section 121(d)(3) of the NCP [40 CFR 300.440], and have been approved for disposal of CERCLA wastes. As a result, this RAO is met through facility design and operating conditions for off-site facilities and compliance with established WAC.

Table 5-2. Alternatives Assembly, RI/FS for CERCLA Waste Disposal

General Response Action	Technology Type	Representative Process Option	No Action Alternative	On-site Disposal Alternative	Off-site Disposal Alternative	Hybrid Alternative	Comments
No Action	None	No actions	X				No central CERCLA action or work scope to consider. Required by NCP.
On-site Disposal	New facilities	Engineered disposal cell (landfill)		X		X	Representative process option applicable only to on-site (and hybrid) disposal.
	Existing facilities	Long-term storage		X	X	X	Retained as interim option for waste that may not meet disposal facility WAC, pending treatment and disposal options.
Off-site Disposal	Existing LLW and mixed waste facilities	Energy*Solutions* Clive, Utah		a	X	X	Energy*Solutions* and NNSS are used for off-site LLW and MLLW disposal. Energy*Solutions* and WCS are used for off-site MLLW treatment and disposal. All are applicable (with restrictions) for the Off-site and Hybrid Disposal Alternatives. Classified waste must go to NNSS.
		DOE NNSS		a	X	X	
		WCS, Texas		a	X	X	
Volume Reduction	Recycle and reuse	Sequencing		X	X	X	Applies to project sequencing to ensure that contaminated soil is available for use as fill material for debris.
	Size reduction processing	Excavator attachments		X	X	X	Refers to primary size reduction as necessary to meet disposal site WAC. Completed at the Project level.
		Industrial processors			X	X	Retained for size reduction of low-density debris.
Waste Packaging and Transport	Packaging	Large containers		X	X	X	All types of waste packages can be used for on-site and off-site transport. The use of intermodal containers, commonly used at the ORR and disposal facilities, is assumed.
	Transport	Truck		X	X	X	Truck transport is used for all transport within ORR and for classified waste shipments to NNSS. Rail will be used for non-classified waste for the Off-site and Hybrid Disposal Alternatives with rail to truck transfer for shipments to NNSS.
		Train			X	X	
Institutional Controls	Access and use restrictions	Physical barriers		X	X	X	All institutional controls apply to On-site, Off-site, and Hybrid Disposal Alternatives. Institutional controls are required at off-site facilities and costs are assumed to be included in disposal fees.
		Administrative controls and security		X	X	X	
	Maintenance and monitoring	Surveillance and maintenance		X	X	X	
		Environmental monitoring		X	X	X	

[a] Off-site disposal facilities are used as necessary when CERCLA wastes do not meet the On-site Disposal Alternative WAC.

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6. ALTERNATIVE DESCRIPTIONS

This chapter provides detailed descriptions of the No Action Alternative (Section 6.1) and the On-site (Section 6.2), Off-site (Section 6.3), and Hybrid (Section 6.4) Disposal Alternatives for the candidate CERCLA waste streams identified in Chapter 2. Representative process options assembled in Chapter 5 have been used to develop conceptual designs and actions described in this chapter. The Hybrid Disposal Alternative is a combination of on-site and off-site disposal; therefore, much of the descriptions provided in Sections 6.2 and 6.3 also serve as descriptions for the hybrid alternative.

6.1 NO ACTION ALTERNATIVE

The No Action Alternative is considered in accordance with CERCLA and NEPA requirements to provide a baseline for comparison with other alternatives. For purposes of evaluation, the following assumptions are made for the No Action Alternative:

- A comprehensive, site-wide strategy to address the disposal of waste resulting from any future CERCLA remedial actions at the ORR and associated waste generator sites after EMWMF capacity is reached would not be implemented.
- A centralized disposal facility would not be constructed on the ORR to accommodate future generated CERCLA waste after EMWMF capacity is reached.
- Future waste streams from site cleanup that require disposal after EMWMF capacity is reached would be addressed at the project-specific level. This could result in the majority of waste transported to off-site disposal facilities by truck, and possibly significant long-term storage of waste.

Unlike the No Action Alternative for a typical FS which assumes no cleanup actions are taken at a contaminated site, the No Action Alternative in this case is based on the assumption that no coordinated ORR effort would be implemented to manage wastes generated by future CERCLA actions after EMWMF capacity is reached. No assumptions are made under this alternative regarding the implementation of remedial strategies or specific actions for the individual sites, or at the watershed or ORR program-wide level. No specific assumptions are made as part of the No Action Alternative regarding future institutional controls, either at the waste generator sites or at the ORR-wide level.

Project-specific remedial decisions, including those concerning on-site, off-site, or in-situ waste disposal, would be made under the No Action Alternative without the benefit of an ORR site-wide disposal strategy or infrastructure. While protective remedies would be implemented, the lack of a coordinated disposal program has potential cost and protectiveness impacts as discussed in Section 7.2.1 and Section 7.3.

6.2 ON-SITE DISPOSAL ALTERNATIVE

The On-site Disposal Alternative proposes consolidated disposal of most future-generated CERCLA waste exceeding the capacity of the existing EMWMF in a newly-constructed, mostly above-grade, engineered waste disposal facility (i.e., landfill) on the ORR, referred to herein as the EMDF. Three distinct site options are individually analyzed; however the disposal facility itself (meaning the components – buffer, liner, berms, cells, final cover) are nearly identical in terms of the conceptual design. Any differences are discussed in this section. Candidate wastes would include LLW and mixed waste with components of radiological and other regulated waste (LLW/RCRA, LLW/TSCA) as described in Chapter 2. Liquid wastes, RCRA-listed wastes, TRU wastes, spent nuclear fuel, and sanitary wastes are not candidate waste streams for the EMDF. Further exclusions were outlined in Section 2.1.1. Project level characterization and segregation efforts would identify uncontaminated or lightly contaminated waste generated during CERCLA remedial actions that can meet the WAC of existing Y-12 industrial or construction/demolition landfills (otherwise known as the ORR Landfill). These wastes can be disposed of at the ORR Landfill regardless of the selected alternative for future CERCLA disposal, and are outside the scope of this evaluation. Similarly, uncontaminated materials that are candidates for recycle would be identified during the CERCLA planning and characterization effort and separated for alternate beneficial purposes. Debris would be size reduced as necessary to meet the EMDF physical WAC using excavators equipped with cutting and crushing attachments. Wastes not meeting the EMDF WAC would be transported to off-site disposal facilities or placed in interim storage until treatment or disposal capabilities become available.

Ultimately, the On-site Disposal Alternative is a combination of on-site and off-site disposal. The volume of future CERCLA waste acceptable at an on-site facility is limited by the WAC of the facility. The remainder of the waste, which does not meet an on-site facility WAC, thus is directed to an off-site disposal option. Because current characterization of the future CERCLA waste is not sufficient to draw an absolute line between waste volumes to be handled on-site versus those that will require off-site disposal, nor has a final on-site disposal WAC been defined to which that characterization can be measured against, assumptions must be made regarding the volume and composition of future CERCLA waste for on-site disposal. Therefore, the volume of waste assumed to be able to meet an on-site WAC is conservatively estimated to allow for a maximum on-site disposal footprint design. The construction of the facility is planned to be conducted in phases over the lifetime of waste generation, which will allow for a smaller facility footprint to be constructed if warranted (e.g., four cells construction versus six cells), as details regarding waste characterization and generation are realized. In the case of the Hybrid Disposal Alternative, the available facility capacity is the limiting factor, and off-site disposal is an integral part of the Alternative (see Section 6.4 for a discussion of the Hybrid Disposal Alternative).

The On-site Disposal Alternative only addresses disposition of CERCLA waste. It includes designing and constructing the landfill, support facilities, and roadways; developing plans and procedures, personnel training and supervision; receiving waste that meets the WAC; unloading and placing waste into the landfill; surveying and decontaminating as needed any containers, equipment, or vehicles leaving the site; and managing the waste and the landfill during the construction, operations, closure, and post-closure periods.

Disposal facility elements that are critical to ensuring adequate long-term protection of human health and the environment include the following:

- Location of the EMDF (Section 6.2.1)
- Design of the facility's waste containment features (Section 6.2.2)
- Characteristics and limitations of the waste placed in the EMDF (Section 6.2.3)
- Facility construction, operations, and operational monitoring (Section 6.2.4 through 6.2.6)
- Management of waste exceeding WAC (Section 6.2.7)
- Facility closure and post-closure care, including institutional controls (Section 6.2.8 and 6.2.9)
- Lessons learned, from design through operation of the EMWMF (Section 6.2.10)

6.2.1 EMDF Proposed Sites

Several proposed sites in Bear Creek Valley (BCV) are evaluated as part of the On-site Disposal Alternative for development of the EMDF. These sites were selected for detailed analyses based on the site screening process outlined in Appendix D. Figure 6-1 shows proposed locations for the EMDF site relative to the ORR; each Site Option is described in the following sections, 6.2.1.1 through 6.2.1.3.

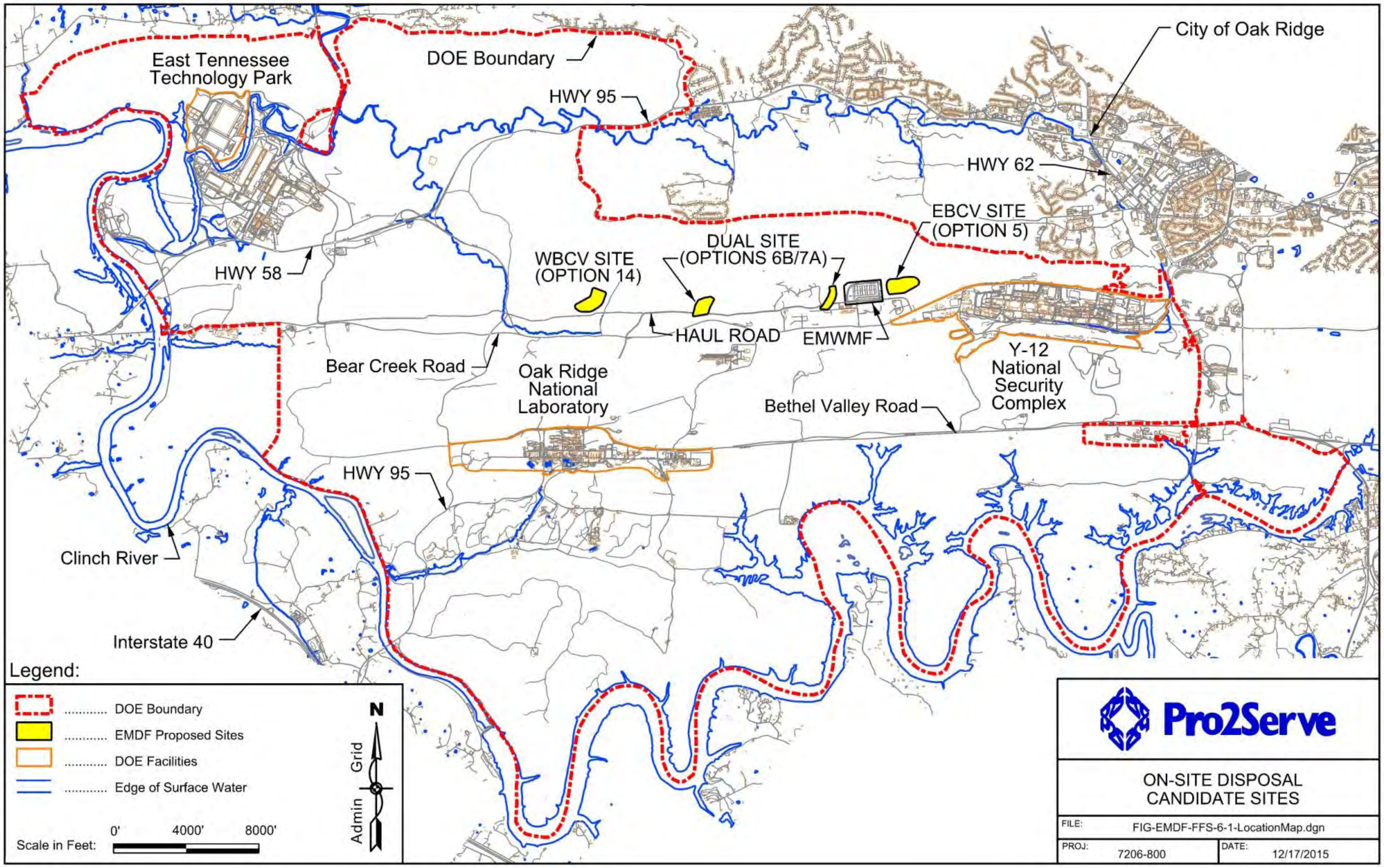


Figure 6-1. EMDF Location Map

The site option descriptions address the following categories: general site conditions, previous site investigations, surface water hydrology, geology/hydrogeology, ground water hydrology, ecological/ cultural resources, karst/seismicity issues, relationships with existing source areas and plumes in BCV, and any other unique or relevant site conditions. To avoid repetition, some of the background descriptions provided for Site 5 (e.g., general explanations of geological conditions, previous investigations encompassing BCV as a whole) are applicable to other sites and therefore are not repeated in subsequent site descriptions. More comprehensive site descriptions for BCV and the four proposed sites are presented in Appendix E, including various figures that illustrate features described below for each site.

6.2.1.1 EBCV Site (Option 5)

The site plan for the EMDF at the EBCV Site is presented in Figure 6-2. The proposed EMDF site is located east of EMWMF on the ORR in the BCV Watershed. The proximity of the site to EMWMF offers advantages through sharing existing infrastructure and by consolidating waste management areas (see Section 6.2.2.5). It is located in the Zone 3 area of EBCV designated for future DOE-Controlled Industrial Use in the BCV Phase I ROD (DOE 2000) as shown in Figure E-1 in Appendix E. Appendix D describes the screening process and selection of this site, which will remain under DOE control within DOE ORR boundaries for the foreseeable future. The nearest resident to the proposed EMDF site at the EBCV location is 0.84 miles directly north, and is separated from the site by Pine Ridge.

Construction of a disposal facility at the EBCV site may or may not require moving the 229 Security Boundary for Y-12 as shown in Figure 6-2. This security boundary is designated pursuant to Section 229 of the Atomic Energy Act of 1954 as implemented by 10 CFR 860. The purpose of this security boundary is to prevent the unauthorized introduction of weapons or dangerous materials into Y-12. In order to revise this boundary, DOE would publish a notice of revision in the Federal Register. The need to redesignate the 229 Boundary is currently being evaluated by DOE.

Site Characteristics

General site conditions. The approximately 70-acre EBCV Site (30 acre waste footprint area) is situated along and below the southern flank of Pine Ridge on undeveloped land immediately east of the EMWMF. Based on process knowledge and a review of historical maps, the site is believed to be uncontaminated. The site is bounded on the south by the Haul Road, a sub-tributary of Northern Tributary (NT)-3 along its western margin, Pine Ridge to the north, and NT-2 to the east and southeast. The site is located within a portion of the uppermost headwaters of NT-2 and NT-3 that flow southward to Bear Creek and is dissected by several stream channels and north-south oriented ravines draining the south flank of Pine Ridge. Site topography varies from low to moderate slopes in the broad valley area of the main (east) NT-3 stream channel, to moderate and steep slopes mostly along the southern flanks of Pine Ridge. Roughly two thirds of the western footprint includes a broad valley along the main intermittent stream channel of NT-3 that drains toward the southwest. The eastern third of the footprint occupies more elevated areas except for two relatively small valleys draining to the south/southeast along sub-tributaries of NT-2. The site had been mostly covered in forest until May 19, 2013, when a tornado-like downburst toppled trees across much of the site. Subsequent timber recovery efforts have cleared a large portion of the footprint. Additional clearing and drill site access road construction preceding the 2014/2015 limited Phase I investigation has further modified surfaces and runoff across portions of the site. Phase I site characterization efforts delineated these three branches of NT-3 in the vicinity of site 5, a western, central, and eastern branch. All three branches of NT-3 would be impacted by construction of the landfill, with the central and eastern branches requiring modifications to accommodate the future landfill. These modifications are discussed in the sections for the upgradient diversion system and the underdrain system. The eastern branch collects the largest area of runoff and tends to have higher flows than the western and central branches. The central branch has the lowest flow and the flow is typically not as well channelized as the other two branches. The central and western branches travel in a more north-south direction, while the eastern branch tends to run diagonally across the site.

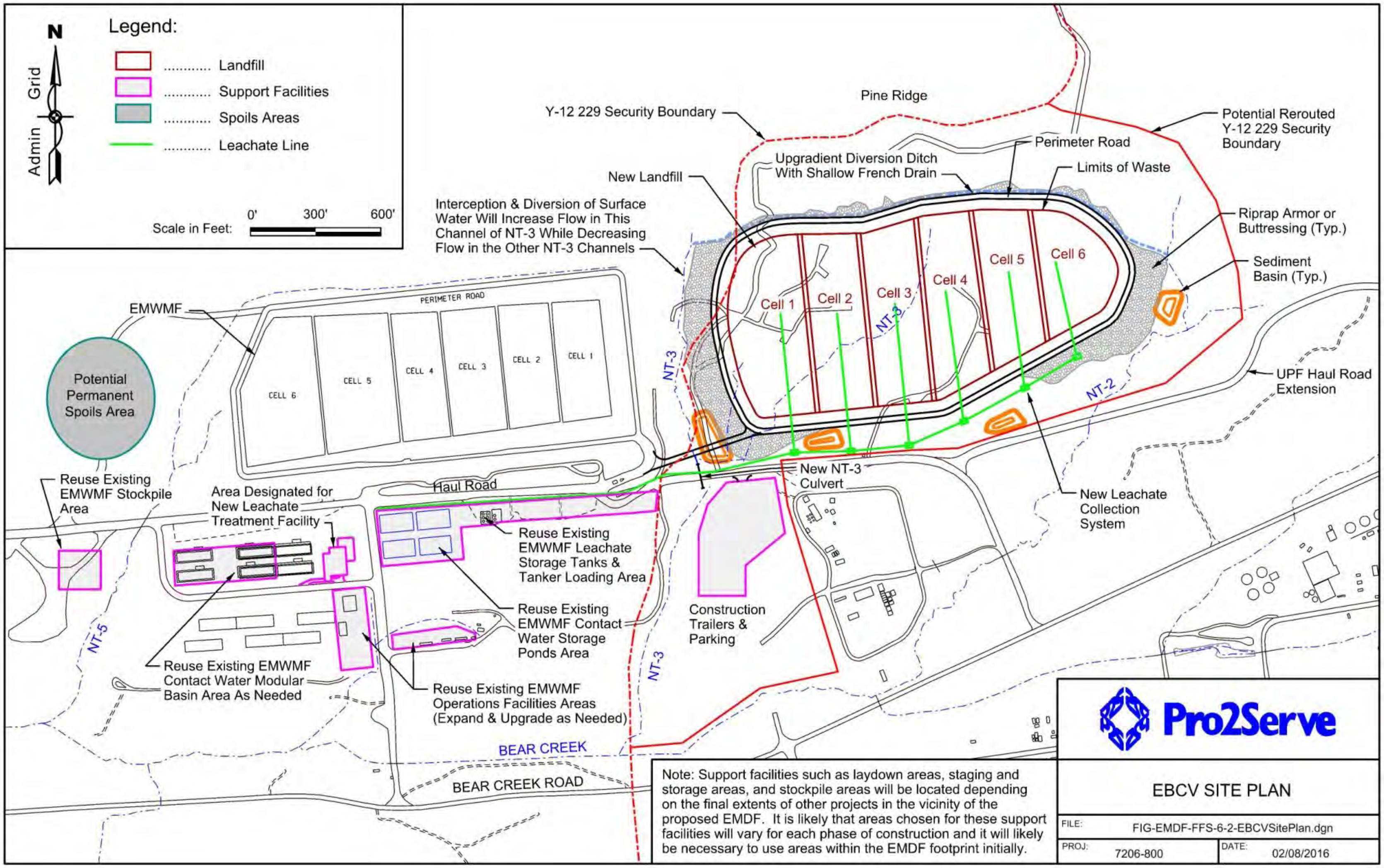


Figure 6-2. EBCV Site Plan (Option 5)

Previous investigations. Subsurface hydrogeological and geotechnical data and interpretations are available from preliminary design investigations completed in 1994 at sites designated as B and C, located directly adjacent to and along geologic strike with Site 5 to the east and west. Additional design investigations were completed in support of the EMWMF just west of Site 5. The results from these investigations provide data and insight into likely subsurface conditions at Site 5. The recent limited Phase I investigation has provided site-specific data for Site 5 from subsurface characterization of saprolite and bedrock at five shallow/deep cluster well locations, and from a full year of surface water and ground water monitoring. Details of the Phase I investigations are addressed in Attachments A and B to Appendix E, and provide site-specific data for Site 5. Summaries of the earlier adjacent site investigations and references to original investigation reports are also provided in Appendix E.

Surface water hydrology. Surface water data for Site 5 come from three primary sources: the 1994 U.S. Geological Survey (USGS) spring/seep and stream channel inventory and base flow measurements program; site reconnaissance by P2S to verify and document spring, seep, and stream flow conditions; and the Phase I monitoring of stream and spring flow at nine Site 5 locations. Among the four proposed EMDF sites, the data for Site 5 are the most complete and accurate, and provide information on surface water hydrology applicable to the other proposed EMDF sites in BCV.

Stream flow along the small headwater stream channels crossing and adjacent to Site 5 is intermittent and changes seasonally and with pulses of runoff associated with storm events. Stream channel base flow that occurs between the relatively short runoff pulses is continuous along the main sub-tributary channels of NT-2 and NT-3 within and adjacent to the site during the winter/spring non-growing wet season. During the summer/fall growing season with warm and often dry conditions, base flow is intermittent and limited to pulsed flow associated with significant storm rainfall events. Base flow measurements made by the USGS throughout the NTs in BCV indicate that dry season flows along NT-2 and NT-3 at and below Site 5 are negligible (i.e. - <0.005 ft^3 per second (cfs) or 2.2 gallons per minute [gpm]). Wet season base flows are relatively low and vary from <0.005-0.01 cfs (2.2-4.5 gpm) at headwater spring locations to 0.03-0.04 cfs (13.5-18 gpm) at stream channel locations along the southern margins of Site 5 (See Appendix E for details). Base flow in the headwater areas of NT-2 and NT-3 at Site 5 is supported by springs and seeps slowly discharging shallow ground water to the surface along the NT valley floors, and from gradual ground water seepage elsewhere along the stream channels. Ground water flux into the NT stream valleys has been well documented on the ORR within the predominantly clastic rocks typical of the proposed EMDF sites. Phase I continuous and weekly stream flow data measured at nine stations along three of the NT-3 sub-tributaries at Site 5 are presented in Attachments A and B to Appendix E. The full year of continuous flow data at Site 5 document the pulses of stormwater runoff that occur under natural conditions and vary according to the duration and intensity of rainfall events and other seasonal and temporal changes in environmental conditions. Flow conditions along Bear Creek south of Site 5 are perennial, although sections of Bear Creek further downstream are known to be seasonally dry as a result of the capture and diversion of stream flow into subsurface karst conduits of the Maynardville Limestone.

Geology/hydrogeology. Site-specific data to define hydrogeological conditions at Site 5 are currently limited to the five Phase I cluster well locations spread across the geologic formations underlying the waste footprint. The geologic strike of the entire section of sedimentary rock formations within BCV trends in a northeast-southwest direction parallel with the trend of Pine Ridge and Chestnut Ridge which border the valley to the north and south. The bedrock formations generally dip to the southeast at an average of around 45 degrees. Site 5 and each of the other site option footprints are located across the outcrop belts of the predominantly clastic bedrock formations of the Conasauga Group that from north to south include the Rome Formation, the Pumpkin Valley Shale, the Friendship/Rutledge formation, the Rogersville Shale, the Dismal Gap/Maryville formation, and the Nolichucky Shale. The footprints are all located north of the Maynardville Limestone in which karst flow occurs. The Maynardville is located south of, adjacent to, and stratigraphically above the Nolichucky Shale and forms the strike valley along the lowest elevations of BCV coincident with Bear Creek and its floodplain. The site 5 waste footprint is underlain by the formations between the Pumpkin Valley Shale and the lower half of the Dismal Gap/Maryville formation. The lower units of the Dismal Gap/Maryville form a series of knolls south of and parallel to Pine Ridge throughout BCV. At Site 5, the lower Dismal Gap/Maryville forms a ridge that provides a natural buttress for the landfill cells along the southern margin of the site.

The general subsurface sequence at Site 5 includes a thin topsoil layer, a relatively thin layer of silty/clayey residuum, a saprolite zone of variably weathered and fractured bedrock, and a zone of unweathered fractured bedrock. In addition, a surficial layer of alluvium and floodplain sediments occurs along valley floor areas, and a veneer of colluvium may also occur in places along the lower portions of steeper slopes across the site. The unstable layers of topsoil, colluvium, and alluvium will be removed from the site during landfill construction leaving uncut portions of the remaining layers available for unsaturated and saturated zone ground water flow beneath the site. The fractures and macro/micro pores within saprolite and bedrock provide the primary routes for ground water flow (and contaminant transport) below and downgradient of the footprint. Subsurface fracture networks tend to be strata bound and related to bed thicknesses and lithologies. Fracture sets are typically orthogonal with several fracture orientations generally parallel and roughly perpendicular to bedding planes.

Ground water conditions and flowpaths. Water table (potentiometric surface) contour maps developed for Site 5 based on the Phase I well data indicate that shallow ground water flows from recharge zones within upland areas of the site below Pine Ridge and the boot shaped spur ridge south of Pine Ridge toward discharge zones along the ravines and valley floors at and adjacent to the site. The depth to the water table varies from tens of feet below surface in the upland areas to depths at or very close to the surface along the valley floors where springs, seeps, and wetland areas reflect the intersection of the water table with the ground surface. The lowest elevations of the water table are therefore constrained by the existing drainage valleys crossing and adjacent to the site. The three headwater springs identified at Site 5 along the base of the most deeply incised ravines cutting into Pine Ridge represent focused points of shallow ground water discharge draining from saturated regolith and bedrock southward from the higher elevations along Pine Ridge. Other springs, seeps, and delineated wetland areas further downslope within and adjacent to the Site 5 footprint also represent zones of ground water discharge draining from the upland areas to lower elevation flatter areas where the water table intersects with the surface. A major zone of ground water discharge occurs along the southeast margin of Site 5 where a broad flat former seepage area drains ground water flowing below the Cell 5 and 6 area in the eastern third of the footprint. The absence of active stream channels in this area suggests that much of the infiltration and runoff in this part of Site 5 reaches the water table and migrates southward to discharge along the southeast side of the footprint. ORR research indicates that most of the ground water flux at Site 5 is likely to be associated with the water table interval (Solomon et al 1992; Moore and Toran 1992). The subsurface water flux associated with the stormflow zone in the topsoil layer will be eliminated across the site after construction, except for undisturbed areas surrounding the footprint. The stormflow zone along the remaining undisturbed narrow swath of Pine Ridge north of the site (~10 acres) would be intercepted by the trench drain along the northern perimeter of Site 5. The overall effects of the stormflow zone on the water table and ground water flow at Site 5 are therefore expected to be minimal.

Superimposed on the hydraulic gradients and generalized flow directions defined by water table contours, ground water at Site 5 moves along three dimensionally complex interconnected fractures. This is particularly important at greater depths below the highly fractured and weathered zone of regolith materials at and near the water table interval. Research on the ORR based primarily on tracer tests in clastic saprolite and shallow bedrock has demonstrated that ground water flow tends to be more pronounced along strike parallel fractures when the water table gradient is parallel with the geologic strike. Conversely, flow is less pronounced along strike when water table gradients are perpendicular to strike. In the former case, tracer plumes tend to migrate more quickly and are long and narrow along strike, whereas in the latter case, tracer plumes tend to migrate more slowly, and spread and diffuse more equally, in directions both parallel and perpendicular to strike (See Section 2.13 in Appendix E for greater detail). The results suggest that ground water below Site 5 is likely to move predominantly along strike parallel fracture pathways toward the various tributary valleys cross cutting and adjacent to the site, and more slowly toward the south across the geologic strike. Upward vertical gradients observed in Phase I well clusters (and elsewhere in BCV) should have no negative influence on the conceptual design for Site 5 because the base elevations of the landfill were established to avoid any deep cuts into the saturated zone.

For each of the proposed EMDF sites, it is important to recognize the significant changes to the water table and to ground water flow that will occur during and after landfill construction. Landfill construction, including underdrain networks, geobuffer/liner systems, diversion of storm water runoff, and final capping will dramatically reduce the infiltration across the footprint to a fraction of the former natural recharge across the sites. For Site 5 in particular, the extensive underdrain trench/blanket network following the NT sub-tributaries, will lower the water table by several feet below the existing NT stream channel elevations and lower the overall water table across the footprint. The reduced water table elevations below the footprint will merge laterally with the water table surrounding and outside of the footprint dictated primarily by the remaining undisturbed elevations of NT-2 and NT-3 tributaries bordering the footprint. After landfill construction, the relatively narrow swath (roughly 10 acres) remaining and available for natural infiltration in undisturbed areas north of Site 5 along Pine Ridge would continue to provide a limited amount of recharge to the water table and to ground water that migrates southward into the upgradient areas below the site. However, the underdrain network in combination with the greatly restricted recharge across the footprint would ensure that ground water would continue to migrate below the footprint by gravity driven flow and drainage and not encroach on the buffer/liner system below the waste mass (See Chapter 2.9 in Appendix E for more detailed descriptions and figures addressing the post construction changes to the water table and ground water flow at the proposed EMDF sites).

The recent Phase I ground water level data were evaluated and used to make slight upward adjustments to base level elevations in the conceptual design of the landfill. Modeling simulations of the post-construction water table were also used in the conceptual design to ensure an appropriate buffer between the waste and the water table (See Section 2.9 of Appendix E for details regarding post construction changes to the water table).

Ecological/cultural resources. Several ORR reports have identified and mapped ecologically special and sensitive areas in BCV encompassing each of the proposed EMDF sites. The area designations include: 1) aquatic natural areas, 2) habitat areas, 3) natural areas, 4) reference areas, 5) potential habitat areas, and 6) wetland areas. While these area designations are important to preserving the ecological integrity and resources of the ORR, they do not represent detailed ecological surveys that are needed to satisfy regulatory requirements related to the preservation of threatened and endangered (T&E) species and wetlands. These area designations are recognized by DOE for land use planning purposes on the ORR but receive no additional special status or protections, except as required by NEPA, the Endangered Species Act of 1973, and Sect. 404 of the Clean Water Act to protect wetlands and surface waters. Appendix E presents more detailed results of the various ecological and cultural surveys applicable to the proposed EMDF sites. Only the key aspects of the surveys most relevant to the impacts from landfill construction are presented below.

Surveys to identify T&E species, make hydrologic stream determinations, and delineate wetland areas were performed as part of the limited Phase I effort for Site 5. Six wetland areas, totaling 1.6 acres, were delineated by Rosensteel for the three main sub-tributaries of NT-3 within and bordering the western two-thirds of the Site 5 (see Section 2.17 in Appendix E). Wetlands on the east and southeast sides of Site 5 associated with NT-2 sub-tributaries were previously delineated by Rosensteel and Trettin (1993) but were not included in the latest wetland delineation work at Site 5 for the NT-3 sub-tributaries.

Wetlands identified in parts of the NT-2 sub-tributaries around Site 5 were also separately delineated in conjunction with more recent impacts from construction of the haul road extension for the Uranium Processing Facility (UPF). As compensatory mitigation for wetland destruction along the UPF corridor, two areas along the southeast margin of Site 5 were excavated, re-graded, and restructured in late 2014 as engineered wetland areas/ponds. These two newly engineered wetland areas and ponds are located directly along the paths of two of the proposed underdrain networks and outfall locations along the southeast side of Site 5 (See underdrain drawings below and drawings and details in Appendix E). Compensatory wetland mitigation would be required to offset the impacts of EMDF construction on the delineated wetlands at Site 5, and to offset the impacts from destruction of the new wetlands constructed for the UPF project. The recent 2015 hydrologic determination surveys at Site 5 classified 450 linear feet of the upper segments of the west and middle sub-tributaries of NT-3 as wet weather conveyances. All of the main eastern sub-tributary of NT-3 crossing the Site 5 footprint and the lower segments of the west and middle sub-tributaries of NT-3 were classified as intermittent streams with a total of 2,780 linear feet.

No known federal- or state-listed T&E species have been identified in the EBCV site area, except for Northern long-eared bats, which are listed as threatened. An acoustic bat survey conducted by ORNL personnel in August 2013 at and near Site 5 prior to timber recovery did not detect any Gray or Indiana bats that are listed as endangered species, but did identify Northern long-eared bats (See Appendix E for details). NT-3 is isolated from fish movement by the Haul Road culvert, and the headwater segments of the NT-2/NT-3 tributaries are quite small with intermittent flow that place severe limitations on any fish populations. There are no known archeological or historical resources in or near Site 5 (DOE 1999; DuVall 1998; DuVall and Souza 1996; Fielder, et al. 1977).

Karst and seismicity. Karst conditions such as sinkholes, sinking streams, and resurgent springs have not been documented in BCV within the predominantly clastic sedimentary rock formations located below and surrounding Site 5. Karst features are documented within the Maynardville outcrop belt south of Site 5. The contact between the Nolichucky Shale and Maynardville Limestone is located 1,270 ft south of the southern waste limit boundary at Site 5. Bear Creek is also located about the same distance south of Site 5. There is no evidence of active seismically capable faults in the vicinity of Site 5 or any of the other EMDF candidate sites in BCV.

Relationships to contaminated areas in EBCV. Soil and ground water contamination is present in several areas south of Site 5, most notably along NT-3 south of the Haul Road. Contaminants originated from wastes disposed at the Oil Landfarm, Boneyard/Burnyard (BY/BY), Sanitary Landfill I, and Hazardous Chemical Disposal Area (HCDA) (B&W 2011; DOE 1997). Remedial actions at these sites have involved removal and/or isolation of source contaminants but ground water plumes have not been remediated. Plume maps for BCV show that the nearest ground water contaminant plume is located about 500 ft south of the southern waste limit margin of Site 5 (See Figure E-2 in Appendix E). The site is far enough away from and upgradient of known waste sites and existing ground water contaminant plumes in EBCV, that release detection monitoring locations along the downgradient perimeter of Site 5 should not encounter existing contaminants. As noted above, site reconnaissance and review of historical topographical maps suggests the EBCV site was not used for DOE waste disposal. Excavation permits issued by Y-12 for the Phase I drilling indicated no subsurface infrastructure at any of the Phase I monitoring locations. Phase I surface and subsurface field screening results for radionuclide activity and volatile organic compounds were all negative.

6.2.1.2 WBCV Site (Option 14)

The site plan for the EMDF at the WBCV Site is presented in Figure 6-3. The proposed EMDF site is located 0.7 mi east of State Route (SR) 95, and approximately 3 miles west of EMWMF in the BCV watershed. The distance of the site from EMWMF means new infrastructure must be developed (see Section 6.2.2.5). It is located in the Zone 1 land use area designated for Unrestricted Use in the BCV

Phase I ROD (DOE 2000) as shown in Figure E-1 in Appendix E. Appendix D describes the screening process and selection of this site, and discusses the need to revisit the future land use designation for this area, should the EMDF be sited at this location. The nearest residence to the proposed EMDF site at the WBCV location is 1 mile northeast, in the Country Club Estates Subdivision, and is separated from the site by Pine Ridge. Construction of a disposal facility at the WBCV site will be outside of the 229 Security Boundary for Y-12.

Site Characteristics

General site conditions. The approximately 71-acre area of Site 14 (29 acre waste footprint area) is situated within an upland area located between the adjacent north-south trending valleys of NT-14 and NT-15. The Site 14 footprint is centered across the crest of a knoll or ridge south of Pine Ridge that is underlain by the Dismal Gap/Maryville formation. A prominent sub-tributary of NT-14 cuts across the northern half of the footprint forming a northwest trending saddle between Pine Ridge and the Dismal Gap knoll. One other relatively large ravine drains southward across the southwest quarter of the footprint. Underdrain networks are proposed along those two sub-tributary ravines cross cutting the footprint. Slopes drop sharply along the northwest side of the footprint into the adjacent valley of NT-15. Relatively steep slopes also occur just northeast of the knoll crest into the sub-tributary of NT-14. Moderate slopes occur along the northern quarter of the footprint along the south flanks of Pine Ridge, and moderate slopes occur across the southern half of the site draining to the south toward Bear Creek and the lower reaches of NT-14 and NT-15. Recent satellite imagery shows that Site 14 and the surrounding area is entirely forested. The existing haul road is located directly along the southern site boundary and would probably not require rerouting.

Previous investigations. Extensive site characterization activities and research were conducted in the WBCV area at and west of Site 14 in support of the Low-Level Waste Disposal Development and Demonstration (LLWDDD) program in the 1980's and 1990's. The proposed LLWDDD above ground "tumulus" facility was never constructed but surface and subsurface conditions were investigated and culminated in a Performance Assessment report in 1997 for a location within the current Site 14 footprint. Results from the many investigation reports and research papers provide data for Site 14 that are unavailable at Sites 6b and 7a (and to a lesser extent Site 5) where little characterization data exists. Because the proposed EMDF sites are all located roughly along geologic strike with one another and in areas of generally similar topography, the results from Site 14 provide insights into similar conditions that may be encountered at Sites 5, 6b, and 7a. Appendix E summarizes the results of previous investigations at Site 14. References to the many characterization reports and research papers available for Site 14 are cited in Appendix E for additional details.

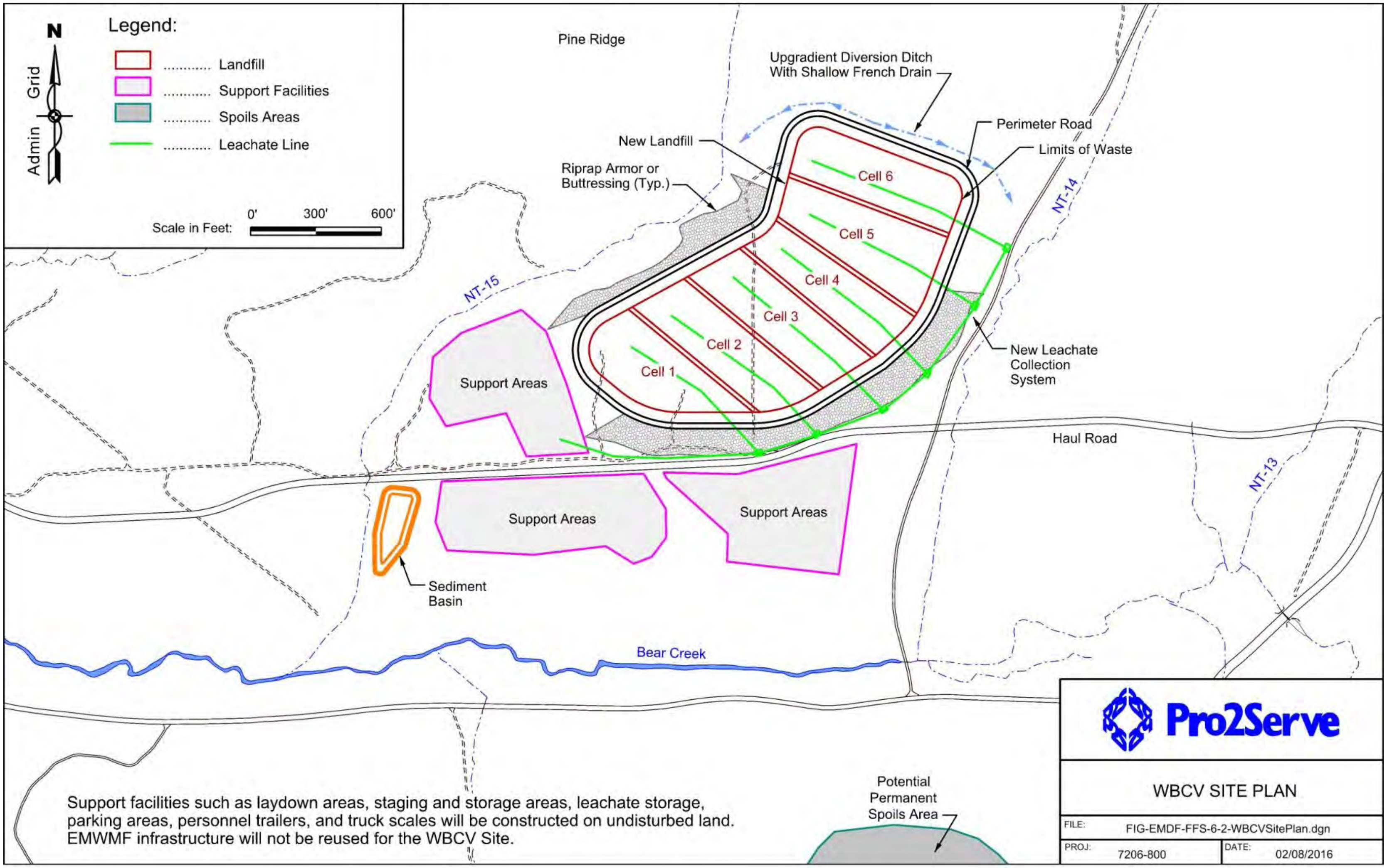


Figure 6-3. WBCV Site Plan (Option 14)

Surface water hydrology. Detailed site reconnaissance has not been conducted to assess the details of surface water hydrology at Site 14, but the USGS dry and wet season base flow data and continuous stream flow monitoring data from weirs along the lower segments of NT-14 and NT-15, and from weirs along Bear Creek provide information to assess surface water hydrology around Site 14. The USGS dry season data indicate that base flow is continuous along the main stream channels of NT-14 and NT-15 during the winter/spring non-growing wet season. During the summer/fall growing season with warm and often dry conditions, base flow in the uppermost headwater tributaries is intermittent and limited to pulsed flow associated with significant storm rainfall events. Base flow measurements made by the USGS indicate that dry season flows along the lengths of NT-15 on the west side of Site 14 are negligible (i.e. - <0.005 cfs) except for the lower reaches of NT-15 where flows are low but apparently persistent (i.e.- around 0.01 cfs). In contrast, dry season base flow conditions along NT-14 along the east side of Site 14 are notably different because of its relatively large watershed area that actually cuts through and extends into areas north of Pine Ridge. The dry season base flow data indicate that the headwaters north of Pine Ridge are essentially dry, but flows along the main channel of NT-14 south of the Pine Ridge water gap are continuous and range from 0.01 cfs near the gap to as much as 0.05 cfs cfs (22 gpm) further downstream on NT-14 (See Appendix E drawings and details). Wet season base flows along NT-15 vary from zero (i.e. - <0.005 cfs) at a headwater spring/seep locations to a maximum rate 0.15 cfs (67 gpm) southwest of the site. Wet season base flows along NT-14 are higher ranging from 0 to 0.01 cfs at several headwater seep locations to rates of 0.16-0.27 cfs (72-121 gpm) along the east and southeast sides of the Site 14 footprint.

Hydrographs and raw data from the LLWDDD era investigations provide daily average stream flow from weir locations south of the site along NT-14, NT-15, and Bear Creek. The results are consistent with hydrographs from Site 5 and elsewhere in BCV that indicate stream flow varies widely according to pulses of runoff associated primarily with rainfall intensity and duration.

Within the Site 14 waste footprint, the USGS identified one seep near the north central part of the main sub-tributary cutting across the northern half of the site, and two springs and one seep along the ravines cutting across the southwestern part of the footprint. These springs and seeps indicate localized areas where shallow ground water discharges to the surface, and areas where the water table is likely to be very shallow throughout the year. The wetlands delineated at and near Site 14 also indicate zones of natural ground water discharge. Two wetland areas were delineated within the footprint area along the sub-tributary of NT-14 crossing the northern half of the site. Wetlands were also delineated along much of NT-15. The closest of those are along NT-14 at the base of the steep slopes along the northwest side of the footprint. Wetlands were also delineated along the mid sections of NT-14 and a sub-tributary of NT-14 west/southwest of the footprint (See site-specific figures in Appendix E). Wetlands located along the lower reaches of NT-14 occur to the southeast of the Site 14 footprint.

Continuous flow monitoring data are not available in close proximity to Site 14, but data is available at several stations, mostly along Bear Creek south of the site. The nearest BCV/ORR monitoring stations are located along Bear Creek at several locations upstream, downstream, and due south of Site 14. Flow along Bear Creek south of Site 14 is perennial. Stream flow there is the highest among the proposed sites because of the location farthest down the BCV watershed.

Geology/hydrogeology. More wells have been drilled within and directly adjacent to the Site 14 footprint between NT-14 and NT-15 than at any of the other proposed EMDF sites. While the investigations were not targeted directly toward the engineering design or modeling needs of the EMDF, the data provide a strong foundation for the conceptual design that can be readily expanded upon if Site 14 is selected for the EMDF. Much effort has been made during the RI/FS process to compile, organize, and complete the preliminary evaluation of the data and reports available for the WBCV area that are relevant to Site 14 and summarized in Appendix E. Additional work will be required, however, to further organize, evaluate, and present the detailed hydrogeological data for Site 14 if selected for the EMDF.

Most of the geological/hydrogeological data available for Site 14 comes from the drilling, logging, and hydrologic testing of numerous wells and piezometers across the WBCV area. Much of the work was conducted by the prime DOE contractor and/or their subcontractors, and evaluated and reported by ORNL researchers and/or by subcontractors such as Golder Associates. The scope of the work typically included broad objectives that were not necessarily focused toward the current and specific needs related to design and construction of the EMDF. However, the results of well drilling and logging of soils, saprolite, and rock cores, ground water level monitoring, slug tests, packer tests, pumping tests, tracer tests, and numerical modeling of ground water flow and contaminant transport are all applicable to the EMDF in general and Site 14 conditions in particular.

Available generalized cross sections for Site 14 are presented in Appendix E, but detailed site cross sections and maps have not been developed to accurately depict and thoroughly evaluate subsurface hydrogeological conditions across and adjacent to the proposed Site 14 footprint. Data from over 57 active and inactive wells are available to allow for the construction of accurate and detailed drawings across the Site 14 area, if selected as the new EMDF. These wells do not include the tracer test area just southwest of the Site 14 footprint where an additional ~72 individual and cluster wells/piezometers are located. The detailed site cross sections and maps would consolidate available data from the previous investigations summarized in Appendix E, and facilitate site planning for additional characterization and detailed design.

The general hydrogeological conditions at Site 14 will be similar in most respects to those found at Sites 7a and 5 which are located over similar terrain and along geologic strike with Site 14. Among the proposed sites, Site 14 spans the greatest distance north and south across the outcrop belts of the Conasauga Group, ranging from the southward to the lower third of the Nolichucky Shale. The Site 14 footprint is roughly centered on and spans the entire outcrop width of the Dismal Gap/Maryville, and extends on the north from the Pumpkin Valley Shale, across the Friendship/Rutledge, Rogersville, Dismal Gap/Maryville, to the lower third of the Nolichucky Shale. The only places within the footprint area where Recent alluvium appears likely in any significant extent are those valley floor areas along the two relatively large sub-tributary/ravines noted above. The typical profile of topsoil, silty/clayey soil residuum, saprolite, and fractured bedrock are likely across the undisturbed areas of the site. The general nature and extent of these key hydrogeological horizons could be defined to some degree based on the data available from the active and inactive wells drilled at the site. Geotechnical data needed for the EMDF design are largely absent from the previous investigations at Site 14.

The southern margin of the waste footprint is approximately 656 ft from the contact between the Nolichucky Shale and the Maynardville Limestone where karst conditions begin. This contact is roughly coincident with the southern margin of the support areas shown in Figure 6-3. Initial landfill construction at Site 14 would include the removal of loose unstable topsoils, alluvium, and colluvium. The fractures and macro/micro pores within the remaining soils/saprolite and bedrock will provide the primary routes for ground water flow (and contaminant transport) below and downgradient of the 7a footprint. Appendix E should be reviewed for additional information regarding the types and limitations of hydrogeological and well testing data available for Site 14.

Ground water conditions and flowpaths. Two water table contour maps are available for the WBCV area encompassing most of Site 14. The maps illustrate synoptic water level conditions in August 1987 and May 1988 for the potentiometric surface of the "near surface system". The contours illustrate generalized ground water flow paths that radiate outward from the recharge zones in upland areas toward discharge zones east, west, and south of the Site 14 footprint (See drawings in Appendix E) along the adjacent stream valleys of NT-14, NT-15, and Bear Creek. The maps are similar to those recently prepared for Site 5 indicating a water table surface that is locally constrained and dictated by stream channel and valley floor elevations within and adjacent to the site.

Tracer tests conducted at the WBCV tracer test site just southwest of the Site 14 footprint demonstrated that narrow, shallow, elongated tracer plumes form along strike dominant parallel flow paths where hydraulic gradients in the water table interval generally align with the geologic strike (see detailed results of tracer tests presented in Appendix E). The results of the tracer tests at the WBCV site along with tracer test results elsewhere on the ORR suggest that shallow and intermediate ground water below Site 14 will follow hydraulic gradients and predominant strike parallel fracture flow paths across the width of the footprint toward local discharge zones along the adjacent valleys of NT-14 and NT-15 immediately east and west of the footprint.

Potentiometric surface contour maps for Site 14 indicate that horizontal hydraulic gradients tend to broadly mimic surface topography and that shallow to intermediate level ground water flows locally from high elevation recharge areas to low elevation discharge zones. The corresponding vadose zone is likely to be thickest below upland areas such as below the crest of the knoll near the center of Site 14, and thin toward the NT valley floors and cross cutting ravines where the water table is at or very close to the ground surface. The orientation of NT-14 and NT-15 roughly perpendicular with the geologic strike results in water table gradients across most of the footprint area that trend in a direction parallel to subparallel with strike and enhance ground water drainage laterally into the adjacent NT valleys. Portions of NT-15 and the sub-tributary to NT-14 along the northwest and northeast margins of the footprint where the hydraulic gradients are at intermediate angles to geologic strike are still likely to drain to those nearest valleys along strike parallel flow paths under steeper hydraulic gradients (See Site 14 water table contour maps in Appendix E). Ground water flow along much of the southern part of the footprint at Site 14 may follow relatively slower and more tortuous fracture flow paths in regolith and bedrock that are roughly perpendicular to strike in the direction of southward hydraulic gradients more directly toward the low elevations and discharge zones along the floodplains of Bear Creek. The wetlands noted above along the NT valley floors indicate areas where ground water discharges to the surface. The locations of these wetlands also support the likelihood of strike parallel ground water drainage and discharge into the adjacent NT valleys (See site-specific wetland maps in Appendix E).

As described for the other proposed EMDF sites, the area (roughly 12 acres) available for natural infiltration in undisturbed areas north of Site 14 along Pine Ridge will continue to provide some recharge to the water table and to ground water that migrates southward to the upgradient areas of the footprint (in the vicinity of Cells 5 and 6). However, under the unique conditions at Site 14, the majority of that ground water flow is likely to be captured and diverted toward the southeast into NT-14 east of the footprint thereby greatly limiting the amount of ground water underflow beneath the footprint after landfill construction and capping. Without this underdrain network across the northern half of the footprint, natural ground water flow from Pine Ridge would be inhibited, increasing hydraulic heads, and elevating the water table below the northern half of the Site 14 footprint.

Ecological/cultural resources. No recent site-specific surveys to identify T&E species have been completed for Site 14. Ecological conditions for the WBCV area were reported in an environmental impact statement data package for the LLWDDD program published in 1988. ORR ecological surveys have mapped an "aquatic natural area 2" that includes a broad belt along the entire length of NT-14 directly east of Site 14, and along Bear Creek floodplains south of Site 14 (See Appendix E). While the aquatic natural areas on the ORR are recognized for their significance in harboring species richness and diversity, the areas do not automatically have the special regulatory protection status offered to protecting wetlands and individually recognized T&E species. As previously noted, two wetlands were delineated by Rosensteel and Trettin (1993) within the northern half of the Site 14 footprint that would be directly impacted by landfill construction. Several other wetland areas have been delineated along the marginal areas of the footprint. Some appear likely to be outside the areas impacted by support facilities; others are less clear but could be addressed during the early planning stages if Site 14 is selected for EMDF construction. Detailed assessments to evaluate potential impacts to wetlands and to identify T&E species would be warranted at Site 14 if the site is selected for construction.

Surveys to identify archaeological features do not appear to have been conducted at or near Site 14. Surveys of historical home sites and cemeteries across the ORR, indicate that foundation materials for one historical structure, designated as 833A, are located along the southeast side of Site 14 between the site margin and NT-14. The location has not been verified since its latest verification in 1994. The nearest cemetery, Currier Cemetery, is located about a half mile west of Site 14, well away from any impacts from construction. (See Appendix E for details and drawings showing locations and summarizing the available assessments of cultural resources in BCV).

Karst and seismicity. Karst conditions such as sinkholes, sinking streams, and resurgent springs have not been documented in BCV within the predominantly clastic sedimentary rock formations located below and surrounding Site 14. Karst features are documented within the Maynardville outcrop belt south of Site 14. The contact between the Nolichucky Shale and Maynardville Limestone is located 656 ft south of the southern waste limit boundary near the possible southern margin of potential landfill support areas. Bear Creek and its floodplain areas south of Site 14 are located roughly 200-400 ft further south of the contact. There is no evidence of active seismically capable faults in the vicinity of Site 14 or any of the other EMDF candidate sites in BCV.

Relationships to contaminated areas in EBCV. Among the four candidate sites, Site 14 is located the farthest away from the Zone 3 area that includes historical waste sites in EBCV and their associated ground water contaminant plumes. Figure E-2 in Appendix E shows that the nearest ground water contaminant plumes are located along the path of Bear Creek and the Maynardville Limestone over 1.5 miles upstream from Site 14. The figure does indicate a zone along Bear Creek and the Maynardville directly south of Site 14 denoted as an "area of periodic plume extension" that extends all the way to near SR 95 located about 0.75 mile southwest of Site 14. This area is located a few hundred feet south of Site 14 and thus would not interfere with release detection and compliance monitoring that would be required along the downgradient perimeters of Site 14. The previous investigation reports at Site 14 have not identified any historical waste disposal or contaminant issues at or near Site 14.

6.2.1.3 Dual Site (Options 6b/7a)

The site plan for the EMDF, to be constructed as two smaller footprints referred to as the Dual Site Option, is presented in Figures 6-4 and 6-5. The first EMDF footprint (Site 6b) in the proposed Dual Site is located immediately west of EMWMF in an area recently used for soil borrow at the EMWMF. The second EMDF footprint (Site 7a) is located approximately 1.5 mi further to the west of EMWMF. The distance of Site 7a from EMWMF means some new infrastructure must be developed (see Section 6.2.2.5), while the proximity of Option 6b to EMWMF will allow use of EMWMF infrastructure during its operation. The Option 6b site is located in land use Zone 3 designated for future DOE-Controlled Industrial Use in the BCV Phase I ROD (DOE 2000), while the Option 7a footprint is located in land use Zone 2 designated for short-term recreational use and for long-term unrestricted use (see Figure E-1 in Appendix E). Appendix D describes the screening process and selection of this site, and discusses the need to revisit the future land use designation for this area should one of the EMDF footprints be sited at this location. The nearest residence to the proposed EMDF site at the Option 6b location is just over one mile to the northeast, and the nearest residence to Option 7a is 0.8 mi directly north of the site; both residents are separated from the sites by Pine Ridge. Construction of disposal facilities at the two sites in the Dual Site Option will be outside of the 229 Security Boundary for Y-12.

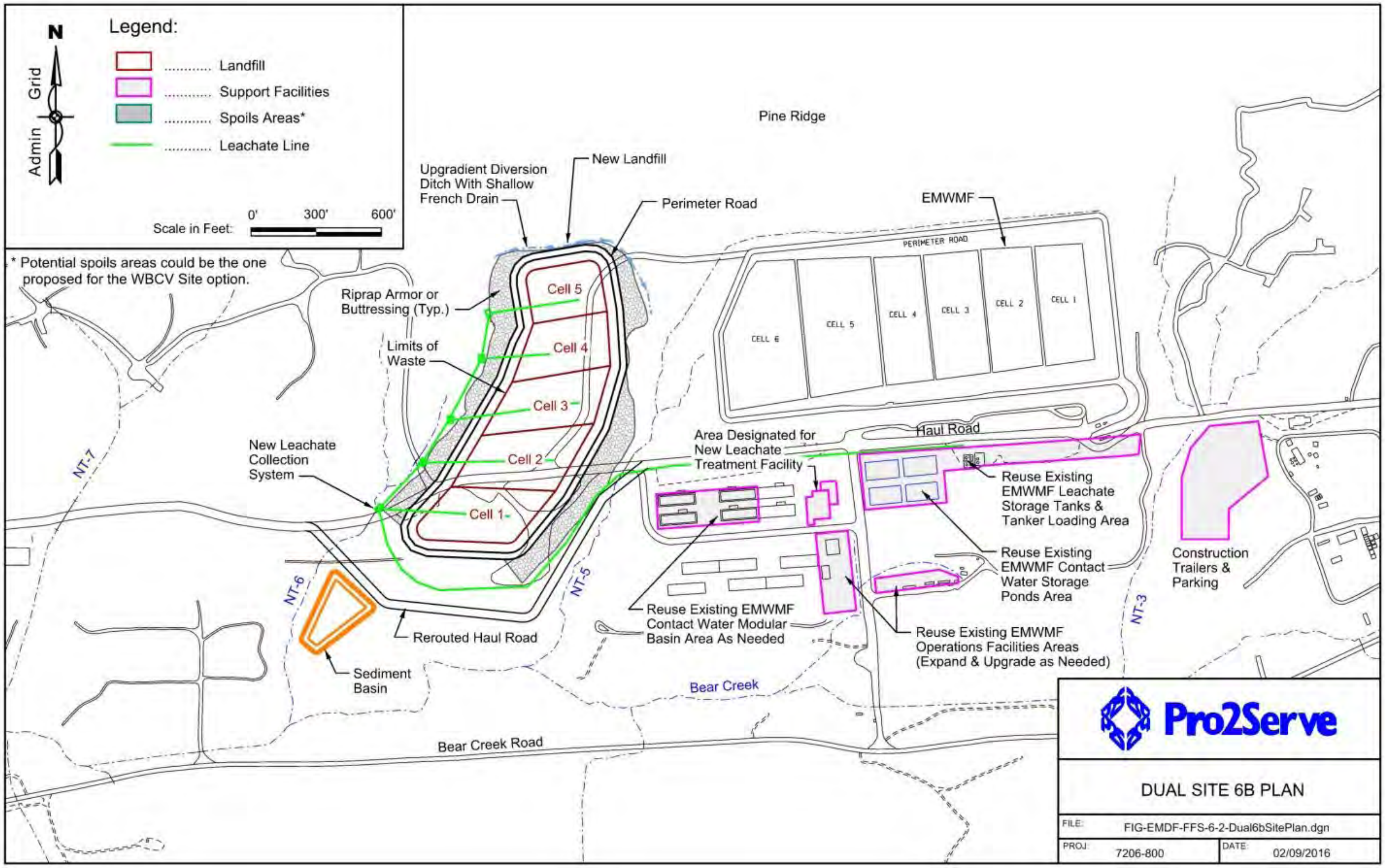


Figure 6-4. Dual Site Plan (Site Option 6b)

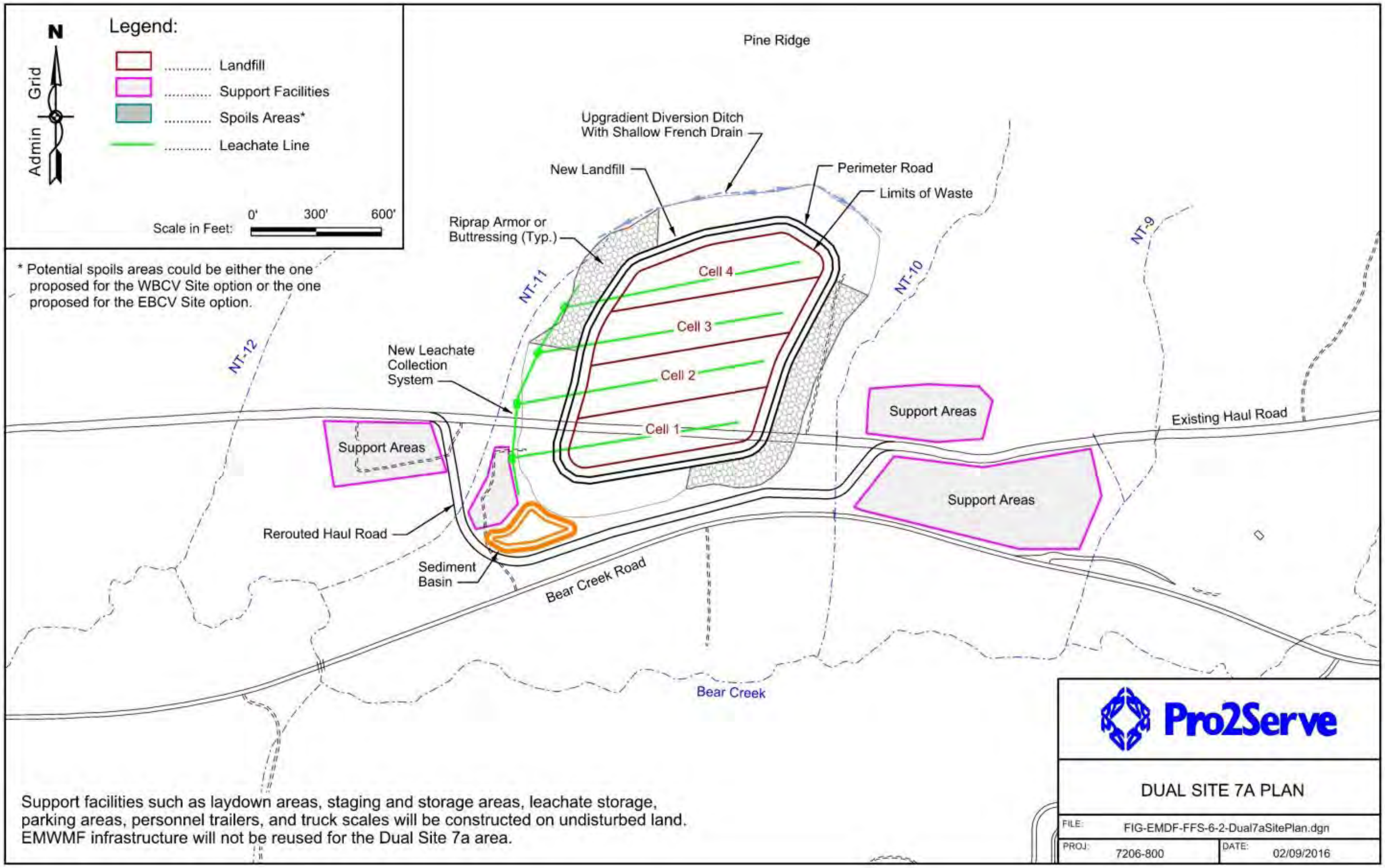


Figure 6-5. Dual Site Plan (Site Option 7a)

Site Characteristics – Site 6b

General site conditions. The approximately 50-acre area of Site 6b (13 acre waste footprint area) is situated along a relatively long and narrow upland area oriented in a north-south direction constrained between the adjacent valleys of NT-5 and NT-6. To accommodate and maximize required waste volumes the site is extended further to the north and south relative to the other candidate sites in BCV. The EMWMF and the Bear Creek Burial Grounds (BCBG) waste site are located directly east and west of Site 6b. The footprint area at Site 6b was used for soil borrow at the EMWMF which has resulted in significant lowering of the original ground surface. Site cross sections indicate as much as 50 ft of unconsolidated regolith has been removed across the former crest of the footprint area. Recent satellite imagery shows grass covered areas across the former soil borrow area with a runoff control basin and crossed by an EMWMF access road within northern two thirds of the 6b footprint (see Appendix E). The existing haul road cuts across the lower third of the proposed footprint and would require rerouting (see Figure 6-4). The imagery also shows open, mostly grass covered areas and unpaved staging areas within the lower third of the footprint. Virtually the entire Site 6b footprint has thus been cleared except for surrounding forested areas along the NT stream valleys and in undisturbed areas to the north and south.

The extensive soil removal and leveling has resulted in low to moderate slopes across the site, except at the northern end of the site resting against the south flank of Pine Ridge. Site leveling has also reduced the extent to which the site is cross cut with sub-tributaries or ravines extending into the site from NT-5 and NT-6. Only two small ravine areas have been identified that would warrant relatively small underdrain networks.

Previous investigations. Previous reports of investigations at Site 6b are limited. Available reports directly applicable to Site 6b include: wetland delineation surveys, the 1994 USGS spring, seep, and stream flow inventory for BCV, T&E species surveys of vascular plant and fish, and cultural resource surveys. Maps in the Y-12 subsurface database for BCV show a few well locations at or near Site 6b between NT-5 and NT-6 and north of Bear Creek. However, the locations and the data from these wells are limited and insufficient for engineering design, fate and transport modeling, and other purposes. As noted for Site 5, investigation data from adjacent sites (BCBG and EMWMF) are available and helpful but do not provide site-specific data necessary for detailed project planning and construction. The available data are limited at Site 6b but provide a starting point for planning additional site characterization if Site 6b is selected for EMDF waste disposal (See Appendix E for details regarding locations and data available for Site 6b).

Surface water hydrology. Detailed site reconnaissance has not been conducted to assess the details of surface water hydrology at Site 6b. However, the available USGS seasonal base flow data suggest that stream flow along NT-5 and NT-6 and the smaller sub-tributary stream channels draining Site 6b is seasonally intermittent, and influenced by pulses of runoff associated with storm events. The USGS data indicate that base flow is continuous along the main stream channels of NT-5 and NT-6 adjacent to Site 6b during the winter/spring non-growing wet season. During the summer/fall growing season with warm and often dry conditions, base flow is intermittent and limited to pulsed flow associated with significant storm rainfall events. Base flow measurements made by the USGS indicate that dry season flows along the lengths of NT-5 and NT-6 are negligible (i.e. - <0.005 cfs), except for limited segments along the upper and middle portions of the stream channels where the lowest measurable flows of 0.01 cfs (4.5 gpm) were recorded at a few measurement stations. Wet season base flows are relatively low and vary from 0.02-0.03 cfs (9-13.5 gpm) at headwater spring locations to flow rates as high as 0.09-0.12 cfs (40-54 gpm) at stream channel locations along the lowest reaches of NT-5 and NT-6 (See Appendix E for details).

Although the 1994 USGS survey identified two head water springs and several seeps along the stream courses of NT-5 and NT-6, only four seeps were identified by the USGS along the margins of Site 6b. Relative to the other proposed sites, Site 6b is not crossed by any relatively large sub-tributaries of NT-5 or NT-6. One former ravine near the center of the footprint draining west into NT-6 has been replaced with a runoff basin. Two seeps were identified along the downstream section of that ravine west of the runoff basin. These seeps may exist but have not been verified. Similar ravines along the northeast and southwest corners of the footprint appear to have seeps along their lower portions. These seep locations represent areas where ground water flowing beneath the site footprint discharge to the surface. Wetlands delineated near Site 6b are limited to narrow swaths along portions of the valley floors along NT-5 and NT-6 mostly in areas directly east and west of the footprint.

Continuous flow monitoring data are not available at Site 5 but BCV/ORR monitoring stations (NT-05 and NT-06) are located along the lowest reaches of NT-5 and NT-6 south of Site 6b, and at stations along Bear Creek up and downstream of Site 6b. Flow conditions along Bear Creek south of Site 6b are continuous during the typical winter wet season, but a lengthy section of Bear Creek above and below the junctions of NT-5 and NT-6 is known to be dry during the summer/fall seasons as a result of the capture and diversion of stream flow into subsurface karst conduits of the Maynardville Limestone (See Appendix E for drawings and details).

Geology/hydrogeology. The detailed subsurface hydrogeological conditions at Site 6b are poorly known but data available from a few well clusters in and adjacent to the footprint provide some basic site characterization data. Analysis of the Y-12 subsurface database for BCV indicates a total of eleven active wells clustered at five locations within the upland area between NT-5 and NT-6, and north of Bear Creek. The database report does not include copies of original descriptive boring or well construction logs, but does include some well construction data, depths to the top of weathered and fresh bedrock, water level data (max/min/mean values), approximate dates of water quality sampling, and other general information about the wells. All of the wells are located along marginal areas of the 6b footprint, except for one well shown near the center of the footprint which appears to have been eliminated during the soil borrow removal process. If Site 6b is selected for the EMDF, the available subsurface data from the five locations (and from a tight cluster of several inactive well locations) would provide fundamental control points for depths to ground water and bedrock. However, additional data would be required for understanding detailed hydrogeological conditions at Site 6b and to support engineering design.

As a result of the extensive excavations for borrow material, much of the original topsoil, silty/clayey residuum, and saprolite across the Site 6b footprint has been removed, thereby greatly decreasing the remaining thickness of regolith materials, decreasing the depths to competent bedrock, and probably placing the water table much closer to the existing ground surface across much of the site. The extent of alluvium and colluvium at Site 6b is probably limited by the general absence of any significant stream channel and floodplain sediments apparent from the general site topography.

From north to south, the footprint of 6b extends across the outcrop belts of the predominantly clastic rocks of the Friendship/Rutledge formation, Rogersville Shale, Dismal Gap/Maryville formation, and lower third of the Nolichucky Shale. The former knoll held up by the more erosionally resistant Dismal Gap/Maryville formation near the center of the footprint was denuded during the soil borrow process. The southern margin of the waste footprint is 597 ft from the contact between the Nolichucky Shale and the Maynardville Limestone where karst conditions are well documented in BCV (about half of the Site 5 distance). The fractures and macro/micro pores within saprolite and bedrock provide the primary routes for ground water flow (and contaminant transport) below and downgradient of the 6b footprint. However, with the removal of much of the regolith soils and saprolite, the remaining fracture pathways may be far less weathered and less fractured relative to subsurface pathways at the other sites where regolith removal has not occurred.

Ground water conditions and flowpaths. Water table contour maps do not exist for Site 6b and the available data are too limited to prepare reliable maps. However, inferences for ground water flow can be made based on contour maps available at Sites 5 and Site 14, and on research conducted in BCV and elsewhere on the ORR in similar terrain and underlain by predominantly clastic rocks of the Conasauga Group. Results suggest that much of the shallow and intermediate ground water below Site 6b will follow hydraulic gradients and predominant strike parallel flow paths across the relatively short width of the footprint toward local discharge zones along the valleys of NT-5 and NT-6 immediately east and west of the footprint. Ground water flow along the southern part of the footprint in the vicinity of Cell 1 may also follow hydraulic gradients and fracture flow paths in regolith and bedrock that are directed across the northeast-southwest strike direction southward toward the low elevations and discharge zones along the floodplains of Bear Creek. At Site 6b, the water table will again be constrained by the lowest elevations along the existing drainage valleys directly adjacent to the site. The wetlands noted above along the NT valley floors indicate areas where ground water discharges to the surface. The locations of these wetlands directly east and west of the 6b footprint support the likelihood of strike parallel ground water drainage and discharge into the adjacent NT valleys (See site-specific wetland maps in Appendix E).

Landfill construction, capping, and diversion of runoff will reduce infiltration across the Site 6b footprint to a fraction of the former natural recharge to the upland area between NT-5 and NT-6. This will reduce water table elevations below the footprint that will merge laterally with the water table surrounding and outside of the footprint, dictated primarily by the remaining undisturbed elevations of NT-5 and NT-6 bordering the footprint. After landfill construction, the relatively broad area (roughly 16 acres) remaining and available for natural infiltration in undisturbed areas north of the Site 6b along Pine Ridge will continue to provide some recharge to the water table and to ground water that migrates southward into the upgradient areas below Cell 5. But much of that ground water flow is likely to naturally diverge around the northern part of the 6b footprint and be discharged along the low elevation upper reaches of NT-5 and NT-6.

Ecological/cultural resources. Two separate surveys to identify T&E species of vascular plants and fish were completed in 1998 for the EMWMF that included the Site 6b area (see Appendix E for details). Neither survey identified T&E species in the Site 6b area, although recommendations were made to preserve habitats and implement best management practices to protect the Tennessee Dace in downstream areas. ORR ecological surveys mapped a “natural area 28” across and adjacent to the Site 6b area (See Appendix E) that includes wetlands delineated east and west of the site. Wetlands on the east and west sides of Site 6b along the NT-5 and NT-6 tributaries were delineated by Rosensteel and Trettin (1993) that could be impacted by EMDF construction (See maps and details in Appendix E). Surveys to evaluate potential impacts to wetlands and other T&E species may be warranted at Site 6b if the site is selected for EMDF construction. Previous surveys in BCV have not identified any archeological or historical resources in or near Site 6b (See Appendix E for details).

Karst and seismicity. Karst conditions such as sinkholes, sinking streams, and resurgent springs have not been documented in BCV within the predominantly clastic sedimentary rock formations located below and surrounding Site 6b. Karst features are documented within the Maynardville outcrop belt south of Site 6b. The contact between the Nolichucky Shale and Maynardville Limestone is located 597 ft south of the southern waste limit boundary at Site 6b. Bear Creek and its floodplain areas are also located about the same distance south of the site. There is no evidence of active seismically capable faults in the vicinity of Site 6b or any of the other EMDF candidate sites in BCV.

Relationships to contaminated areas in EBCV. Soil and ground water contamination associated with the BCBG has been documented in areas immediately west of Site 6b. Ground water contaminant plume maps at the BCBG indicated low concentrations of alpha and volatile organic contaminants detected in cluster wells near the west and southwest margins of Site 6b. EMDF ground water detection and compliance monitoring that would be required along the downgradient margins of Site 6b have the potential to be complicated by some contaminants originating from the BCBG and the potential future commingling of ground water contamination from Site 6b. Complications might also occur in establishing statistically valid background levels for baseline ground water chemistry at Site 6b prior to initial disposal operations (based on at least four quarters of ground water sampling and analysis). Detailed analysis of the potential impacts from the BCBG on Site 6b would be warranted if the site were selected for EMDF construction, including evaluation of results from ground water sampling and analysis of active and inactive wells at and near Site 6b.

Site Characteristics – Site 7a

General site conditions. The approximately 59-acre slightly rectangular area of Site 7a (19-acre waste footprint area) is situated within an upland area located between the adjacent north-south trending valleys of NT-10 and NT-11. The Site 7a footprint is centered just south of the crest of the knoll or spur ridge that is underlain by the Dismal Gap/Maryville formation. The overall footprint area of Site 7a is situated further south of Pine Ridge, relative to the other proposed sites. The northern part of the footprint sits across a saddle between Pine Ridge and the Dismal Gap knoll. Slopes drop sharply along the east side of the footprint into the adjacent valley of a tributary designated as NT-10W that is parallel to and just west of NT-10. The eastern areas of the footprint would cover much of the valley formed by NT-10W and would warrant an underdrain system to ensure proper drainage of shallow ground water. Relatively steeper slopes also occur along the northwest corner of the site into the upper reaches of the NT-11 valley. Moderate slopes across most of the footprint are toward the west and south. An east-west trending ravine drains westward into NT-11 near the center of the footprint that also warrants an underdrain segment.

Recent satellite imagery shows that Site 7a and the surrounding area are entirely forested except for areas along the south side of the footprint between the Haul Road and Bear Creek Road, where the area has been cleared. The cleared area includes a recent soil borrow area south and southwest of the southern footprint margin, and two newly constructed wetland basins completed in 2015 for compensatory wetland mitigation. The existing haul road cuts across the lower part of the proposed footprint and would require rerouting (see Figure 6-4).

Previous investigations. Except for surface water, wetland, ecological, and cultural surveys that encompass all of BCV including the 7a area, almost no site characterization data exists for this site. Maps in the Y-12 subsurface database for BCV show a paucity of active/inactive wells at or near Site 7a. Isolated from the waste sites in EBCV, there are no neighboring site investigations in close proximity to 7a.

Surface water hydrology. Detailed site reconnaissance has not been conducted to assess the details of surface water hydrology at Site 7a. However, the available USGS base flow data suggest that stream flow along NT-10W and NT-11 directly adjacent to Site 7a, and the smaller sub-tributary stream channels draining the site is seasonally intermittent, and influenced by pulses of runoff associated with storm events. The USGS data indicate that base flow is continuous along the main stream channels of NT-10W and NT-11 during the winter/spring non-growing wet season. During the summer/fall growing season with warm and often dry conditions, base flow is intermittent and limited to pulsed flow associated with significant storm rainfall events. Base flow measurements made by the USGS indicate that dry season flows along the entire lengths of NT-10W and NT-11 are negligible (i.e. - <0.005 cfs) from the headwater spring/seep locations on Pine Ridge down to the junctions with Bear Creek (among the 13 dry season measurement stations surrounding Site 7a, only one indicated flow at the lowest measurable level of 0.01 cfs off the northwest corner of the site). Wet season base flows are relatively low along NT-10W and vary from 0.01 cfs (4.5 gpm) at a headwater location to a maximum rate 0.04 cfs (18 gpm) southeast of the site. Wet season base flows along NT-11 are slightly higher ranging from 0.01 cfs (4.5 gpm) at a headwater spring location to a rates of 0.14-0.16 cfs (63-72 gpm) southwest and downstream of Site 7a.

No springs or seeps were identified by the USGS within the waste footprint boundary at Site 7a, but four seeps were identified along marginal areas of the site. As noted above, the most significant surface water features at Site 7a include the portions of the NT-10W valley located along the east and northeast sides of the footprint, and the east-west trending ravine that cuts across the west-center of the site. A seep was identified by the USGS along the lower section of that ravine suggesting that localized shallow ground water discharge occurs there at least seasonally. The wetlands delineated at and near Site 7a encompass the majority of NT-10W along the entire eastern margins of the footprint and much of NT-11 along the west side of 7a. These wetland areas also represent zones of ground water discharge to surface water directly adjacent to Site 7a.

Continuous flow monitoring data are not available at Site 7a or anywhere along NT-10/10W or NT-11. The nearest BCV/ORR monitoring stations are located along Bear Creek at locations up and downstream of the Site 7a area. Flow along Bear Creek south of Site 7a is perennial.

Geology/hydrogeology. The detailed subsurface hydrogeological conditions at Site 7a are unknown based on the very limited amount of available site-specific characterization data (see Appendix E for a review of the limited available data and inactive wells in the area). Fundamental site characterization data will be required if Site 7a is selected for EMDF construction.

Because of the relatively undisturbed conditions at Site 7a, the general hydrogeological conditions will be similar to those found at Sites 5 and 14 (and other sites in BCV) which are located over similar terrain and along geologic strike with Site 7a. The conditions described above for Site 5 are applicable. The waste footprint at Site 7a is located further south than at the other proposed sites in BCV. It is roughly centered on and spans the entire outcrop width of the Dismal Gap/Maryville, and extends on the north from the Rogersville Shale across the Dismal Gap/Maryville to the lower third of the Nolichucky Shale. The only places within the footprint area where Recent alluvium appears likely in any significant extent are those valley floor areas along NT-10W along the eastern margin of the site. The typical profile of topsoil, silty/clayey soil residuum, saprolite, and fractured bedrock are likely across the undisturbed areas of the site.

The crest of the knoll below the north center of the footprint is upheld by the more erosionally resistant Dismal Gap/Maryville formation. Similar knolls exist at Site 5 and Site 14 underlain by the Dismal Gap/Maryville. The southern margin of the waste footprint is 593 ft from the contact between the Nolichucky Shale and the Maynardville Limestone where karst conditions begin. Initial landfill construction at Site 7a would include the removal of loose unstable topsoils, alluvium, and colluviums. The fractures and macro/micro pores within the remaining soils/saprolite and bedrock will provide the primary routes for ground water flow (and contaminant transport) below and downgradient of the 7a footprint.

Ground water conditions and flowpaths. No ground water data or water table contour maps are available for Site 7a, but based on similar conditions at Sites 5 and 14, it is inferred that shallow and intermediate ground water below Site 7a will follow hydraulic gradients and predominant strike parallel flow paths across the width of the footprint toward local discharge zones along the adjacent valleys of NT-10W and NT-11 immediately east and west of the footprint. Potentiometric surface contour maps for Sites 5 and 14 and other similar sites on the ORR indicate that horizontal hydraulic gradients tend to broadly mimic surface topography and that shallow to intermediate level ground water flows locally from high elevation recharge areas to low elevation discharge zones. The corresponding vadose zone is likely to be thickest below upland areas such as below the crest of the knoll at Site 7a [documented below the crest of a similar knoll at Site 5 in well cluster GW-976 (I)/GW-977(S)], and thin toward the NT valley floors where the water table is at or very close to the ground surface. The north-south orientation of NT-10W and NT-11 roughly perpendicular with the geologic strike results in water table gradients across most of the footprint area that trend in a direction parallel to subparallel with strike and enhance ground water drainage laterally into the NT valleys. Ground water flow along the southern part of the footprint in the vicinity of Cell 1 may also follow hydraulic gradients and fracture flow paths in regolith and bedrock that are directed across the northeast-southwest strike direction southward toward the low elevations and discharge zones along the floodplains of Bear Creek. As with each of the proposed sites, the water table will be constrained by the lowest elevations along the existing drainage valleys directly adjacent to the site. The wetlands noted above along the NT valley floors indicate areas where ground water discharges to the surface. The locations of these wetlands directly east and west of the 7a footprint also support the likelihood of strike parallel ground water drainage and discharge into the adjacent NT valleys (See site-specific wetland maps in Appendix E).

As described for Site 6b, the relatively broad area (roughly 26 acres) available for natural infiltration in undisturbed areas north of Site 7a along Pine Ridge will continue to provide some recharge to the water table and to ground water that migrates southward to the upgradient areas of the footprint (in the vicinity of Cell 4); but much of that ground water flow is likely to naturally diverge to the southwest around the northern part of the 7a footprint and be discharged along the low elevation upper reaches of NT-11. The remainder of this southward draining ground water from Pine Ridge would migrate toward the southeast into the headwater area of NT-10W and be captured and drained via the proposed underdrain system following the path of NT-10W. Without this underdrain network, natural ground water flow from Pine Ridge would be inhibited, increasing hydraulic heads, and resulting in an elevated water table below the northeast corner of the 7a footprint.

Ecological/cultural resources. Site-specific surveys to identify T&E species have not been completed at Site 7a. ORR ecological surveys mapped a "natural area 13" across a broad belt within BCV that includes the central areas of the 7b footprint (See Appendix E) and adjacent areas to the east and west. Three major wetland areas were delineated by Rosensteel and Trettin (1993) on the east and west sides of Site 7a along the central and upper reaches of NT-10/10W and NT-11 that would be partially impacted by EMDF construction (See maps and details in Appendix E). Surveys to evaluate potential impacts to wetlands and to identify T&E species would be warranted at Site 7a if the site is selected for construction.

As noted above, the two wetland basins recently constructed for compensatory wetland mitigation would be directly impacted and eliminated by the construction of buttress areas along the southeast margin of Site 7a. The destruction of these wetland mitigation areas would presumably require new areas to compensate for their loss. Surveys to identify archaeological and historical home sites and cemeteries across the ORR, indicate that the Douglas Chapel Cemetery is located near the northeast corner of the Site 7a footprint near a knoll located between NT-10W and NT-10. The cemetery and a road leading to it are illustrated on several USGS topographical maps covering BCV. The location and condition of the cemetery has not been verified but would warrant an assessment if Site 7a is considered for EMDF disposal. Two historical home site/structures were also identified near Site 7a (designated as 850A and 849A). The 850A site originally identified on the southeast margin of Site 7a could not be relocated during a reassessment completed in 1994, but foundation materials were identified at the 849A site to the southwest of Site 7a. Maps showing the locations of these two structures suggest that the 849A site would not be impacted by construction at Site 7a. Neither of the locations has been verified by recent field reconnaissance. (See Appendix E for details summarizing the available assessments of cultural resources in BCV).

Karst and seismicity. Karst conditions such as sinkholes, sinking streams, and resurgent springs have not been documented in BCV within the predominantly clastic sedimentary rock formations located below and surrounding Site 7a. Karst features are documented within the Maynardville outcrop belt south of Site 7a. The contact between the Nolichucky Shale and Maynardville Limestone is located 593 ft south of the southern waste limit boundary at Site 7a, and along with Site 6b is the closest to the contact among the candidate sites. Bear Creek and its floodplain areas south of Site 7a are located roughly 200-300ft further south of the contact. There is no evidence of active seismically capable faults in the vicinity of Site 6b or any of the other EMDF candidate sites in BCV.

Relationships to contaminated areas in EBCV. Site 7a is located well southwest of and outside the Zone 3 area that includes historical waste sites in EBCV. Figure E-2 in Appendix E shows that the nearest ground water contaminant plumes are located around 2,500 ft southeast of Site 7a along the path of Bear Creek and the Maynardville Limestone well upstream of 7a. The figure does indicate a zone along Bear Creek and the Maynardville directly south of Site 7a denoted as an "area of periodic plume extension" that extends all the way to near SR 95.

6.2.2 EMDF Conceptual Designs

An EMDF feasibility-level conceptual design is developed for each site option, and is used to provide a comparative analysis for the On-site Disposal Alternative siting options. If one of these site options in the On-site Disposal Alternative is the selected remedy in the ROD, the final design for the selected site may differ from the conceptual design and would require approval by regulatory agencies. The designs are based primarily on the EMWMF design as described in the Remedial Design Report (RDR) for the EMWMF (DOE 2001a), which has been approved by EPA and TDEC, but draw on design elements of other CERCLA disposal facilities as well (e.g. those at the Fernald and Portsmouth DOE sites). The conceptual designs comply with ARARs and to-be-considered guidance identified for disposal of RCRA, TSCA, LLW, and mixed waste.. The subsequent sections describe common and site-specific features of the landfill and support facilities, as well as process modifications that could potentially improve the feasibility-level designs.

The primary design elements of the EMDF are described in the following order:

- Remedial design
- Early actions
- Site development
- Disposal facility
- Support facilities
- Conceptual design approach
- Process modifications

The convenient experience and proximity of the operating EMWMF disposal cells allows for a unique opportunity to examine the elements that worked or could use improvement in terms of the design, construction, and operations of a new CERCLA landfill in BCV. The major lessons learned are briefly mentioned where applicable in each of the subsections that follow, and are then summarized in Section 6.2.10.

6.2.2.1 Remedial Design

Remedial design is a common element (regardless of the location selected for an on-site facility) and would include preparation of the Remedial Design Work Plan, RDR and Remedial Action Work Plan (RAWP), operating plans, WAC Attainment (Compliance) Plan, Environmental Monitoring Plan, and application for requisite permits (if any). A fast-track design process may be used to expedite construction, as was done for the EMWMF. The fast-track design process involves sequentially designing project elements and proceeding with their implementation while other elements are still being planned and designed. Use of this process would require cooperative design/approval effort by project integration, design, construction, operations, and oversight contractors; DOE; and regulators. For the Dual Site Option, remedial design is completed for each site.

A major lesson learned from the EMWMF RDR preparation was regarding the action leakage rate (ALR). This value is an estimate of the maximum allowable leachate discharge from the leak detection layer of the liner system. This allowable leachate discharge limit serves as a threshold value to indicate when rates of leachate collected might suggest that there is an unacceptable accumulation of leachate within the secondary collection layer (leak detection layer) of the liner system. It is expected that there will always be a certain amount of secondary leachate generated due to the physical properties of geomembranes and imperfections of installation of landfill components. The ALR sets the value at which action must be taken to ensure that the landfill liner system is functioning properly. Response actions triggered by an ALR exceedance start with a written notification to the appropriate regulatory agencies, followed by an assessment of the conditions, additional discharge rate reporting, and remedial actions if deemed necessary. The method employed to calculate the ALR per cell for EMWMF used generic EPA values which resulted in an ALR estimate that was too low. This resulted in extra paper work and effort for the EMWMF management staff to report "exceedances" that are actually within normal ranges for landfills of this nature.

Another lesson learned from EMWMF operations is the need to improve project sequencing to ensure availability of contaminated soil for filling debris void spaces and for general waste placement. The EMWMF design assumed that contaminated soil remediation projects would be sequenced to ensure full utilization of waste soil to replace clean fill during placement of debris waste. However, sequencing has not been executed efficiently to date and unanticipated quantities of clean fill have been necessary, which has added cost to landfill operations. Planning future project sequencing must be improved in order to minimize the need for clean fill and conserve landfill capacity. Current ORR Baseline planning and scheduling has been organized to alternate D&D projects with RA projects as much as possible in order to maximize landfill capacity by minimizing the need for clean soil to be used to fill void spaces around debris. (D&D projects tend to produce debris wastes such as building rubble, piping, and equipment and the RA projects tend to produce soil wastes.)

Another related lesson regarding the use of soil fill at EMWMF stems from the initiation of the annual CARAR. Not only was it initially thought that no clean soil fill would be needed for EMWMF, the general ratio of soil waste required for debris waste was underestimated at 1:1 based on literature values reported by Benson, et. al. (2008). In 2004 the first CARAR was published to help apply historical data and set calculated density factors and ratios to improve waste disposal tracking and forecasting of future disposal volume needs (DOE 2004). Current forecasts for EMDF utilize a soil-to-debris ratio (for general demolition debris) of 2.26:1 based on the information established by the CARARs (now reported as part of the EMWMF annual PCCR). This should be factored into planning and cost estimating, because soil-like waste will not always be available for use as void space fill within the landfill.

6.2.2.2 Early Actions

It is necessary to perform certain remedial design activities early in the remedial design process. These activities are referred to as early actions, are site-specific, and include: a baseline site topographic survey, wetlands delineation, field surveys to identify and map wetlands and T&E species, hydrogeological and geotechnical investigations, construction and upgrade of ground water monitoring wells, and baseline ground water monitoring. Early actions that have already been completed are noted within the following descriptions. Other early actions would not be completed until and unless a site were selected, and are also noted below.

Baseline Site Topographic Survey: The EMDF site topography and surface features would be mapped using civil land surveying techniques. This information is needed to perform hydrogeological/ geotechnical investigations; establish locations, elevations, and depths for new ground water monitoring wells; map wetlands (in concert with a qualified wetlands delineator); and conduct landfill site design. Limited topographic survey information has been collected as part of the Phase I Site Characterization efforts for the EBCV Site Option in order to establish ground elevations of newly installed monitoring wells. A full-scale site survey would be performed as part of the Phase II Site Characterization. The WBCV Site Option and Dual Site Option (6b/7a) would require site topographic surveys for each site as well, should either of those options be selected.

Wetlands Delineation: A field wetlands delineation survey for the EBCV Site Option has been conducted by a qualified wetlands specialist to determine the areal extent of wetlands along streams and other low-lying portions of the landfill site and other areas, such as existing roadways where construction would take place. Wetland boundaries have been mapped using civil land surveying techniques. Results of the wetlands survey are included in Appendix E attachments. Wetland extents for other sites (WBCV and Sites 6b/7a) are taken from comprehensive surveys across BCV reported in 1993 by Rosensteel and Trettin; however, if either of these options were to be selected additional surveys would be required.

Potential wetland impacts during early actions (e.g., hydrogeological and geotechnical investigations), construction, operations, and/or closure of the landfill would be evaluated for any site. Wetland protection considerations will be incorporated into planning and implementation, including mitigation of adverse impacts.

Field Surveys for Threatened and Endangered Species: Field surveys have been performed by qualified biologists to identify the presence of T&E species within areas of potential site disturbance at the EBCV site. These surveys have been performed as part of the Phase I characterization; results are summarized in Appendix E attachments. Information on potential T&E species for other sites (WBCV and Sites 6b/7a) are taken from general ORR reports; however, if either of these options were to be selected additional surveys would be required.

Hydrogeological and Geotechnical Investigations: The EMDF footprint and surrounding land would be investigated in order to determine surface hydrological, hydrogeological, and geotechnical conditions for the selected option. No previous hydrogeological or geotechnical explorations are known to have been performed within the EBCV footprint (that is, none prior to the Phase I characterization, see next section) or the Dual Site Option (6b/7a) footprints. Some intensive investigations were completed in the WBCV site (Golder 1988 a/b/c, 1999 a/b/c). Existing geotechnical information from previously drilled borings would be used, where possible, and additional geotechnical borings would be drilled, as needed. The investigations for all sites would evaluate areas selected for landfill support facilities, roadways, and on-site spoil/borrow areas. Off-site borrow areas may also be explored and characterized. Samples of soil, surface water, and ground water would be collected and analyzed to establish physical and chemical baseline conditions. This data/information would be used to develop the facility structural design and the ground water and surface water monitoring program. The hydrogeological and geotechnical investigations may be performed concurrently or in multiple phases.

Construct New Ground Water Monitoring Wells and Surface Water Weirs: Five ground water well pairs (deep and shallow) and three surface water weirs were installed in the proposed EBCV footprint as part of Phase I characterization to determine baseline ground water and surface water hydrogeological conditions. This data supports PreWAC modeling efforts presented in this document for the EBCV site. Existing ground water monitoring wells down gradient of the EMDF site would be used, where possible, and additional ground water monitoring wells would be installed as needed for the EBCV site, if selected. Boring and well logs, geophysical data, hydraulic conductivity data, and ground water flow data would be collected. It is estimated that approximately 19 new ground water monitoring wells and six surface water monitoring weirs would be required. However, these numbers of ground water monitoring wells and surface water monitoring weirs are estimates that have not been thoroughly evaluate within the data quality objectives (DQO) process, but have been prepared solely for costing purposes. A formal DQO process will be followed to identify the objectives for pre-design investigation, and a sampling and analysis plan will be prepared for approval and implementation. Similar estimates are used for the WBCV site, as that site has some existing data. However, the Dual Site Option (6b/7a) has a need for more extensive analysis, as two sites are involved and no data are available for Site 7a.

Baseline Ground Water and Surface Water Monitoring: As part of site characterization, ground water levels and surface water and ground water quality parameters (for example, specific conductivity, pH, temperature, dissolved oxygen and oxidation-reduction potential) would be monitored continuously for one year, if feasible, and contaminants [radionuclides, metals, volatile organic compounds, and polychlorinated biphenyls (PCBs)] would be monitored quarterly for one year, to establish a baseline for any of the possible sites. Ground water flow will be determined by down-hole measurements and surface water flow rates would be monitored by flume measurements for at least one year. These activities would be performed before construction of the landfill to establish pre-disposal baseline conditions, support design, and support WAC finalization. Phase I characterization of the EBCV site has provided some of this information (e.g., surface flow rates and baseline water table measurements for one year). The WBCV site also had site characterization completed for a period of time (water table measurements in particular) to provide information for a "geohydrologic site characterization and ground water flow computer model" for a proposed low level waste disposal facility. This investigation was reported by Golder and Associates in a series of reports from 1988-1989 (Golder 1988a/b/c/d, and 1989a/b/c) and is discussed in depth in Chapter 6 of Appendix E.

Four major EMWMF lessons learned are applicable to Early Actions and emphasize the importance of performing thorough site characterization of the project footprint and selected borrow area(s). Items identified for improvement include the following:

- Overestimation of the availability of suitable low permeability clay from the ORR borrow site
- The quality of the background constituent characterization, especially in terms of statistical thoroughness and detection limits
- Underestimation of the amount of unusable spoils that would require hauling off-site
- Underestimation of the seasonal high ground water table

The complications that arose from these factors significantly slowed construction and increased construction and operating costs of the landfill. Fernald had similar landfill construction issues with unsuitable low-permeability clay from the borrow area selected for the project. Poor background characterization has caused issues in the course of routine environmental monitoring during operations at EMWMF.

6.2.2.3 Site Development

The following development actions (common for all sites, but for the Dual Site Option would need to be completed for each site) would prepare the site for construction of the EMDF:

- Installing initial sediment and erosion controls for site development activities. Initial erosion and sediment controls (e.g., silt fence, check dams, etc.) and storm water control structures (e.g., culverts) would be among the first site development protective measures installed. Standard erosion and sediment controls would be installed per best management practices (BMPs) as construction proceeds.
- Clearing and grubbing of the site.
- Constructing/upgrading access roads to the landfill site.
- Extending power lines, water lines, phone lines, and other utilities to the landfill site from existing infrastructure (see Section 6.2.2.5).
- Preparing additional parking, laydown, and staging areas.
- Leveling and preparing areas for construction of leachate management support systems.
- Preparing on-site spoil/borrow areas for future construction activities.
  - A temporary spoils area would be prepared near the landfill for storage of materials excavated during clearing and grading that would be reused. Materials stored could include topsoil for establishing the vegetative cover on the landfill cap or other areas and excavated

soil that meets the specifications for structural fill used to build roadways or the clean-fill dike. The area could also be used to store materials such as soil used for daily cover or filling of void spaces during operation of the landfill. Since the landfill would be constructed in phases, temporary spoils and staging areas may be established within the areas of future landfill cells.

  - A permanent spoils area would be established for disposal of excess or unsuitable cut materials (excavated to achieve design grade) that are not useable as fill during construction, expansion, operation, or closure. Excess fill would be placed and graded, and the area would be restored for appropriate future uses after landfill closure.

- Creating/expanding wetlands, as required, to mitigate impacts of proposed facility construction.
- Relocating the Y-12 Atomic Energy Act Section 229 Security Boundary, if required, and installing new guard stations and fencing (EBCV site only, assumed to occur for estimating purposes).
- Upgrading the existing truck weigh scale and/or installing a new truck weigh scale.
- Setting up construction trailers.
- For the WBCV Site and Site 7a of the Dual Option, new support structures and site preparations for those structures (personnel trailers and facilities, additional weigh scales, additional support facilities – tankage for leachate, parking areas) would be needed. Site 5 and Site 6b are assumed to utilize support structures available at EMWMF, but costs have been added to upgrade or replace most infrastructure to cover the operating life of the EMDF. Site preparations are significant additions the Sites WBCV and 7a.
- For the Dual Site Option, each Site (6b/7a) would require, in addition to the above, re-routing of the Haul Road, which is included in each respective cost estimate.

6.2.2.4 Disposal Facility

Key elements of the disposal facility, regardless of the site selected, would include a clean-fill dike to laterally contain the waste, a multilayer base liner system with a double leachate collection/detection system to isolate the waste from ground water and the geologic buffer, a contouring layer installed over the waste to provide an even and stable base for installation of the cover system, and a final multilayer cover to reduce infiltration and isolate the waste from human and environmental receptors. Estimates developed for the various sites are scaled to the materials/construction/labor required for the individual sites. The engineered disposal facility design basis incorporates the following:

- Attainment of RCRA, TSCA, and LLW regulatory design criteria (see Table G-4 of Appendix G).
- Effective protection of human health and the environment through waste isolation as defined by the remedial action objectives (see Chapter 4) and by DOE O 435.1, DOE O 458.1, and associated manuals and guidance.
- Protection against animal and plant intrusion, and minimization of the potential for human intrusion per DOE O 435.1 requirements.
- Collection, treatment, and/or monitored discharge of landfill leachate.
- Reduction of potential for incremental and total settlement, and slope failure under static and seismic conditions, through proper design and waste placement techniques.

Design components of an on-site disposal facility are described in the following paragraphs. Where site-specific components are needed, a discussion of those modifications between conceptual designs is provided. As mentioned above, individual site estimates have taken into account material differences (e.g., cut and fill). Cross-sections and details of the conceptual design(s) for the EMDF are provided in Figures 6-6 through 6-15.

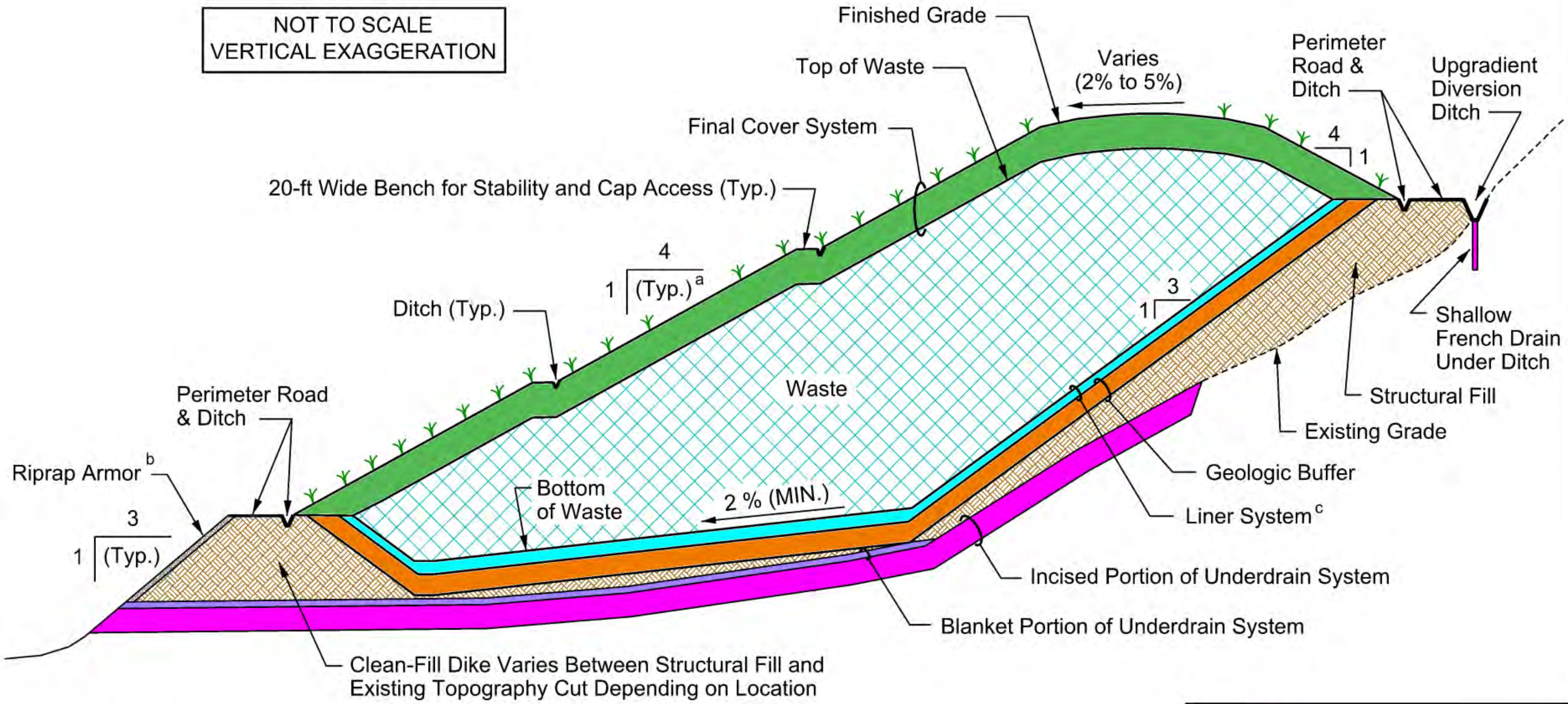
6.2.2.4.1 Clean-fill Dike

A clean-fill dike would be constructed around the perimeter of the landfill in areas where there is insufficient excavation into the ground surface to provide lateral containment and stability to the waste (see Figure 6-6). The clean-fill dike would also protect against erosion, biointrusion, and inadvertent intrusion by humans. The clean-fill dike would be constructed of structural fill. (For this application, structural fill would consist of suitable earthen material used to create a strong, stable base for the landfill and to construct portions of the clean-fill dike. Native soil excavated from the site may be deemed suitable for use as structural fill if it is free from large rocks and exhibits the appropriate compressibility and shear strength.) The inner slope of the dike would be covered by the liner system and possibly the geologic buffer. The top of the dike would anchor the liner components, tie into the cover system, and provide for drainage ditches and a perimeter access road. The outer slope would be armored with an 18 in. thick layer of durable rock riprap, to protect against erosion. It is anticipated the clean-fill dike would have a typical grade of 33% or lower (3H:1V or flatter), as will be determined by slope stability and erosion analyses in the final design phase. In order to maximize the waste disposal capacity of the landfill, the conceptual design shows the outer slopes of the clean-fill dike steepened to 2:1 in some areas to avoid encroachment on adjacent streams and wetlands. Side slopes steeper than 3:1 would include a 20 ft wide rock buttress for added stability and erosion resistance (see Figure 6-7). The viability of steepening the side slopes of the clean-fill dike to 2:1 would be further evaluated as detailed design progresses. Final design slopes for the clean-fill dike and details for rock buttressing would depend on the results of slope stability and erosion analyses.

6.2.2.4.2 Upgradient Diversion Ditch with Shallow French Drain

A geomembrane-lined drainage ditch with underlying shallow French drain would be constructed along the upper (i.e., northern) side of the landfill at all sites to intercept and divert upgradient storm water and shallow stormflow zone ground water away from the landfill (see Figure 6-8). All sites are located abutting slopes of Pine Ridge, thus requiring this capture and diversion of runon storm flow. The ditch and French drain network is a passive system requiring little maintenance.

The geomembrane liner and underlying compacted clay layer in the drainage ditch would prevent surface water infiltration and recharge of ground water along the ditchline. The drainage ditch would be armored with durable rock riprap to prevent erosion. It is anticipated the French drain would extend about 12 ft below the ground surface and would be comprised of durable and insoluble siliceous gravel wrapped with a geotextile filter fabric. The French drain would collect and divert the uncontaminated ground water primarily from the shallow stormflow zone to surface discharge outlets along the down gradient sides of the landfill. The French drain trench portion of the drainage feature will be designed in terms of flow capacity and material of construction (rock material and size), such that some acceptable level of clogging could occur without adversely affecting the overall function of the system. Placement of the drainage ditch above the trench with larger riprap along the ditch surface also provides long-term protection from clogging with minimal upkeep needed, by armoring the ditch to prevent erosion and maintaining the integrity of the underlying layers. Clogging of these systems can occur via three mechanisms: (1) chemical; (2) physical (i.e., particulate); and/or (3) biological.



[a] 4:1 side slopes would likely be the maximum allowable cap side slopes. Stability analyses will be performed to determine the final cap side slopes necessary for long-term performance of the landfill.

[b] An 18" thick layer of riprap armor would be used on 3:1 perimeter side slopes. 2:1 side slopes would receive a 20-ft wide layer of riprap buttresssing.

[c] Includes leachate collection & removal system and leak detection and removal system.

Pro2Serve

TYPICAL CROSS-SECTION
OF EMDF

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Figure 6-6. Typical Cross-section of EMDF

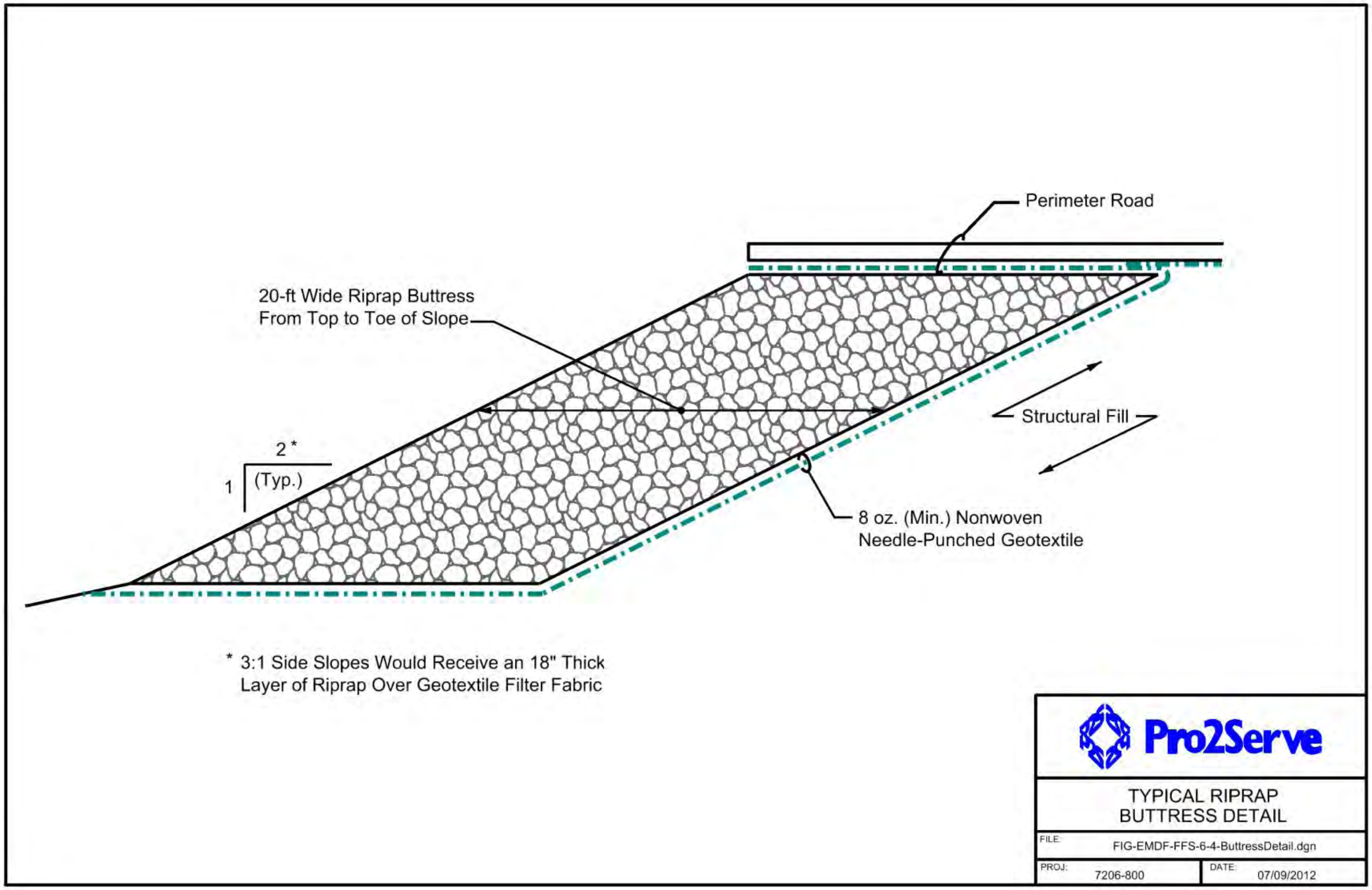

Figure 6-7. Typical Riprap Buttress Detail

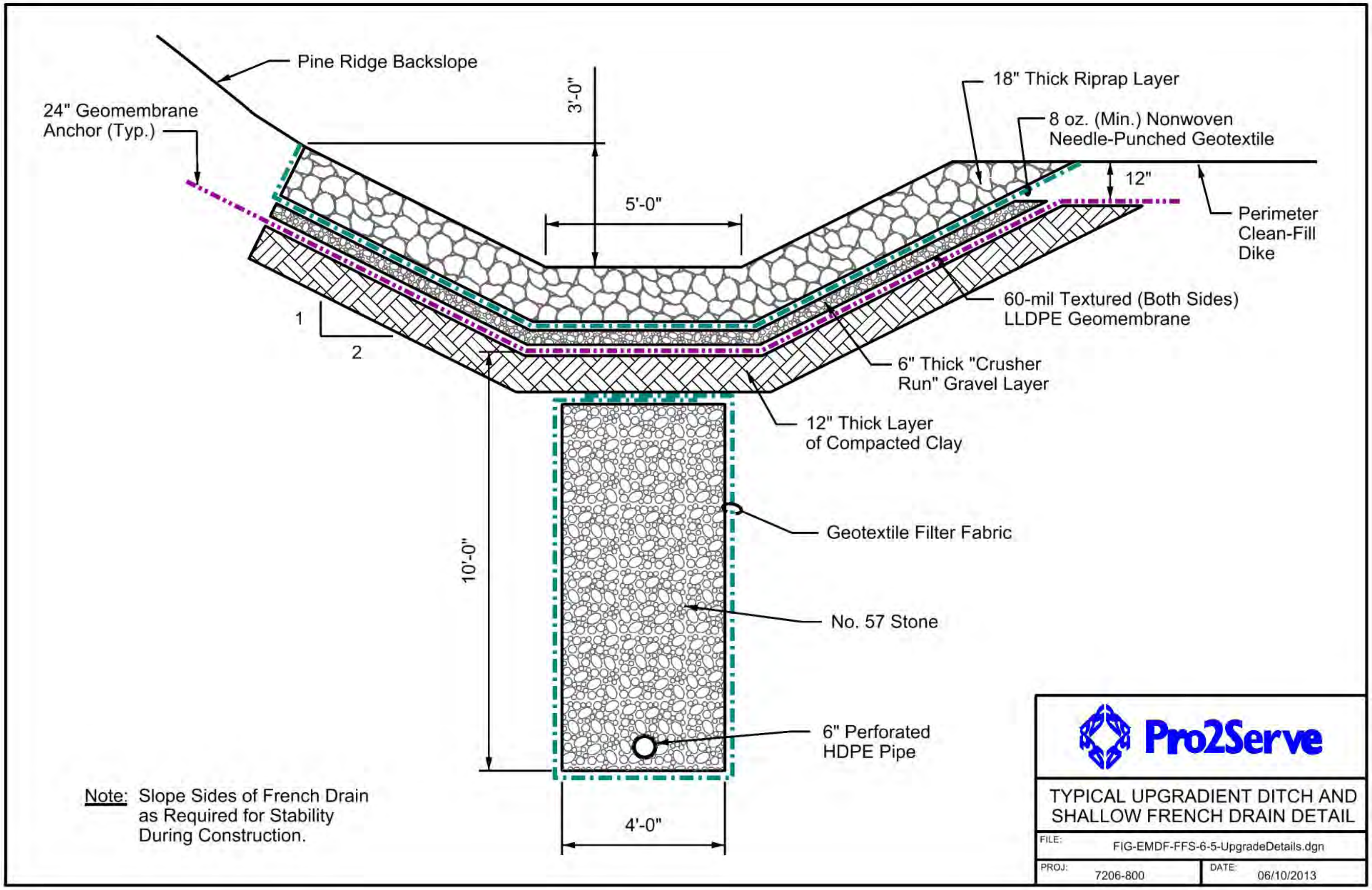

Figure 6-8. Typical Upgradient Ditch and Shallow French Drain Detail

Chemical clogging can result from dissolution/precipitation of stone containing high calcium carbonate combined with water alkalinity. Conditions where a low pH would allow dissolution, combined with conditions further downstream where pH increases would cause precipitation and result in clogging. Avoidance of this type of clogging is accomplished by: (1) specifying use of soils and gravels with low dissolvable calcium carbonate content (e.g., less than 5% based on ASTM D 3042 with a pH of 4); (2) specifying use of stone with a high permeability; and (3) performing hydraulic capacity calculations for short and long-term conditions. For the long-term conditions, appropriate reduction factors are applied to the permeability of stone, due to the potential for chemical clogging (and other factors). Calculations are carried out to ensure the long-term capacity exceeds the required capacity (i.e., has an adequate factor of safety).

Chemical clogging can also result from precipitation of iron. Design considerations would include (1) use of hard rock that is resistant to weathering and is relatively free of fines; (2) a graded filtration system (design methods are well established); (3) size perforations in drain pipes so that surrounding stone will not enter the pipe; and (4) as with above, hydraulic capacity calculations are carried out to address short and long-term conditions.

Particulate clogging can occur if stone contains a high percentage of fines or breaks down (i.e., weathers easily), or if filter is not adequate and allows fines to migrate into the stone and pipe. Maintenance of the drainage system will ensure this is not an issue in the short-term. Long-term particulate clogging will be guarded against through the following: (1) use of rock that is resistant to weathering and relatively free of fines; (2) use of a graded filtration system; and (3) hydraulic capacity calculations to address sizing of drainage features and to provide assurance that pathways will maintain a clear channel in the long-term.

Biological clogging is the result of microorganism buildup. However, this is not likely to be a concern due to a lack of conditions required for that growth (e.g., food). The depth of the French drain will guard against root growth in that portion of the drainage system.

This diversion ditch/French drain would help divert a considerable volume of water that moves on and just below the ground surface in the upper few feet of soil during storm events, to minimize underflow towards the liner system, and reduce recharge to the ground water table in the vicinity of the landfill. For example, diversion features at the EBCV Site will reroute the storm water currently flowing into the central and eastern branches of NT-3 into both the existing western branch of NT-3 (around the northwest side of the landfill) and NT-2 to the northeast of the landfill. Final cap systems and underdrain systems will further limit the contact of water with waste. For all sites, a holistic water management approach is used to divert and reroute runon using upgradient diversion systems, shed direct precipitation over the waste using landfill cover systems, and collect and divert shallow ground water using underdrain systems.ground water

6.2.2.4.3 Liner System

A multi-layer liner system will be installed to prevent leachate from migrating out of the disposal unit and impacting ground water. The liner system would be comprised of a double liner system with two leachate collection/detection and removal systems. In accordance with RCRA requirements, the top (primary) liner would be *". . . constructed of materials (e.g., a geomembrane) to prevent the migration of hazardous constituents into such liner during the active life and post-closure care period."* The lower (secondary) component of the composite bottom liner would be designed and constructed of materials to minimize the migration of hazardous constituents if a breach in the primary liner component were to occur. As described below, this system will meet TSCA leachate collection requirements in 40 CFR 761.75(b)(7). The liner system would be comprised of multiple layers of synthetic and natural materials that would be compatible with the waste and resistant to degradation by chemical constituents expected to be present in the leachate. For a discussion of the longevity of this system see Section 6.2.2.4.8. The layers of the liner system are depicted in Figures 6-9 and 6-10. The approximately 5 ft thick (approximately 4 ft thick on side slopes) liner system would be comprised of the following components from the bottom of waste downward:

- Protective Material Layer – typically a 12 in. thick (minimum) layer of native soil capable of supporting truck and operating equipment traffic during initial waste placement operations. The primary purpose of this layer is to protect the underlying components of the liner system from damage during waste placement during the operational life of the landfill. The thickness and composition of this layer may be variable and must consider the physical nature of the waste to be placed immediately above it, waste placement procedures, and water management operations within the disposal cell. For instance, a thicker and harder protective soil layer would be required for bulky structural steel debris than for soil-like waste materials.

  The design for EMWMF stipulated use of a protective soil layer with a hydraulic conductivity greater than the waste, but less than the leachate collection drainage layer so that during landfill operations runoff from the waste and unused portions of the disposal cell would pond temporarily above the protective soil layer. This liquid, referred to as contact water, was directed to the low area of the landfill cell where waste had not yet been placed. Temporary berms were constructed within the landfill cell to separate the waste from the contact water. This design feature allowed contact water to be collected and managed separately from the fluid collected within the leachate collection and removal system (LCRS), because it was anticipated that the contact water would be contaminated mostly with sediments from the protective soil itself and not from the waste. Actual operations of EMWMF have shown the difficulty of inhibiting the contact of storm water with the waste, and, therefore, the contact water collected in the cells has had to be managed as potentially contaminated liquid until it could be tested and deemed suitable for discharge. In most cases the contact water has met the facility discharge requirements, but in some instances the contact water has required shipment to the Process Waste Treatment Complex (PWTC) at ORNL for treatment prior to release.

  The EMDF conceptual design assumes a free-draining granular material as the protective layer within cell low areas, essentially creating windows, so that runoff collected there could be more easily managed within the leachate collection system. The free-draining granular material would be the same type of material used in the leachate collection drainage layer – a hard, durable, inert (non-limestone) material having a hydraulic conductivity of approximately 1×10^{-2} cm per second. The majority of the protective layer within the cell would be a native soil material. Continuing to use a native soil material as the protective layer for the majority of the liner helps to balance cost (native soil material is less expensive than inert granular material) and helps to reduce the amount of water collected in the leachate system (soil material provides substantial temporary storage and evaporation for precipitation that falls within the cells).

- LCRS – in order to enhance slope stability and constructability, design components of the LCRS would be somewhat different on the floor of the landfill than on the side slopes.

  . <u>Floor of Landfill</u>

  - Geotextile Separator Layer – nonwoven, needle-punched geotextile having a nominal mass per unit area of at least 8 oz per yd^2, and used to separate the protective soil layer and leachate collection drainage stone. The purpose of geotextile as separator layers is to provide a filter that restricts finer particles of a material on one side of the textile from traveling through to the other side in order to reduce the potential for clogging.

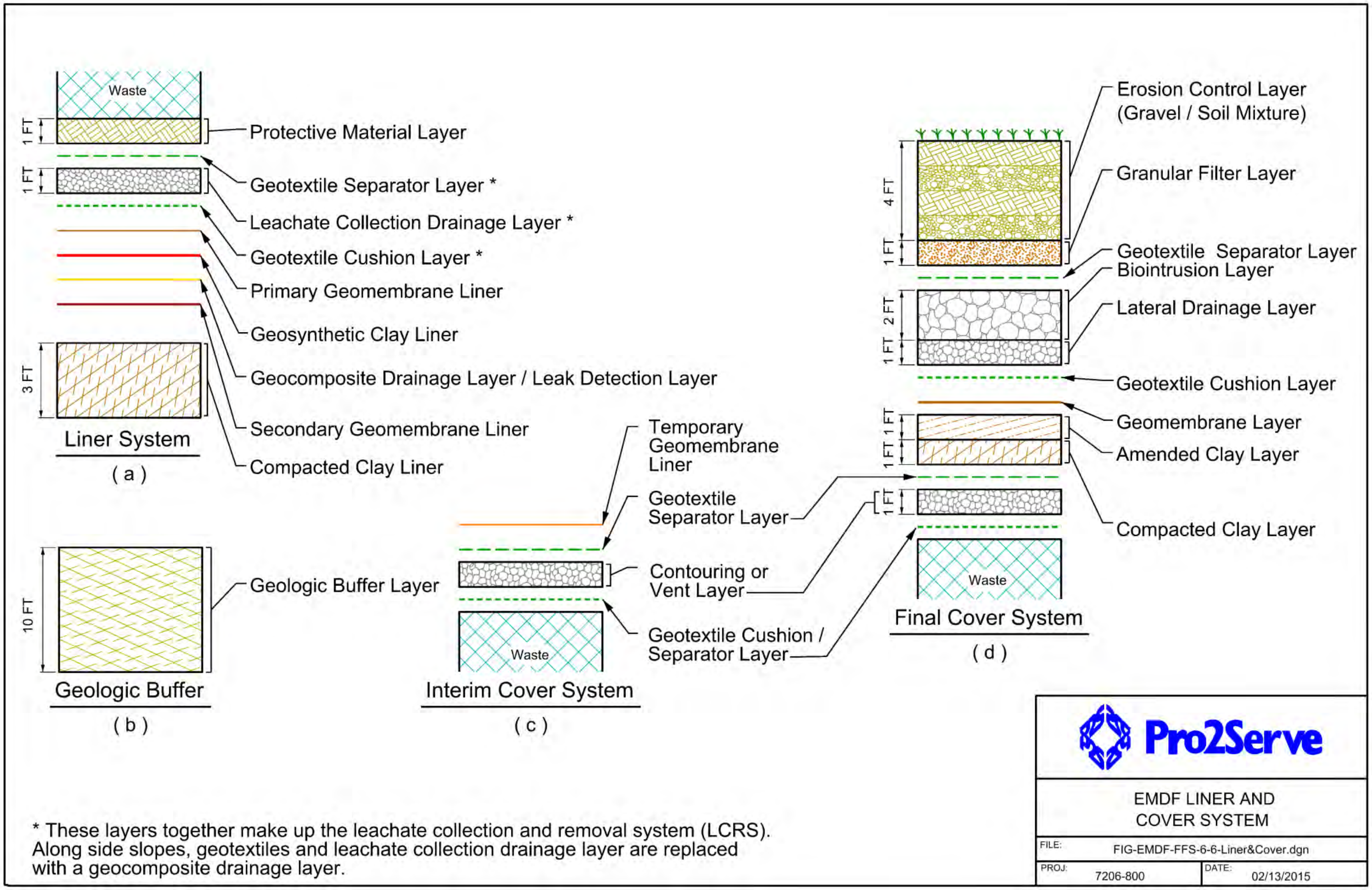

Figure 6-9. EMDF Liner and Cover Layers

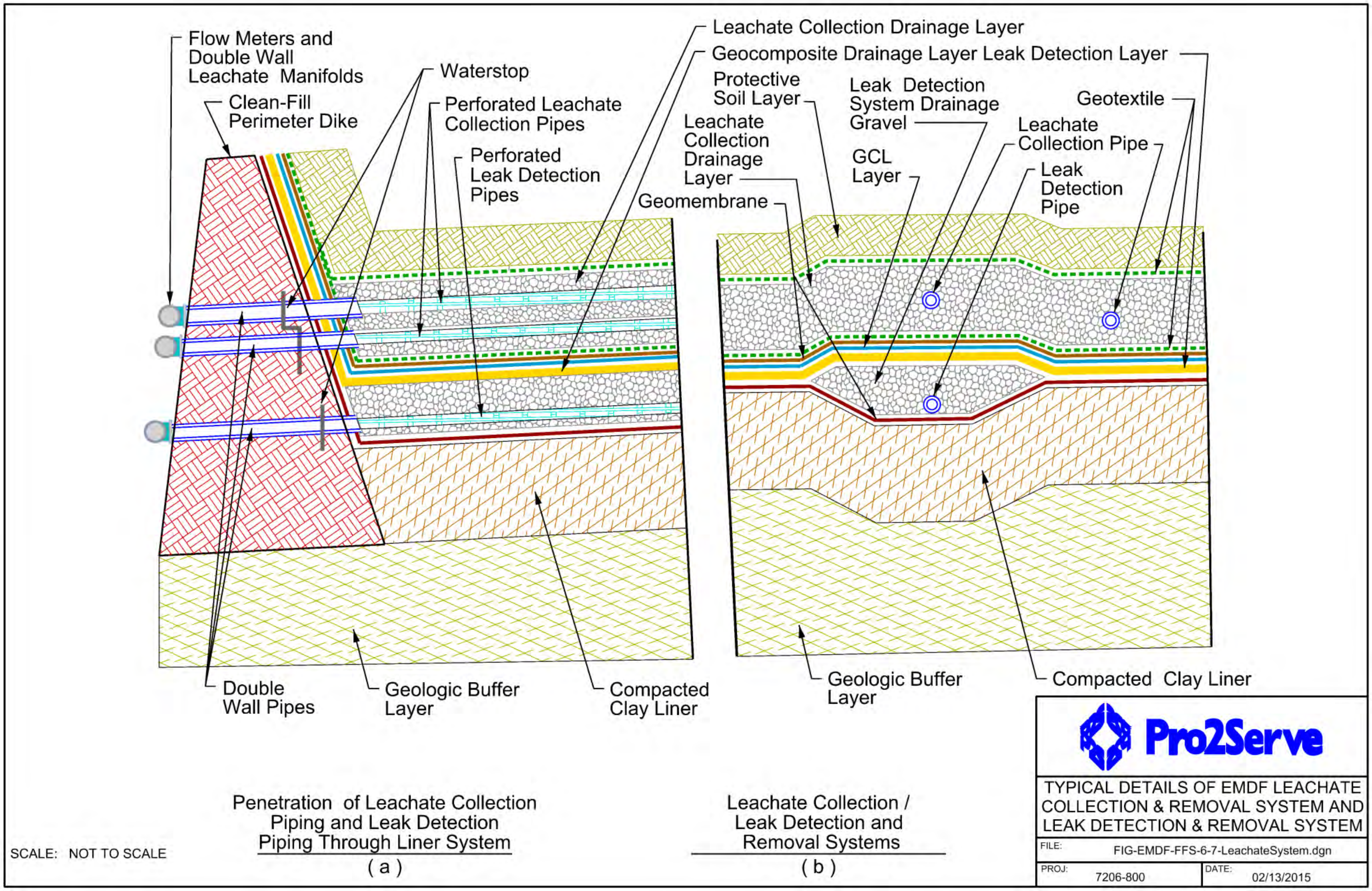

Figure 6-10. Typical Details of EMDF Leachate Collection and Removal System and Leak Detection and Removal System

- Leachate Collection Drainage Layer – a 12 in. thick (minimum) layer of hard, durable, inert (siliceous) granular material, preferably rounded to subrounded, and having a hydraulic conductivity greater than or equal to 1×10^{-2} cm per second. Perforated high-density polyethylene (HDPE) pipe (i.e., leachate collection piping) would be installed in this layer to collect and direct the leachate to manholes and lift stations. As was done for EMWMF (DOE 2001a), redundant collection piping would be installed at slightly higher levels than the primary collection piping to provide a secondary leachate collection route should the primary collection piping become blocked with sediment. This layer would serve as the primary leachate collection and removal layer.
- Geotextile Cushion Layer – nonwoven, needle-punched geotextile having a nominal mass per unit area of at least 16 oz per yd^2, used as a cushion over the underlying geomembrane. The purpose of geotextiles as cushions layers is to provide protection of materials such as geomembranes by acting as a cushion to absorb impacts and potential sharp edges of neighboring materials.

<u>Side Slopes</u>

- Geocomposite drainage layer, consisting of an HDPE geonet core with nonwoven, needle-punched geotextiles thermally bonded to both sides. This layer would slope to drain to the leachate collection drainage layer.

- Primary Geomembrane Liner – a 60 mil thick HDPE geomembrane, textured on both sides to enhance sliding resistance. This layer would retard leachate migration out of the landfill and direct leachate into the primary leachate collection layer.
- Geosynthetic Clay Liner (GCL) – geocomposite layer consisting of sodium bentonite encapsulated between woven and non-woven geotextiles, which are needle-punched together to provide internal reinforcement and deter the shifting of the bentonite layer. This layer would be selected to achieve a saturated hydraulic conductivity less than or equal to 1×10^{-9} cm per second. The purpose of this layer would be to help hydraulically isolate the leachate collection drainage layer from the leak detection drainage layer. This is a feature that was not part of the EMWMF design. A GCL layer has been added beneath the geomembrane layer between the leachate collection and leak detection layers for the EMDF conceptual design to decrease leakage and create a composite primary liner. The use of a GCL layer between the leachate collection and leak detection drainage layers is consistent with the liner system that was used for Fernald, what is currently proposed for Portsmouth, and what is set forth in DOE guidance (SRNL 2014). Use of a GCL layer between the leachate collection layer and leak detection layer will aid in reducing the amount of fluid collected in the leak detection layer by serving to plug in holes that may be present or develop over time in the primary geomembrane liner.
- Leak Detection and Removal System (LDRS) – geocomposite drainage layer consisting of an HDPE geonet core with nonwoven, needle-punched geotextiles thermally bonded to both sides would serve as the leak detection layer. The geocomposite drainage layer would be selected to achieve a long-term design transmissivity greater than or equal to that of a 1 ft thick layer of granular material with saturated hydraulic conductivity of 1×10^{-2} cm per second. The geocomposite drainage layer would be sloped to drain to perforated HDPE pipe (i.e., leak detection piping). This layer would be used to detect and remove any leachate that may leak through the primary geomembrane liner. Allowable leachate collection rates for this layer would be calculated based on site specific data in order to ensure that primary liner layers are functioning as intended.

- Secondary Geomembrane Liner – a 60 mil thick HDPE geomembrane, textured on both sides to enhance sliding resistance. This layer would provide secondary protection against leachate migrating out of the landfill and helps contain leachate within the leak detection layer.
- Compacted Clay Liner – 3 ft thick (minimum) layer of unamended, native clay soil or bentonite-amended soil compacted to produce an in-place hydraulic conductivity less than or equal to 1×10^{-7} cm per second. This layer would further reduce the potential for leachate migrating out of the landfill. Compacted clay liner material would be selected on the basis of a borrow source assessment that would include performing a suite of geotechnical laboratory tests as recommended by EPA (1993). The choice of whether to use unamended native clay soil or bentonite-amended soil for this layer would depend on the results of the borrow source assessment, availability of low-permeability (i.e., hydraulic conductivity $\leq 1\times10^{-7}$ cm per second) unamended clay soil, and cost considerations.

6.2.2.4.4 Geologic Buffer Layer

The EMDF conceptual design includes at least a 10 ft thick geologic buffer between the landfill liner and ground water table per TDEC Rule 0400-11-01-.04(4)(a)(2). This ARAR is cited as a design requirement in Table G-4 in Appendix G. The thickness of the geologic buffer is measured from the bottom of the landfill liner to the top of the seasonal high water table of the uppermost unconfined aquifer, or to the top of the formation of a confined aquifer. The geologic buffer would consist of the geologic formation (i.e., in situ soil or rock) or an engineered structure (e.g., compacted native soil) meeting the following criteria:

- At least 10 ft thick with saturated hydraulic conductivity $\leq 1.0\times10^{-5}$ cm per second, or
- At least 5 ft thick with saturated hydraulic conductivity $\leq 1.0\times10^{-6}$ cm per second, or
- Other equivalent or superior protection.

The actual thickness and hydraulic conductivity of the geologic buffer would depend on subsurface conditions determined during the hydrogeological and geotechnical investigations for the EMDF. The geologic buffer could be comprised of compacted native soil or in situ fine-grained native soil, saprolite, or combinations of these geologic materials, depending on measured in situ hydraulic conductivity and layer thickness.

Further protection of ground water comes from the RCRA-compliant liner system. The liner system would extend up the sides of the clean-fill dikes, which would be constructed of structurally competent fill material. The dikes would surround the entire landfill, and intermediate dikes would be constructed in between cells.

6.2.2.4.5 Facility Underdrain

Facility underdrains are incorporated in the conceptual designs for all four site locations. The extent of those underdrains varies depending on the hydrology of each of the proposed sites, and cost estimates for each location factor in the extent of the underdrain systems. The following description is applicable to all sites, but to varying degrees.

Landfill construction, operation, and long-term performance depend on maintaining the water table below the base of the landfill liner system. A lesson learned from the EMWMF underdrain construction is the importance of planning for an underdrain system in the detailed design. Not only is it important to have a complete underdrain design that is part of the initial landfill design, that underdrain network should be aligned with and entrenched into pre-existing ravines and stream valleys where shallow ground water discharges or is close to the surface. While the underdrain should not be depended upon as the sole measure to prevent ground water intrusion, it is a critical component. At each of the sites, ground water flows downgradient from upland recharge areas to low elevation discharge areas along ravines and stream valleys. Infilling of existing ravines and valleys below and adjacent to the EMDF footprints with low permeability soils can prevent the natural drainage and underflow of ground water below the site resulting in a potential backup of ground water that can encroach upon and into the geobuffer and liner systems.

The EMDF underdrains are designed to provide avenues for natural egress of ground water that continues to very slowly migrate below and around the footprints. The base elevations for the geobuffer in the conceptual landfill designs for the proposed sites are based on known or inferred seasonal high ground water elevations. The underdrain system below this geobuffer zone provides the primary defense against ground water intrusion. Two separate Engineering Feasibility Plans have been issued for the EMWMF with respect to suspected ground water intrusion into the geologic buffer. The first of these was issued in August of 2003 and identified the need for the design and installation of the EMWMF underdrain due to ground water intrusion into the geologic buffer. The second plan was issued in October of 2013 in response to elevated ground water levels in the vicinity of a pneumatic piezometer (PP-01) under the EMWMF that indicated ground water intrusion into the upper 5 ft of the geologic buffer. Conceptual designs for the EMDF consider improved approaches to underdrain planning and implementation, in that trench areas will follow the natural water flow/drainage paths, detailed design will incorporate these drainage features from the start, stream/seep/spring sources and locations will be considered in detail as will flow patterns within and outside the footprint. Even at proposed sites with the least extensive underdrain networks (e.g., Site 6b), a significant portion of shallow ground water will still continue to discharge toward and into adjacent NT stream valleys east and west of the footprints.

The general layout and approach for the underdrain systems is to capture ground water in springs, seeps and wetland areas, capture both point and blanket ground water elsewhere along probable discharge zones, follow existing drainage paths, and then exit at the perimeter of the clean-fill dike of the landfill. Underdrain systems would intercept ground water along horizontal and vertical flow paths and prevent it from rising up into the geologic buffer and liner system. The base level elevations in the conceptual design have been established to heighten the basal elevations of the landfill above existing surfaces and minimize deep cuts into existing grades to avoid the potential for strong upward hydraulic gradients that might encroach on the geobuffer. Figure 6-11 shows a typical detail of an underdrain cross-section that could be used. The trench portion of the system would be constructed in areas where the drainage path is well defined and narrow and the blanket portion would be constructed in areas where the drainage face is broad and not well defined. The facility underdrain would be constructed either directly beneath the geologic buffer layer or under the structural fill layer that would then receive the geologic buffer layer, depending on the location of the underdrain section. It is anticipated the underdrain would consist of permeable layers of durable, insoluble, siliceous crushed stone or river gravel and sand, wrapped with filter fabric along the base of the landfill. Limestone is highly susceptible to dissolution over time, which may lead to clogging or the formation of voids, and thus should not be used. EMDF conceptual designs specify underdrain filter and drainage layers of inert, siliceous rocks and the structural backfill of non-calcareous soils in order to eliminate the potential for dissolution of those materials.

Loose and unstable topsoils and alluvium would be removed prior to landfill construction so that the underdrain materials would be placed against relatively stable soils and saprolite. The conceptual design for the base of the trench is at least 4.5 ft below grade and 5-15 ft wide. The much lower elevation of the trench relative to the original pre-construction ground surface along with the much higher hydraulic conductivity of the trench materials would consequently lower the pre-construction water table by several feet. The lowered water table would propagate away from the underdrain trench back through the fracture network of the surrounding undisturbed saprolite and bedrock allowing for slow active drainage of ground water underflowing and peripheral to the footprint. The upgradient shallow French drain would intercept and divert shallow, perched stormflow zone ground water (which flows intermittently down slope during storm events) around the landfill. Construction of the landfill components would eliminate ground water recharge across the footprint of the landfill. Consequently, these measures would collectively lower ground water levels and reduce ground water fluctuations beneath the landfill.

Once fitted with the underdrain system, the former ravines and valleys would behave hydraulically to allow shallow ground water discharge preferably to surface water on the downgradient side of the landfill. The underdrain system would be designed with graded filtration to prevent clogging and would be conservatively sized to accommodate the flow rates of the intercepted ground water, based on maximum field measurements, storm flow calculations, and ground water modeling. The engineering specifications for the EMWMF NT-4 underdrain provide a starting point for potential refinements to the EMDF underdrain designs. In addition, the relatively uniform flow (averaging around 4 gpm) and water quality characteristics of the EMWMF underdrain provide baseline data useful for the EMDF underdrain designs.

The facility underdrain networks ensure the water table does not rise into the geologic buffer. However, the underdrain system could act as a preferred migration pathway for contaminant movement under some conditions if a failure in the liner system occurred. While leachate could percolate into the ground water system and migrate downgradient in the saturated zone, some leachate would be captured in the underdrain system and discharge directly into surface water. Potential future releases are highly unlikely to be uniformly distributed below the footprint and are more likely to occur from one or more localized areas. Contaminants entering from one or more point sources below the footprint and migrating laterally into the underdrain could thus commingle with uncontaminated ground water from upgradient areas passing below the footprint that is also captured within the underdrain. Underdrain discharge points would be included as ground water sampling points in release detection monitoring plans, as has been done at EMWMF. Modeling results of long-term facility conditions for the EBCV Site show the proposed conceptual design, which includes the underdrain system, would be protective for a hypothetical receptor near the facility (see Appendix H). Sensitivities with regard to clogging of the underdrain are also considered in Appendix H.

A concern regarding the use of underdrain systems is the potential for the feature to function as a highly permeable unit that funnels directly to surface water, resulting in potentially very short travel times of a contaminant(s) release to the environment. While the potential for fast travel times clearly exists along the lengths of the underdrain networks, if a leak in the liner system occurred, it seems unlikely that a leak or leaks would occur in a rapid catastrophic event that would result in concentrations that would pose an immediate threat to human health or the environment. Any leaks through geosynthetic materials, are more likely to be small and isolated points such as those along seams or folds in the materials (Peggs 2003). More importantly, leaks migrating below those points must penetrate at least 15 ft or more of low permeability clay liner and geobuffer materials and native low permeability materials in the unsaturated zone before reaching the water table, whereupon lateral migration then occurs toward the underdrains or toward natural zones of discharge along adjacent NT valleys. The most extensive underdrain area among the proposed sites (the EBCV Site) only comprises approximately 10% of the waste footprint. Ample opportunity thus exists for releases to incur long and relatively slow travel times and natural attenuation before contaminants might reach an underdrain. Considering the size of the landfill with the density of contaminants overall being quite low based on the PreWAC limits, a much more likely scenario would be that a leak(s) might result in a very low, but elevated measurement of a contaminant that would extend and gradually increase over a longer period of time. As the underdrain is planned to be monitored per 40 CFR Part 264 requirements, a statistically significant change in the concentrations measured might result in the need for corrective actions. Again, 40 CFR Part 264 is included in the ARARs, and corrective action is required if deemed necessary (statistical significance also defined in these regulations and included as ARARs), and would be implemented as needed under the FFA. For a discussion of what corrective actions would entail, see Section 7.2.2.6. Section 7.2.2.4.8 discusses liner/geosynthetics longevity in more detail.

EBCV Site Option Underdrain System

For the EBCV Site, an extensive underdrain system (to be installed beneath the geologic buffer) would be required in order to provide a hydraulic break beneath the landfill within the portion of NT-3 to be backfilled, and beneath the geologic buffer where other low areas containing a spring and seep are presently located. The underdrain system would be located along the tributary channels to provide an enhanced natural flow path for ground water immediately below the landfill in order to prevent upwelling, as tributaries are natural discharge areas for ground water. Additional trenches and blanket underdrain areas would be added as required to capture any additional ground water seepage. The conceptual layout plan for the underdrain is shown in Figure 6-12.

WBCV Site Option Underdrain System

For the WBCV Site, the proposed underdrain system follows the two main drainage channels located within the site footprint. The system also intercepts any documented seeps and springs located within the landfill footprint. The individual pieces of the system are similar to the EBCV option because the natural drainage ways extend across most of the WBCV site, but fewer areas of underdrain appear to be required. The conceptual layout plan for the underdrain is shown in Figure 6-13.

Dual Site Option (Site 6b) Underdrain System

Site 6b in the Dual Site Option has the smallest underdrain system. The system is very small because the terrain has been heavily modified as a borrow area, and the slopes have become quite flat. There are no clearly defined drainage channels within the footprint as can be seen at the other sites. Documented seeps in the locale are very near the perimeter of the proposed landfill footprint. Site 6b was selected as the on-site location for the Hybrid Alternative based on a conceptual design that requires the least expansive underdrain system. It is likely that these seeps would not produce any water once the liner had been fully constructed for this site. The locations would no longer have available recharge. The conceptual layout plan for the Site 6b underdrain is shown in Figure 6-14.

Dual Site Option (Site 7a) Underdrain System

The conceptual underdrain proposed for Site 7a in the Dual Site Option is similar to that for the WBCV Site. The trenched portion is proposed in the higher elevations that have more defined channels and a blanket drain is added as the drainage ways approach the surrounding NTs and flow tends to become less defined. The conceptual layout plan for the Site 7a underdrain is shown in Figure 6-15.

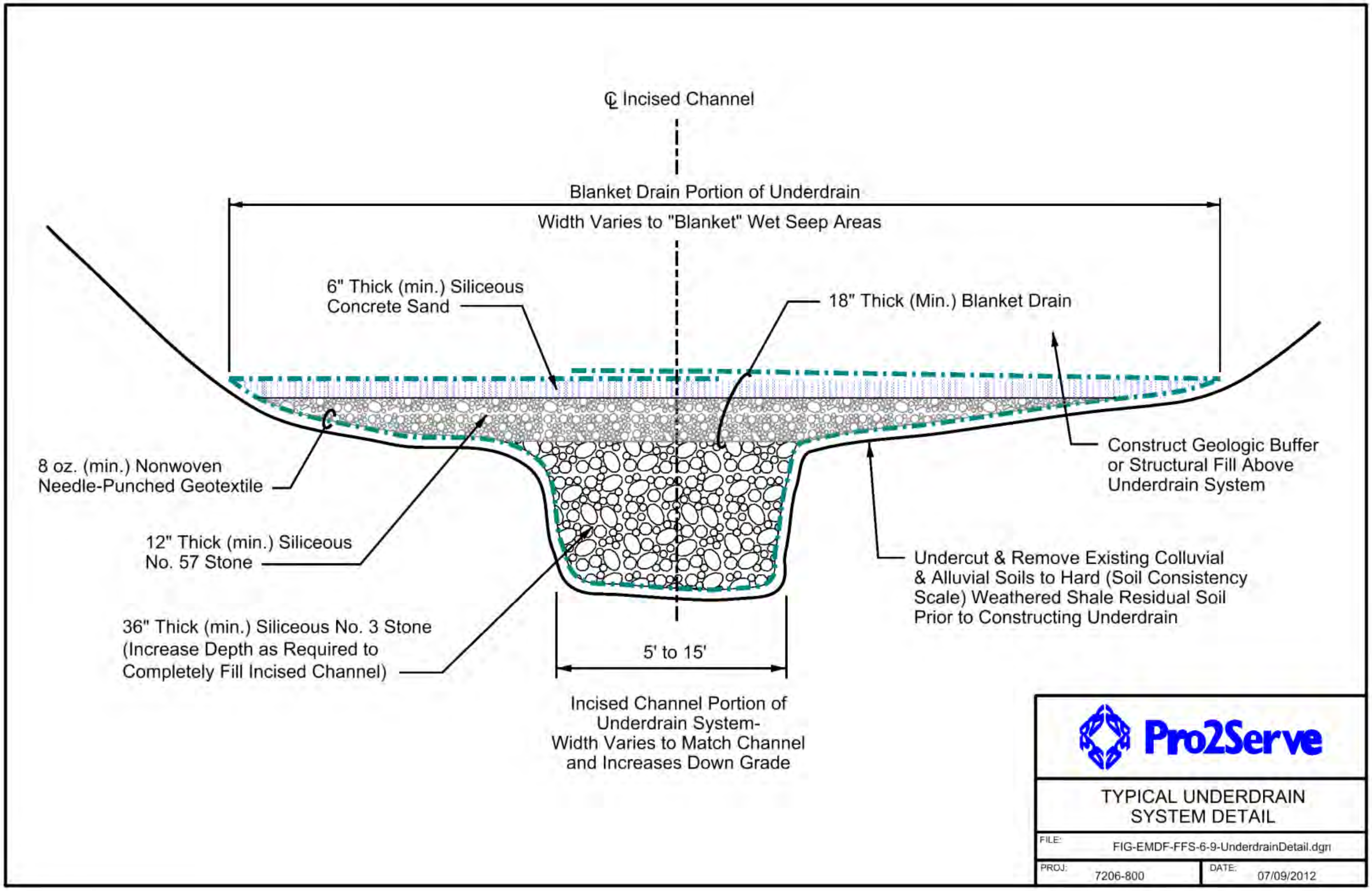

Figure 6-11. Typical Underdrain Detail

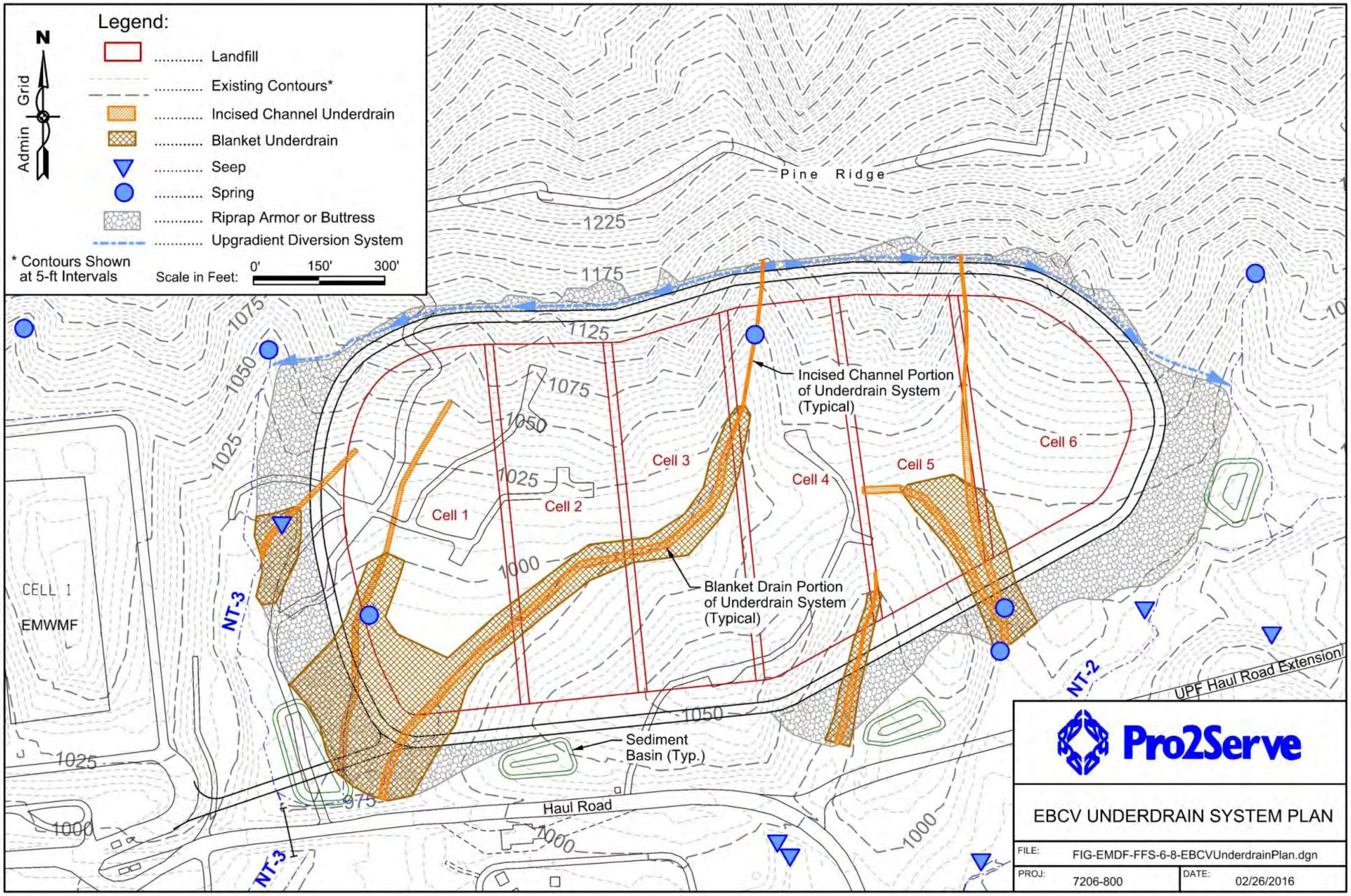

Figure 6-12. EBCV Site, EMDF Underdrain System Plan

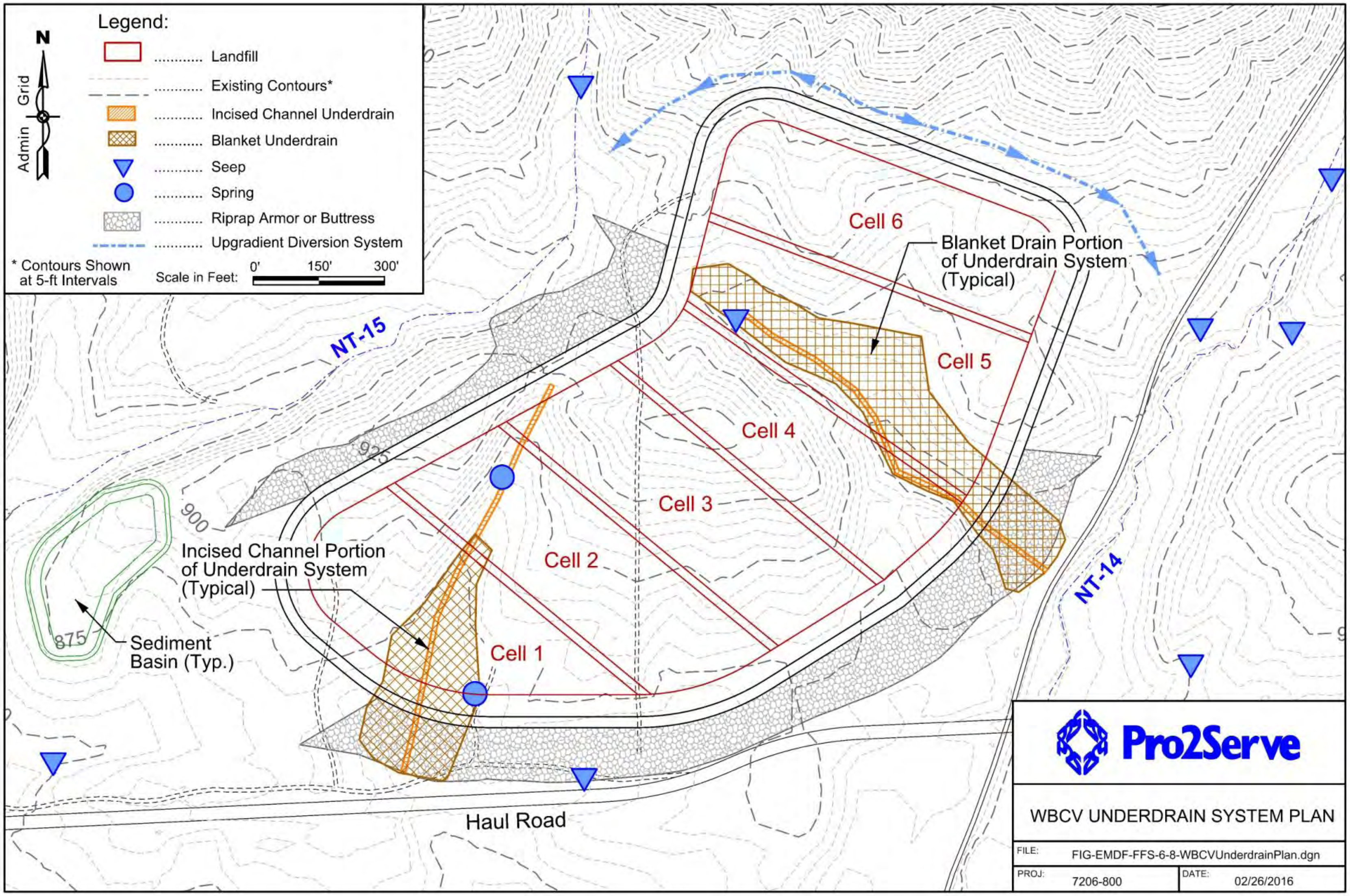

Figure 6-13. WBCV Site, EMDF Underdrain System Plan

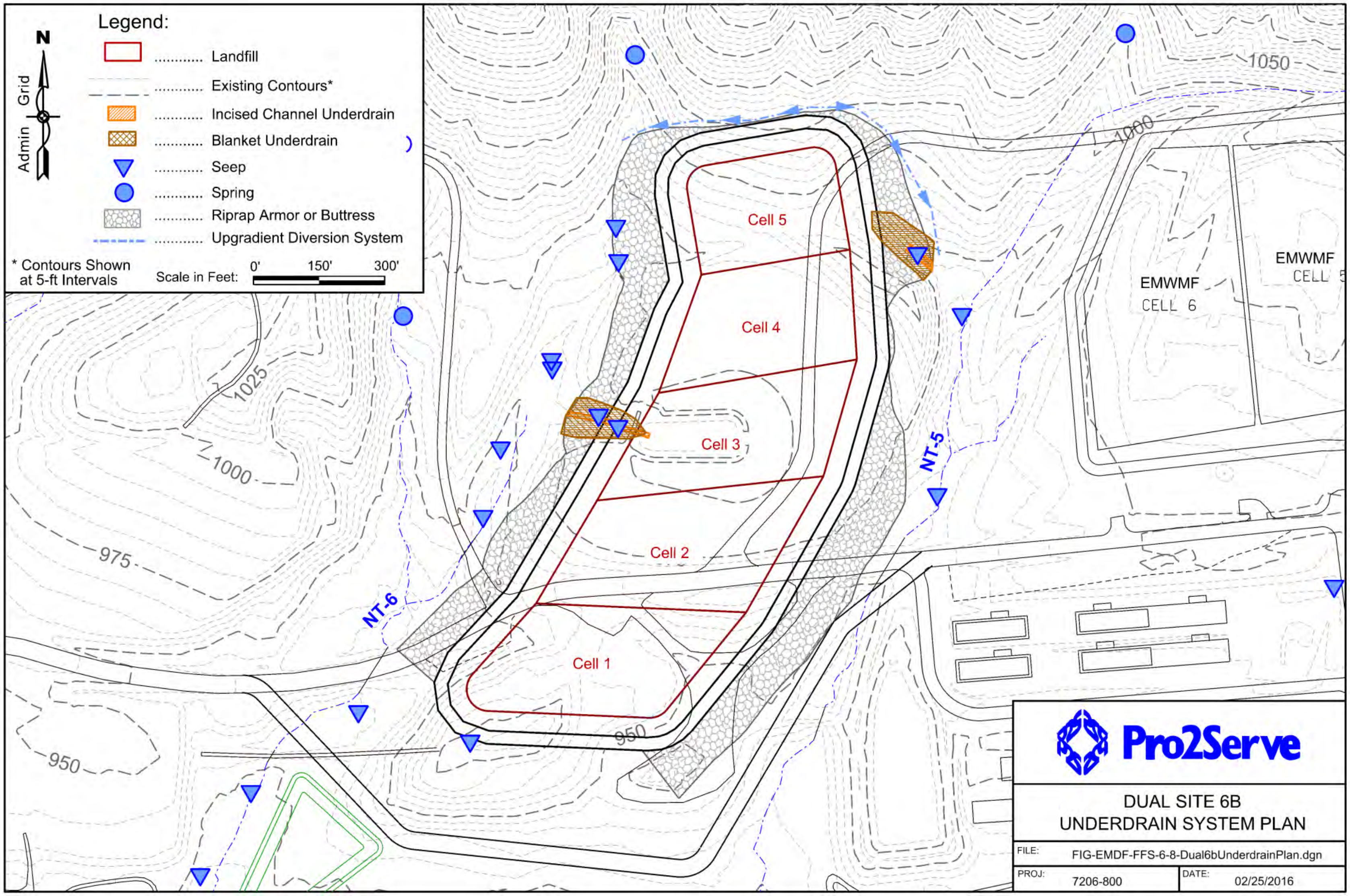

Figure 6-14. Dual Site (and Hybrid Alternative Site), Site Option 6b, Underdrain System Plan

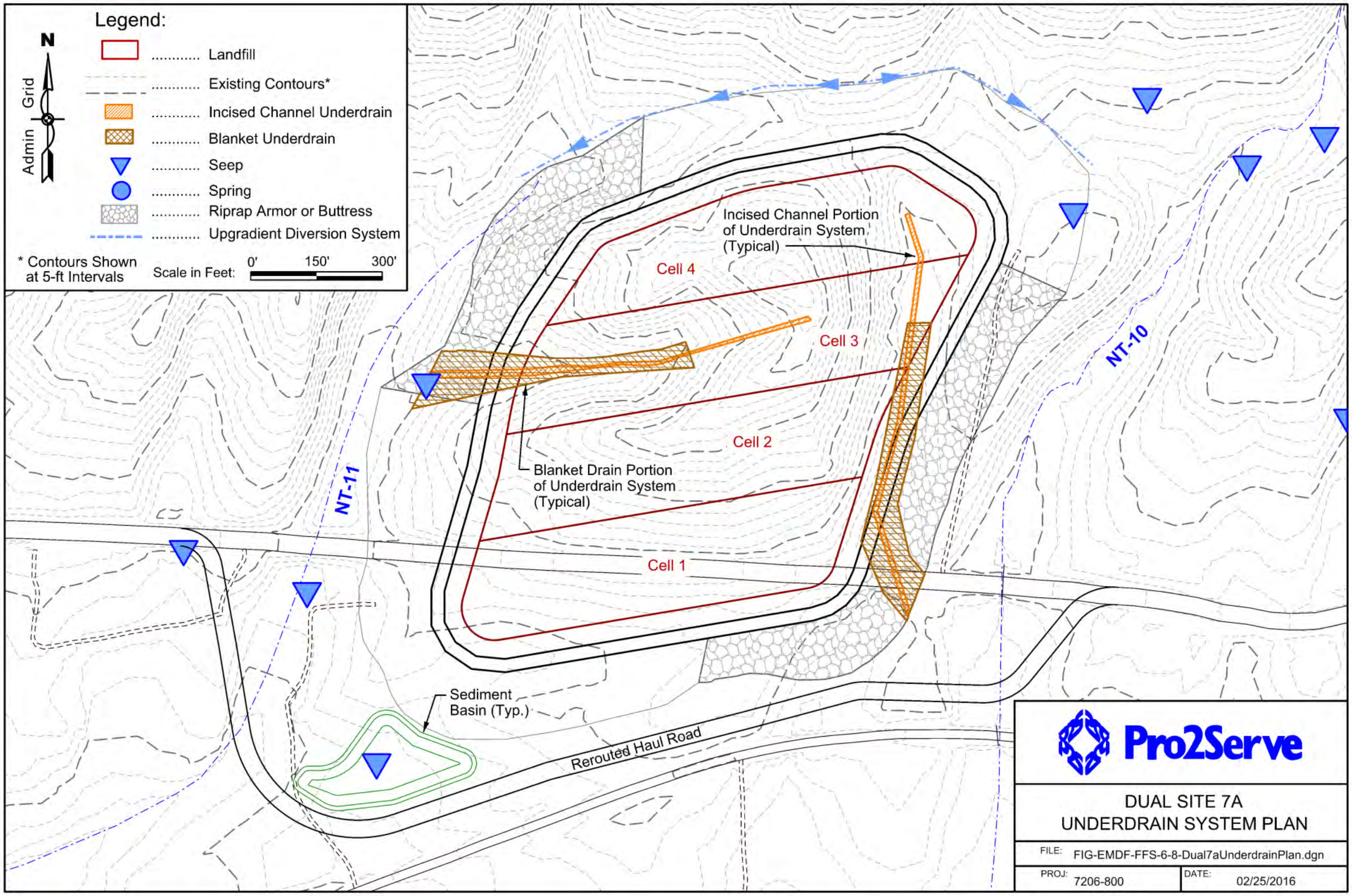

Figure 6-15. Dual Site, Site Option 7a, Underdrain System Plan

6.2.2.4.6 Leachate Collection, Storage, and Transfer within Landfill Footprint

As previously stated, the LCRS and LDRS would collect landfill leachate and detect leaks in the liner system. The perforated HDPE collection pipe that exits the landfill boundary would connect to solid double wall pipes that extend through the clean-fill perimeter dike. Redundant perforated collection piping in the LCRS would be installed at slightly higher levels than the primary collection piping to provide an alternate route for leachate drainage should the primary piping become obstructed with sediment. The collection piping would penetrate the liner, and would be sealed to the geosynthetic material using anti-seep collars and other fittings to prevent leakage around the penetrations. The solid double wall piping from the collection system and detection system in each cell would connect to manholes that flow to a main header that routes the leachate to a lift station for transfer to leachate storage tanks. Flow meters would be installed in manholes to measure the leachate volume from each cell collected during operations, cap construction, and during the long-term maintenance period following capping and closure. Leachate generated from the landfill would be properly collected, characterized, and treated as necessary to meet discharge limits (given in the Integrated Water Management Focused Feasibility Study or IWM FFS [UCOR 2016]), or released if sample analysis indicated it meets discharge criteria (e.g., Managed Discharge, see Section 6.2.2.5.1 for more information).

6.2.2.4.7 Cover Systems

After support systems are constructed and the liner and clean-fill dikes for each construction/disposal phase are completed, waste would be placed in the active cells as described in Section 6.2.5. After waste disposal is complete, an approximately 11 ft thick multilayer cover system (or cap) would be installed to prevent infiltration of precipitation into the waste.

Cover systems consist of three different stages: (1) operational cover that represents a single "layer" used during daily operations to prevent spreading of waste temporarily, (2) interim cover that represents a cover system (multiple layers) used once a cell has been filled, as a temporary protection from infiltration of rainwater and to stabilize waste until final closure, and (3) final cover, the multi-layered system installed over all cells at closure of the landfill. Note that some of the final cover layers may be installed as an interim cover system to reduce the volume of leachate generated during active operations. A gas venting system, if necessary, is also considered part of the final cover system. The cover system is described in detail below, and was shown previously in Figure 6-9.

- **Operational Cover:** Depending on the properties of the waste, it may be necessary to place a thin layer of clean soil over a lift of waste to prevent spreading of the waste by wind or other forces. This layer, referred to as daily cover or intermediate cover, may be removed and stockpiled for reuse prior to placement of subsequent layers of waste, as practicable, to conserve air space within the landfill.
- **Interim Cover System:** An interim cover system, also referred to as an interim cap (see Figure 6-9), would be installed when waste has been placed to the final design grade over a large enough area of the landfill to allow practical construction. The primary requirements of the interim cover system are to (1) minimize surface water infiltration into the waste, thus minimizing the volume of leachate generated prior to installation of the final cover system; (2) contain waste against wind dispersion; and (3) ensure no adverse impact to stability or other aspects of final cover performance. The design elements of the interim cover are as follows, from the top of waste upward:
  - Geotextile Cushion/Separator Layer – nonwoven, needle-punched geotextile having a nominal mass per unit area of at least 16 oz per yd^2 used as a cushion and separator layer over the underlying waste.

- Contouring Layer – Standard sanitary landfill designs would require the layer between the waste and the final cover system to be a vent layer. This would typically consist of a 1 ft thick (minimum) layer of No. 57 stone to serve the dual function of contour fill layer and gas vent layer. This layer would provide a smooth, firm foundation for construction of the overlying cover layers, as well as a highly permeable layer for collection and venting of landfill gases. The venting layer is important in municipal settings where high volumes of organic wastes that are susceptible to decomposition and gas generation, also known as putrescible waste, might be expected. A vent layer coupled with vent mechanisms through the cap provide relief from excessive pressure build up within such a landfill. In the case of EMDF, however, careful consideration should be given to whether this layer would facilitate the release of radionuclides into the environment, whether the venting is even necessary considering the low quantities of organic waste, and whether the vent mechanisms would meet the life span needed for the cover system of this nature. For purposes of cost estimating, this vent layer was not included. These analyses will be performed during the final design. For the EMDF RI/FS this layer will be referred to as a contouring layer.
- Geotextile Separator Layer – nonwoven, needle-punched geotextile having a nominal mass per unit area of at least 8 oz per yd^2, used as a separator between the granular contour/vent layer and overlying temporary geomembrane layer (and permanent compacted clay layer).
- Temporary Geomembrane Layer – 30 mil thick polyvinyl chloride geomembrane. The geomembrane would be properly ballasted with sandbags, tires, or similar non-damaging objects of sufficient mass to prevent wind uplift.
- The geomembrane would be removed prior to construction of the final cover. The underlying layers would remain as part of the final cover system.

- **Final Cover System:** In accordance with RCRA requirements, the final cover system, also referred to as the final cap, would be designed and constructed to:
  - Minimize migration of liquids through the closed landfill over the long-term.
  - Promote efficient drainage while minimizing erosion or abrasion of the cover.
  - Control migration of gas generated by decomposition of organic materials and other chemical reactions occurring within the waste, if found to be necessary.
  - Accommodate settling and subsidence to maintain the cover integrity.
  - Provide a permeability less than or equal to the permeability of any bottom-liner system or natural subsoil present.
  - Resist inadvertent intrusion of humans, plants, and animals.
  - Function with little maintenance.

  The final cover would be sloped to facilitate runoff and would be placed over the waste and tie into the top of the perimeter clean-fill dike. It is anticipated the surface of the final cover system over the waste would be sloped at a grade of 2% to 5% and the sides would be sloped at a maximum grade of 25%. The conceptual design includes 20 ft wide horizontal benches spaced at maximum vertical intervals of 50 ft to reduce slope lengths, increase erosion resistance, and enhance slope stability. Actual slopes may vary and would depend on slope stability and erosion analyses performed during remedial design. The approximately 11 ft thick, multilayer final cover system would be comprised of the following layers, starting from the top of the waste and moving upward:

  - Contouring Layer – It should be noted that this layer was discussed previously as one of the first three bullets under the Interim Cover System section. This layer, as part of the Interim Cover System, provides a working and contouring surface. It can then later function as a gas collection layer for the Final Cover System if deemed necessary. If used as a gas vent layer, it would be comprised of a 1 ft thick (minimum) layer of No. 57 stone sandwiched between a 16 oz per yd^2 geotextile cushion/separator layer below and 8 oz per yd^2 geotextile separator layer above. If a gas vent layer is not deemed to be appropriate, suitable structural fill would be contoured and compacted to provide a stable base for the landfill cover system. Remedial design efforts will include calculations to estimate possible off-gassing of buried waste and evaluate the need for a gas venting capability.

- Compacted Clay Layer – 1 ft thick (minimum) layer of native clay soil or amended soil compacted to produce an in-place hydraulic conductivity less than or equal to 1×10^{-7} cm per second. This layer, in conjunction with the overlying amended clay layer and geomembrane layer, would function as a composite hydraulic barrier to infiltration. Similar to the compacted clay liner for the liner system, compacted clay layer material would be selected on the basis of a borrow source assessment that would include performing a suite of geotechnical laboratory tests as recommended by EPA (1993). The choice of whether to use native clay soil or bentonite-amended soil for this layer would depend on the results of the borrow source assessment, availability of low-permeability (i.e., hydraulic conductivity $\leq1\times10^{-7}$ cm per second) native clay soil, and cost considerations.
- Amended Clay Layer – 1 ft thick (minimum) layer of native soil amended with bentonite and compacted to produce an in-place hydraulic conductivity less than or equal to 3.5×10^{-8} cm per second. It is necessary to amend native soil with bentonite for this layer to achieve the very low design hydraulic conductivity value less than or equal to 3.5×10^{-8} cm per second.
- Geomembrane Layer – 40 mil thick HDPE geomembrane, textured on both sides to enhance sliding resistance.
- Geotextile Cushion Layer – nonwoven, needle-punched geotextile having a nominal mass per unit area of at least 16 oz per yd^2, used as a cushion over the underlying geomembrane.
- Lateral Drainage Layer – 1 ft thick layer of hard, durable, free-draining, granular material (e.g., No. 57 stone) with sufficient transmissivity to drain the cover system and satisfy the requirements of the infiltration analysis.
- Biointrusion Layer – 2 ft thick layer of free-draining, siliceous coarse granular material (i.e., 4 in. to 12 in. diameter riprap) sized to prevent burrowing animals and plant root systems from penetrating the cover system and reduce the likelihood of inadvertent intrusion by humans by increasing the difficulty of digging or drilling into the landfill.
- Geotextile Separator Layer – nonwoven, needle-punched geotextile having a nominal mass per unit area of at least 8 oz per yd^2, used as a separator between the granular filter layer and biointrusion layer.
- Granular Filter Layer – 12 in. thick layer of granular material graded to act as a filter layer to prevent clogging of the biointrusion layer with soil from the overlying erosion control layer. The required gradation would depend on the particle size distributions of both the erosion control layer and biointrusion layer and would be calculated using standard soil filter design criteria once these properties have been established.
- Erosion Control Layer – 4 ft thick vegetated soil/rock matrix comprised of a mixture of crushed rock and native soil and constructed over the disposal facility to protect the underlying cover layers from the effects of frost penetration, and wind and water erosion. This layer would also provide a medium for growth of plant root systems and would include a surficial grass cover or other appropriate vegetation, with seed mix specially designed for this application.

The final cover system would tie into the top of the perimeter clean-fill dike. The drainage and overlying layers would discharge water into perimeter ditches that would carry runoff away from the landfill.

The overall effectiveness of the final cover system in reducing infiltration is a key long-term performance objective of the landfill. Cover technology is evolving and additional methods for reducing infiltration may be available at the time of final design. The overall goal is to reduce leachate generation through the reduction of infiltration.

- **Landfill Gas Collection and Venting System:** Wastes to be disposed of in the EMDF could include a small percentage of organic soils and biodegradable materials such as vegetation, trees, roots, and lumber which generate methane, carbon dioxide, and other gases during decomposition. As already mentioned the accumulation of these gases beneath the landfill cover could reduce the stability of the cover system and create a potentially explosive environment if unvented. However, it is recommended that the decision to implement a landfill gas venting system be carefully evaluated and should consider the risk of radionuclide releases. Examination of forecasted waste types and resulting limitations on putrescible waste types could be implemented for the EMDF in order to minimize the likelihood that appreciable amounts of gas would be generated within the landfill. Construction/demolition debris, wood waste, and things such as yard waste are typically classified as "non-putrescible". The worst offenders for gas generation tend to be food wastes, which would not be disposed of within the EMDF landfill.

  If a gas vent layer were deemed appropriate, it is anticipated that this system would be comprised of a gas vent layer consisting of free-draining crushed stone (e.g., No. 57 stone) wrapped with geotextile or a geocomposite drainage layer and vented through the cover using HDPE pipe extending approximately 5 ft above finished grade. It would serve the dual purpose of providing a contouring fill and gas vent layer. In either case, the contouring fill establishes uniform contours upon which to construct the overlying layers of the cover system. No costs associated with a gas venting system have been included in the on-site facility estimate.

6.2.2.4.8 Longevity of Engineered Features

The previous seven sections, 6.2.2.4.1 through 6.2.2.4.7, discussed the conceptual design of the proposed facility. Many of the features of that facility design will be expected to function well into the future to protect the public and environment by effectively isolating the waste, mostly in terms of reducing contact of water with waste. Therefore, the longevity of those features becomes a key topic. This section discusses the longevity of those engineered features, namely the surface water drainage systems, cover/liner systems (e.g., geosynthetics and clay layers), and underdrain systems. All features are common to all sites. These systems are all passive systems, functioning through the use of gravity. They are constructed of natural and chemically inert materials (with the exception of the geosynthetics in the cap and liner systems). The sizing of the systems will be completed as part of final design, using standard industry accepted models and calculations, detailed site characterization, and incorporating safety factors. All water sources are considered: subsurface as well as surface. Site protectiveness, in terms of site-specific features, is addressed in Section 7.2.2.2.3 where the sites' compliance with ARARs is reviewed, and Section 7.2.2.2.4 where site-specific long-term effectiveness is reviewed.

Surface Water Drainage Systems

Engineered subsurface and surface drainage systems are included in the conceptual designs of the EMDF at all sites. The extent of those drainage systems differs, depending on site-specific hydrologic characteristics and topography. Surface drainage features (upgradient diversion ditch and French drain) between Pine Ridge and the installed facility (all sites) will provide diversion of upgradient flow, reduce potential erosion and subsidence of the cover and promote stability, all of which will support the isolation of the waste from contact with water. All drainage systems are designed with graded filtration, and non-weathering materials to provide long-lived performance. All drainage systems will be designed based on site-specific hydrologic data and predictions of extreme flow conditions, and sized accordingly.

All proposed sites are situated such that upland drainage areas are minimized by locating the footprints as far upslope as possible. Upland drainage areas will remain forested, reducing surface runoff and reducing runoff velocity thereby reducing erosion of the landfill cover. The ditch and French drain network is a passive system designed to require little maintenance and perform long-term.

Clogging of the surface water drainage features was discussed in Section 6.2.2.4.2. In that discussion, the following features were outlined that will guard against clogging:

- Specifying use of soils and gravels with low dissolvable calcium carbonate content (e.g., less than 5% based on ASTM D 3042 with a pH of 4).
- Specifying use of stone with a high permeability.
- Utilizing hard rock that is resistant to weathering and is relatively free of fines.
- Utilizing a graded filtration system (design methods are well established).
- Sizing perforations in drain pipes so that surrounding stone will not enter the pipe.
- Performing hydraulic capacity calculations for short and long-term conditions. For the long-term conditions, appropriate reduction factors are applied to the permeability of stone, due to the potential for chemical clogging (and other factors). Calculations are carried out to ensure the long-term capacity exceeds the required capacity (i.e., has an adequate factor of safety).

Cover/Liner Systems

The EMDF conceptual design at all Site Options is essentially the same in terms of cover and liner design. Geomembrane liners of the landfill liner system at all sites would control releases of leachate to ground water for their design life reported to extend from 500 to 1000 years or more (Koerner, et al. 2011, Rowe, et al. 2009a, Benson 2014, EPA 2000). Both cap and liner systems contain geomembranes to prevent water infiltration into the waste, reduce contact of water and waste, and minimize leachate production and migration. As described by Bonaparte et al. (2016), it appears that HDPE geomembranes of the type being used in some MLLW disposal facilities are relatively unaffected at total alpha doses of 5 megarad (Mrad), or more. These geomembranes are also reportedly unaffected by radiation from gamma and/or beta sources until total doses reach on the order of 1 to 10 Mrad, which is much higher than what would be expected to be disposed in the EMDF. Bonaparte et al. (2002) proposed three stages of HDPE geomembrane service life: 1) depletion of antioxidants; 2) induction, and 3) degradation of material properties. Despite the depletion of antioxidants in Stage 1 and oxidation induced-scission of polyethylene chains in Stage 2, there is no loss of performance during these stages. Stage 3, or degradation, occurs when the effect of oxidation induced-scission of polyethylene chains becomes measurable. Bonaparte et al. (2002) found that the approximate durations for each stage for a 1.5-millimeter (mm) HDPE geomembrane are: (i) antioxidant depletion (200 years), (ii) induction (20 years), and (iii) half-life (50% degradation) of an engineering property (750 years). This implies a service lifetime for an HDPE geomembrane of 800 to 1,000 years. Subsequent research conducted by Rowe et al. (2009b) found similar durations and concluded that HDPE liners may perform as designed for upwards of 500 to 1,000 years. Similarly, Phifer and Denham (2012) estimate that the HDPE liners in the Portsmouth CERCLA cell design may function for 600 to 1,400 years. A service life of about 500 years would ensure enough containment time to allow for decay of short-lived radionuclide contaminants (e.g., less than 100 year half-life) to innocuous levels as noted by the NRC (NRC 1981). Leachate and geosynthetic material compatability studies will be undertaken if on-site is the selected remedy.

The leachate collection and removal system above the primary liner and the leak detection and removal system below the primary liner would be effective for the period of active institutional controls. The period of active institutional controls is not known, but is assumed for design purposes to extend for at least 100 years. Subsequently, the final cover system, secondary liner, and geologic buffer would provide long-term control of leachate release since these engineered features would last minimally for 500 years.

The final cover system would be designed to have a lower long-term vertical percolation rate than the basal liner system and geologic buffer. This would prevent leachate from mounding on top of the basal liner system after the period when the leachate removal system is no longer active and would control the long-term release of leachate by limiting the rate of infiltration into the waste and down through the basal liner system and geologic buffer.

In addition to the geomembrane liners, natural clay plays a key role in cover and liner systems in limiting infiltration and reducing contact of water with waste. Environmental conditions that have been shown to alter the effectiveness (i.e. hydraulic conductivity) of the compacted clay layers in cover systems include freeze-thaw cycles, penetration by plant roots and/or burrowing animals and insects, and desiccation or drying of the clay (Benson and Othman 1993, Daniel 1993, Albrecht and Benson 2001, Bontaparte et al. 2002). All of these factors can lead to cracks and loosening of the clay layer that create preferential flow paths that allow for more water to pass through the material (Albright et al. 2006). The cover system for the EMDF proposes a robust configuration to protect the compacted clay layers. Coupling the clay layer with membranes is one method of preserving the clay properties. Geosynthetic membranes overlying the clay layers serve to buffer or isolate the clay from environmental variations in moisture that could cause desiccation, cracking, and loss of performance. In addition to the geomembrane, 8 ft of material would be installed above the clay barrier layers of the cover, which also serve to reduce variations in moisture, but in addition ensure the clay layers are well below freeze-thaw depths and thus not subject to temperature fluctuations that would degrade the clay. (Refer to Section 6.2.2.4.7 for a detailed description of the cap layers.) These conditions differ greatly from those studied by Albright and his colleagues (2006) where the cover systems typically consisted of only a protective surface layer atop a compacted clay barrier layer and were on average 4 ft thick.

Performance of the clay depends on its installation and how its properties change over time. To ensure that the compacted clay layers meet the design specified hydraulic conductivities at the time of installation strict construction quality assurance and control measures are implemented and test pad construction is utilized to verify materials and methods of installation. Once the cover is constructed, freeze-thaw would not affect the clay within the EMDF cover system due to the 8 ft of cover. According to the U.S. Army Corp of Engineers the "Depth of Frost Action" for East Tennessee is between 1 and 2 ft (Figure 2-1 EM 1110-1-1905). Furthermore, the high rock content in the layers above the compacted clay have unit weights that are greater than typical soils which will help protect the installed material properties of the clay by providing higher overburden stresses than soil alone. Penetration by plant roots and burrowing animals/insects would be restricted by the rock within the biointrusion layer and lateral drainage layer. Desiccation cracking of the clay would be controlled first by the geomembrane and then by the 8 ft of buffer from direct exposure to the environment. Having the 8 ft of cover provides a dampening effect from the drying factors that tend to lead to cracking of the clay layers. Fluxes in temperature and water content would not be as pronounced under 8 ft of overburden (Albrecht and Benson 2001). It is anticipated that the system would operate in a far greater state of equilibrium compared to a clay layer only covered by 1 to 2 ft of protective soil. As a conservative measure, fate and transport modeling does account for some degradation of the clay. See Appendix H for a discussion of assumptions regarding how the cover system properties may change over time.

Erosion of the final cover is also a concern. Final design work for the cover will consider this process. The ability of the planned grass cover and topsoil to resist the rill and interrill erosions would be evaluated using applicable models. This evaluation would consider the resistance of the system to formation of erosion gullies using, for example, a 2000 year design storm. The ability of the riprap in the biointrusion layer to resist gully advancement would also be considered under a 2000 year storm scenario using industry standard models and methods.

Underdrain Systems

Underdrain engineered features are relied on to maintain lowered ground water tables below the geobuffer systems. All drainage systems are designed with graded filtration, and non-weathering materials to provide long-lived performance. The bullet list of relevant practices used to ensure longevity of surface drainage features given above is applicable as well for underdrain features.

Underdrain systems are common practice in civil engineering projects to maintain separation and protection of structures, roadways, facilities, and utilities from both seepage and ground water. Examples of landfills utilizing underdrain systems can be found across the U.S. and in other countries. The Southeastern Public Service Authority (SPSA) Regional Landfill in Suffolk, Virginia began operating in 1983 and utilized underdrain systems, piping, and geocomposites to facilitate construction and lower the water table under the landfill cells. In 2011 an application submitted by the SPSA to expand the landfill was approved. The new expansion included additional underdrain systems to control ground water.

The Crossroads Landfill located in Norrisridgewock, Maine incorporated vertical wick drains and a blanket underdrain to manage water under new landfill construction. The site saw a catastrophic slope failure of the soft clays under the site in 1989 which impacted 50 acres of waste. To prevent future problems under new cells, over 75,000 vertical wick drains were installed at depths ranging from 20 ft to 75 ft to discharge into a 2 ft thick sand blanket layer. A new landfill liner system was then constructed over this blanket drain and over 1 M yd^3 of material was relocated from the failed area to the new cells. Intensive monitoring was performed for years to ensure that newly constructed landfill areas were stable and that there was no potential for shear failure of underlying soft clays.

Examples of landfills using underdrain systems in order to construct liner systems below the water table can be found in Texas at the Construction Recycling & Waste Corporation Landfill, in Arkansas at the Fort Smith Landfill (10 ft below in some areas), in Arizona at the Gray Wolf Regional Landfill (10 to 15 ft below in some areas), and at the Sonoma County Landfill in California. The Sonoma County Landfill is located in Petaluma, California and involved a 50 acre landfill expansion that was excavated as much as 45 ft below the water table and then constructed along canyon walls as steep as 2H:1V. The already complex configuration was further complicated by the strict seismic requirements of California, surface water drainages towards the site, and limited downstream space available for sediment ponds. Both static and dynamic stability analysis was performed and a design was implemented that met state requirements for factors of safety for static slope stability and allowable acceleration and deformation for dynamic slope stability. Disposal of waste commenced in August of 2002 within Phases I and II of the landfill expansion. These are only a short example of a long list of landfills utilizing underdrains to control ground water levels. Of the ground water collection systems found for the various landfills, all of them incorporated underdrain monitoring into the facility ground water monitoring plans because it was seen as an early warning indicator of contaminant transport from the waste unit.

Studies were conducted at the existing EMWMF to address the potential for plugging of the underdrain by inorganic mineral precipitates. If this were to occur, mineral deposition in the core of the multizone filter might reduce the hydraulic conductivity, and thus, the overall effectiveness of the underdrain. To evaluate the potential for plugging, ground water geochemical data were evaluated to determine the solution saturation with respect to common minerals present in the ground water. Additionally, potential changes to the geochemical environment induced by the underdrain were considered to determine if a shift in the solution equilibrium might still result in undesirable formation of mineral precipitates. Four quarters of site ground water data from calendar year 2001 were used for the analysis. The data were analyzed using the public domain software application HYDROWIN. The output demonstrated that calcium-bicarbonate water was expected to be collected by the underdrain. Therefore, the major ions of concern would be calcium, magnesium, and iron, and the common minerals associated with these ions would be calcite, dolomite, and siderite. The saturation indexes for these minerals were calculated and a statistical evaluation conducted. It was determined that within the underdrain, all three indexes were undersaturated with respect to these three common carbonate minerals and plugging of the underdrain by inorganic mineral precipitates was unlikely (UCOR 2013).

To preclude the underdrain materials themselves affecting the concentration of soluble minerals (i.e., calcite, dolomite, and siderite), the drain materials would be comprised only of siliceous materials, which under the low temperature and near neutral pH of the ground water system is essentially an inert/insoluble material. These materials would not be expected to adversely impact the saturation index. Even with some degree of diminished porosity and permeability, the underdrain is assumed to provide an effective avenue for long term drainage based on a much higher permeability of underdrain materials relative to that of in-situ materials. The measured hydraulic conductivity, K, of in-situ soils/saprolite and bedrock materials generally ranges between 10^{-4} cm/sec to 10^{-6} cm/sec or less. The design calculation sheets by Bechtel Jacobs in 2003 for the underdrain installed below Cell 3 at the EMWMF, indicate K values for various underdrain materials ranging from 2.0 x 10^{-2} cm/sec for sand, to 15 cm/sec for gravel (#57 size stone), to 35 cm/sec for rock (#3 ballast stone). Even with some degree of potential clogging, the minimum of five orders of magnitude difference between underdrain and in-situ K values will help to ensure the persistence of a lowered water table.

If a site is selected for an on-site disposal facility, drainage features will be configured to follow natural site drainage characteristics, and sized in final design considering site-specific hydrology, to optimally function over the long-term. A natural analog to achieving long-term successful site drainage is Machu Picchu, where rainfall exceeded 75 in./year, and drainage features were designed to withstand damage from potential landslides, settlement, and erosion. Machu Picchu has functioned as it was designed to for over four centuries (Wright, et. al. 1997). Because of the long-time frames involved, the NRC recommends using these natural analogs to support longevity assumptions (e.g., thousands of years) (NRC 2015).

6.2.2.5 Support Facilities

Site layouts depicting proposed locations of the primary support facilities relative to the landfill footprints and surrounding existing and future facilities were shown in the site plans of Figures 6-2 through 6-5. WBCV and Site 7b of the Dual Site Option require new infrastructure siting and construction as shown previously in their respective site plans, and no restrictions due to existing or potential other uses apply for those locations. Locating the EMDF immediately east or west of EMWMF (as for proposed sites EBCV and Site 6b of the Dual Site Option) offers advantages relative to sharing existing EMWMF infrastructure and being in close-proximity to existing utilities; however, there are restrictions as well.

Land suitable for development of new support facilities is very limited near the EBCV site and Site 6b (see Figures 6-16 and 6-17). The EMWMF landfill occupies the land to the west of NT-3. The slopes north of EMDF are too steep for construction of support facilities. Development east of the proposed EMDF would require crossing NT-2. Much of the land south of the existing haul road and south/southwest of the proposed EMDF is occupied by former waste disposal areas, existing EMWMF support facilities, and land planned for use by the Y-12 UPF Project (e.g., construction of a concrete batch plant, staging construction materials/equipment, parking for UPF construction workers, and wetland expansion/creation areas to offset wetlands impacted by the planned extension of the existing haul road to the Y-12 Plant). The former waste disposal areas (e.g., Oil Landfarm, Sanitary Landfill, BY/BY, and HCDA) have soil or RCRA-type covers, which limit potential use of these sites. With such limited space in the area, it is proposed to utilize the soil covered area of the BY/BY for construction trailers and parking areas. Care would need to be taken not to infringe on the riparian habitat that has been established along NT-3 on the western edge of the BY/BY, not to infringe on the RCRA capped area (HCDA) in the southern extents of the BY/BY, and to avoid excavating for construction of support facilities. The approach to support facilities for the EBCV site and Site 6b would be nearly identical, with the main difference being that the EBCV Site would use area proposed for the Site 6b footprint as needed, and vice versa. Site 6b is slightly more limiting in terms of support facility area due to the fact that the landfill and rerouted Haul Road segment would consume an area that has already been cleared and prepared as a storage yard for EMWMF activities.

Site 7a of the Dual Site Option and the WBCV Site, both in Greenfield areas, allow for much more space to incorporate support facilities as demonstrated previously in Figures 6-3 and 6-5. For the conceptual designs, it is assumed each design would utilize and upgrade, as necessary, support facilities and structures that are being used by the EMWMF where possible. New support facilities and infrastructure are assumed to be needed as well, as indicated in Table 6-1.

Table 6-1. Assumed Status of Infrastructure and Support Facilities at EMDF Site Locations

Location	Use of Existing Infrastructure	New Support Facilities/Infrastructure
EBCV Site Option	• Operations/support trailers, staging/laydown areas, stockpile area, parking areas • Leachate storage tanks and truck loading stations • Contact water tanks and basins • Haul road • Electrical, water, communication utilities • Truck weigh scale • Guard station	• Wastewater management systems • Wastewater storage • Storm water management systems • Parking areas • Laydown/storage/staging areas • Material stockpile area • Spoils areas (temporary and permanent) • Guard station
WBCV Site Option	• Haul road	• Operations/support trailers, staging/laydown areas, stockpile area, and parking areas • Leachate storage tanks and truck loading stations • Contact water tanks and basins • Electrical, water, and communication utilities • Truck weigh scale • Guard stations • Wastewater & storm water management systems • Storage/staging areas • Material stockpile area • Spoils areas (temporary and permanent)
Dual Site Option (Site 7a)		• Operations/support trailers, staging/laydown areas, stockpile area, parking areas • Leachate storage tanks and truck loading stations • Contact water tanks and basins • Electrical, water, communication utilities • Truck weigh scale • Guard stations • Wastewater & storm water management systems • Storage/staging areas • Material stockpile area • Spoils areas (temporary and permanent) • Haul Road
Dual Site Option (Site 6b)	• Operations/support trailers, staging/laydown areas, stockpile area, parking areas • Leachate storage tanks and truck loading stations • Contact water tanks and basins • Electrical, water, communication utilities • Truck weigh scale • Guard station	• Wastewater management systems • Wastewater storage • Storm water management systems • Laydown/storage/staging areas • Material stockpile area • Spoils areas (temporary and permanent) • Guard station • Haul Road

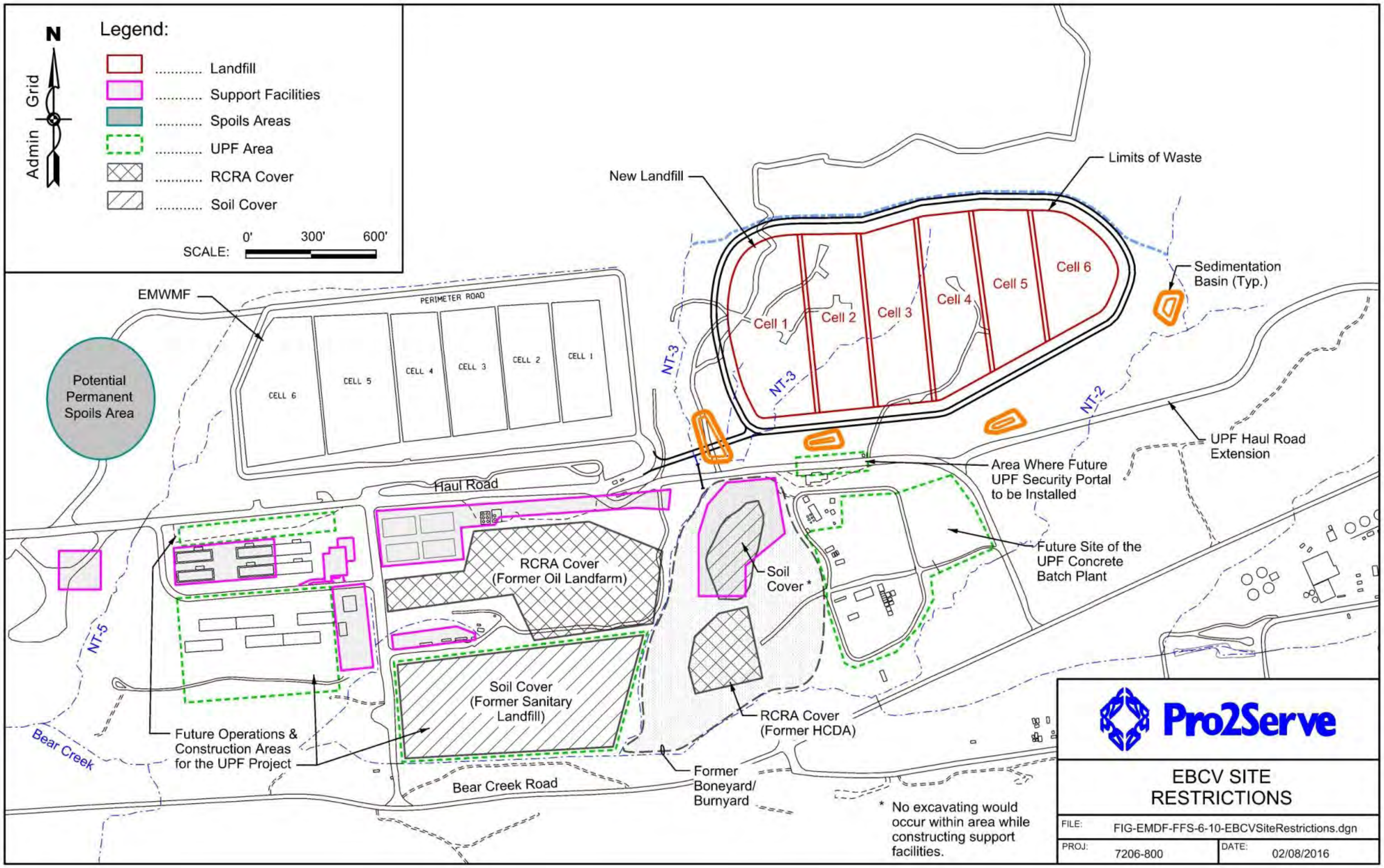

Figure 6-16. EBCV Site Option with Restrictions

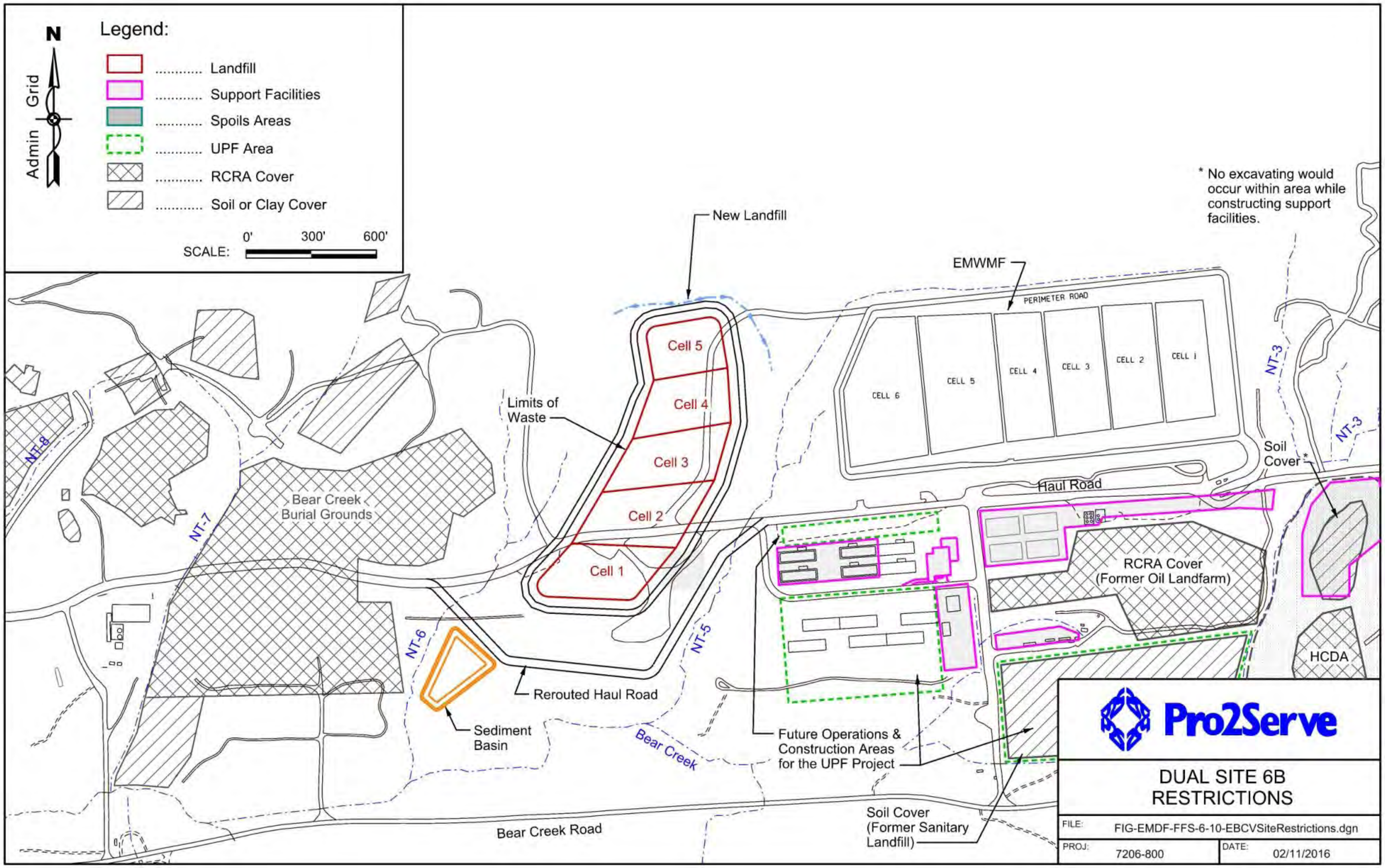

Figure 6-17. Dual Site Option Site 6b with Restrictions

EPA suggests that environmental effects of the proposed remedial alternatives be evaluated in accordance with Green Remediation, *Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites* (EPA 542-R-08-002), dated April 2008 and *Methodology for Understanding and Reducing a Project's Environmental Footprint* (EPA 542-R-12-002), dated February 2012. Air pollution affects are evaluated for construction of proposed Site 7b in Appendix F; very little change was seen in evaluating the previous site under the D3 RI/FS (EBCV) versus Site 7b in this document. It is expected that very little difference between sites would be seen in energy usage or other elements as outlined in the EPA guidance, for the various proposed sites, especially in light of the phased construction proposed (whereby if a site were selected, it would be built only to the capacity required for waste disposal). Design and construction should consider green practices and conservation of resources as much as possible. As a DOE action, any remediation will pursue sustainability as required in DOE O 436.1a *Departmental Sustainability* and per Executive Order 13693 *Planning for Federal Sustainability in the Next Decade.*

6.2.2.5.1 Wastewater Management Systems

A companion CERCLA document to this RI/FS, the *Focused Feasibility Study for Water Management from the Disposal of CERCLA Waste on the Oak Ridge Reservation Oak Ridge*, DOE/OR/01-2664&D2 (UCOR 2016) (IWM FFS), evaluates in detail the management of wastewater at both EMWMF and the proposed EMDF. The IWM FFS presents treatment alternatives for wastewater that fails to meet discharge criteria[15], and "Managed Discharge" for wastewater that meets discharge criteria (e.g., sampling and discharge). Several treatment alternatives are examined in the document, including continuing to truck to the ORNL PWTC as EMWMF currently does; building a pipeline to transfer wastewater to the ORNL PWTC or to the future Outfall 200 Mercury Treatment Facility for treatment and discharge; or building a new on-site treatment facility. The combination of Managed Discharge and an on-site (EMWMF/EMDF) treatment system is used in this RI/FS document as a "place holder", to allow for incorporation of a treatment cost in the on-site alternative cost estimates. A potential site for constructing the treatment system for the EBCV Site Option or the Dual Site Option would be the area adjacent and east of the existing EMWMF contact water tanks (see Figure 6-18). For the WBCV Site Option, a treatment facility might be located adjacent to the landfill (assumed for cost estimating purposes), or piping and pumping capabilities supplied to access EMWMF infrastructure.

The existing EMWMF leachate and contact water management systems (existing tanks) would be used for management of EMDF leachate for the EBCV and Dual Site Options. Due to the anticipated larger leachate volume for the combined EMWMF and EMDF leachate expected during the operational overlap of these two facilities, additional storage tanks would be needed with a total capacity of 1.5 M gallons. These tanks would be constructed in the area immediately east of the existing EMWMF leachate storage tanks. The leachate treatment system could be constructed in the area east of the existing contact water tanks. Proposed locations for these facilities are shown in Figure 6-18. Again, for the WBCV Site Option these support facilities would be located adjacent to the landfill or pumping/piping provided.

For details regarding the water treatment alternatives and their operation (discharge limits and discharge locations), refer to the IWM FFS. ARARs associated with the IWM FFS are incorporated into the ARARs table of this document. It is intended that complete merging of conclusions reached in the IWM FFS and this RI/FS are addressed at the Proposed Plan stage. A single ROD will address the final integrated alternative, and include ARARs from both the RI/FS and the IWM FFS. This is done to avoid "double review/double updating" of the water management approach. Therefore, necessarily, the coverage of the wastewater management in this RI/FS document is kept to a minimum. Costs, however, are entirely

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[15] Discharge criteria and locations are given in the IWM FFS. They are not repeated in this document. These criteria will be stipulated in a future ROD that will incorporate the results of both the IWM FFS and this RI/FS document.

captured within the On-site Disposal Alternative Options in this RI/FS. Cost assumptions are provided in Appendix I.

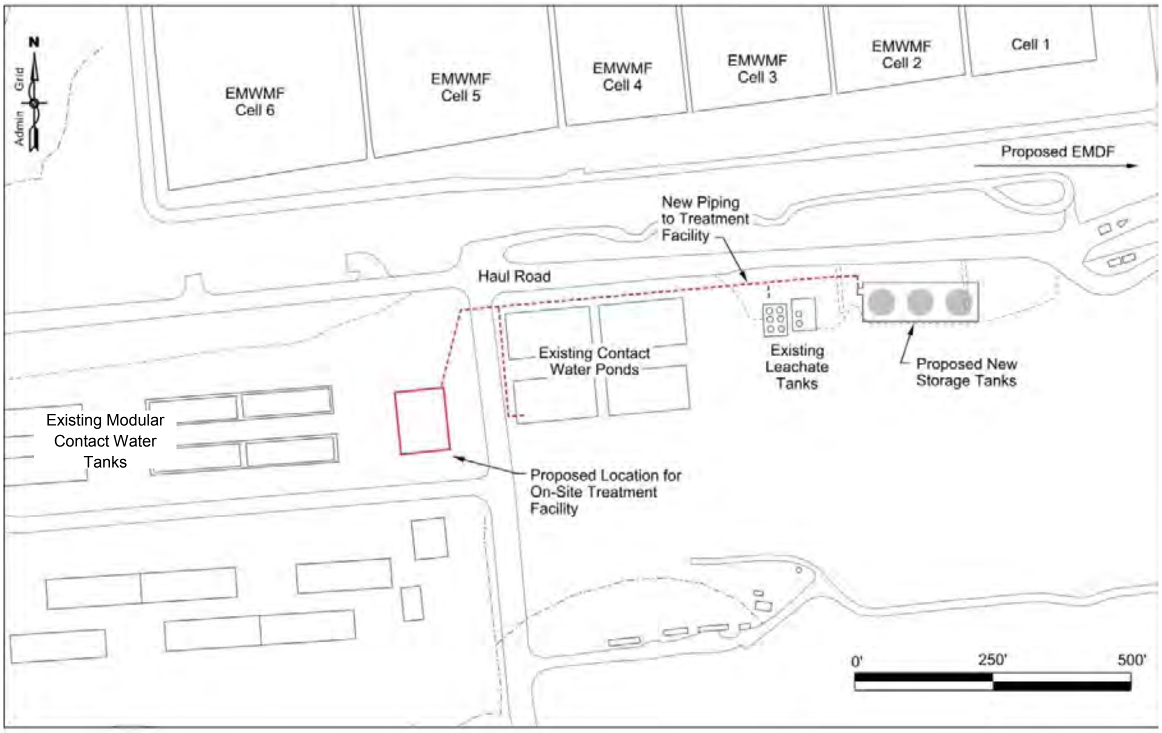


Figure 6-18. Proposed Locations for Water Treatment Systems for the EBCV Site and Site 6b Options

6.2.2.5.2 Wastewater Storage

Existing EMWMF leachate storage tanks and contact water basins and tanks will be used for collection and holding of leachate generated during operation of EMDF at the EBCV Site or Dual Site Option. For the WBCV Site it is assumed that new landfill waste water storage tanks and basins will be required. These EMWMF systems include transport tanker loading stations as a near-term or contingency measure for transporting wastewater to the ORNL PWTC for treatment and discharge (see 6-2). In addition to EMWMF storage systems, additional tanks will be constructed for the EMDF leachate, providing 1.5 M gallon storage capacity to accommodate additional leachate flow expected when both the EMWMF and EMDF landfills are operating at the same time (EBCV and Dual Site Options). As defined in 40 CFR 260.10, leachate is any liquid, including any suspended components in the liquid, which has percolated through or drained from hazardous waste. Landfill systems that collect and transfer leachate are described in Section 6.2.2.4. Leachate production is highly dependent on operational practices used to limit exposure of the waste to precipitation and weather conditions, with high volumes of leachate corresponding to periods of heavy rainfall. Leachate generation would be expected to increase as the volume of disposed waste increases and additional cells are opened; likewise, leachate generation would decrease with placement of interim covers. After capping and closure of the landfill, leachate volumes will significantly decrease because precipitation infiltration into the waste would be virtually eliminated. The capped landfill will dewater over time as leachate within the waste drains into the leachate collection system at a declining rate. Contact water and leachate storage tanks and basins would be removed over time as the leachate generation rate declines.

Leachate that has percolated through the waste and into the EMWMF LCRS is collected and stored separately in existing leachate storage tanks. The EMDF leachate collection system will be designed to provide a high permeability media near the bottom of the cell (referred to as "windows") that will allow water that falls into the cell to be collected in the EMDF LCRS. Temporary in-cell storage of water would still be available in emergency circumstances by closing valves that connect the lateral leachate transfer lines to the main leachate header. The EMDF leachate may be collected in existing EMWMF leachate storage tanks, existing basins, or new storage tanks constructed to increase leachate storage capacity. New leachate storage for the EMDF would be constructed to meet RCRA ARARs. When EMDF landfill operations begin, EMWMF and EMDF leachate and EMWMF contact water may be combined and managed as one stream. These assumptions, usage of EMWMF facilities, may require adjustments depending on the selected alternative; however, for purposes of cost estimating, the WBCV Site Option includes new facilities in the estimate because of the remoteness of the facility.

6.2.2.5.3 Storm Water Management

Storm water runoff that does not come in contact with waste materials would be directed through ditches and culverts directly into the storm water detention basin(s) and discharged, provided sampling indicates discharge criteria are met. Design for the EMDF storm water runoff takes into consideration the need to manage multiple storm events and also considers that this is a more specialized construction project than what is typically being evaluated. The most important lesson learned from EMWMF regarding storm water management is in selecting an appropriate storm event during landfill operations for the design basis. The EMWMF design followed the typical requirements for sizing holding basins, the 25-year, 24-hour storm event, but during the first year of operations EMWMF experienced well above average amounts of precipitation. It was not typically a single event that proved to be the problem, but several occurrences back-to-back. During construction of Cells 1 and 2 of EMWMF the amount of total suspended solids contained within the site discharge that released from the sediment basin and into Bear Creek drew attention of the state water quality regulators. The sediment basin was not providing the necessary time for the solids to settle out of the runoff. Problems were also seen once operations began. During the first year of EMWMF operations, May 2002 through May 2003, the total rainfall was 50% above average. This was compounded by precipitation that occurred over extended periods of time and as above average storm events. In calendar year 2003, EMWMF generated 7,570,000 liters of leachate. This was double what had been estimated as the annual quantity in the project design basis.

Footprint availability for sediment basins for the EMDF at the sites bordering EMWMF is a challenge. At the EBCV Site, the EMDF conceptual design utilizes multiple smaller basins to meet the anticipated capacity required. This approach works well with the Phased construction approach of the landfill, but will need to consider longer term sampling needs. Accommodating a single large basin may be more appropriate from a monitoring standpoint. The WBCV Site Option and Site 7a of the Dual Site Option have fewer constraints on land usage, and incorporate the needed infrastructure.

6.2.2.5.4 Other Support Facilities

The Haul Road extension supporting the UPF project has impacted wetland areas in the vicinity of the proposed EBCV Site footprint. Mitigation of this loss has been achieved through expansion and/or creation of wetland acreage at several locations within the Bear Creek watershed (B&W 2010). The eastern part of the proposed EBCV EMDF footprint, if fully constructed, would impact two of the expanded wetlands identified in the Aquatic Resources Alteration Permit (ARAP) issued in June 2010 (TDEC 2010). If the On-site Disposal Alternative EBCV Site Option is selected, coordination of EMDF activities with planned UPF project activities, including a modification to the ARAP, would be required. All sites, with the exception of Site 6b of the Dual Site Option, will require mitigation of wetlands.

Earthwork spoil materials that can be reused in future landfill construction would be stored on-site, since construction of the landfill would be phased for any site selected. Existing potable water/fire water, electrical, and communication lines used by EMWMF are in close proximity to the proposed landfill footprints at EBCV Site Option and Site 6b of the Dual Site Option, and could be extended as needed for the new facility or brought on-site from Bear Creek Road lines. WBCV Site Option and Site 7a of the Dual Site Option would both require extension of utilities from Bear Creek Road lines. Water from showers and toilet facilities would be temporarily stored in a collection tank prior to transport for treatment at an off-site sanitary treatment facility as is currently the practice for EMWMF.

Waste operations would be conducted in the exclusion area, which would be assumed to be contaminated during operations. Any personnel, equipment, vehicles, or containers leaving the exclusion area would be monitored and, if necessary, decontaminated. Clothing worn in the exclusion area would be managed by an off-site contractor/facility. An enclosed decontamination facility with high-pressure water spray equipment, a collection sump, and pump would be available to inspect and decontaminate vehicles, equipment, and containers. It is anticipated wastewater from decontamination operations would be pumped to a temporary storage tank. The wastewater would be combined with leachate for treatment or used for dust control in the exclusion area.

An equipment storage, maintenance, and fueling area would be constructed in the exclusion area for use during operations. A waste staging area inside the exclusion area would serve as a temporary storage area for incoming waste. This area would be used if the rate of incoming waste deliveries exceeds the rate of waste placement in the disposal facility, as could occur during inclement weather. A covered storage area would be included in the staging area.

6.2.2.6 EMDF Conceptual Design Summary

Conceptual final cover grading plans for the EMDF landfill at the proposed site locations are shown in Figures 6-19 through 6-21. Site-specific calculations for final cover material quantities were made and included in each cost estimate. Landfill cross-sections for each site location are depicted in Figures 6-22 through 6-25.

The conceptual design for EMDF at the various locations would provide disposal capacities of between approximately 2.25 M and 2.8 M yd^3 (see Chapter 2). Each landfill would be somewhat rounded in shape to enhance geomorphic stability and more closely model the natural topography of each site. The approximate total area of each site for development, including temporary construction activities, existing and new support facilities, and spoils areas is presented in Table 6-2. With the given layouts, the landfill footprint (computed to the outside edge of grading for perimeter clean-fill dike) areas are as given in the table. Commitment of land (area) post-closure is the last entry in the table.

Table 6-2. Land (Acreage) Usage at On-site Facility Locations

EMDF Site Location	Acreage for Development [a]	Footprint of Disposal Facility [b]	Area of Permanent Commitment
EBCV Site Option	71[c]	48	70
WBCV Site Option	94	52	71
Dual Site (Site 6b/7a) Option	127[c]	68	109

[a] Area for development, including temporary construction activities, existing and new support facilities, and spoils areas.
[b] Area of disposal facility footprint, computed to the outside edge of grading for perimeter clean-fill dike.
[c] Areas for development at Sites EBCV and 6b have been reduced by 21 acres because that acreage is already developed for the EMWMF facility.

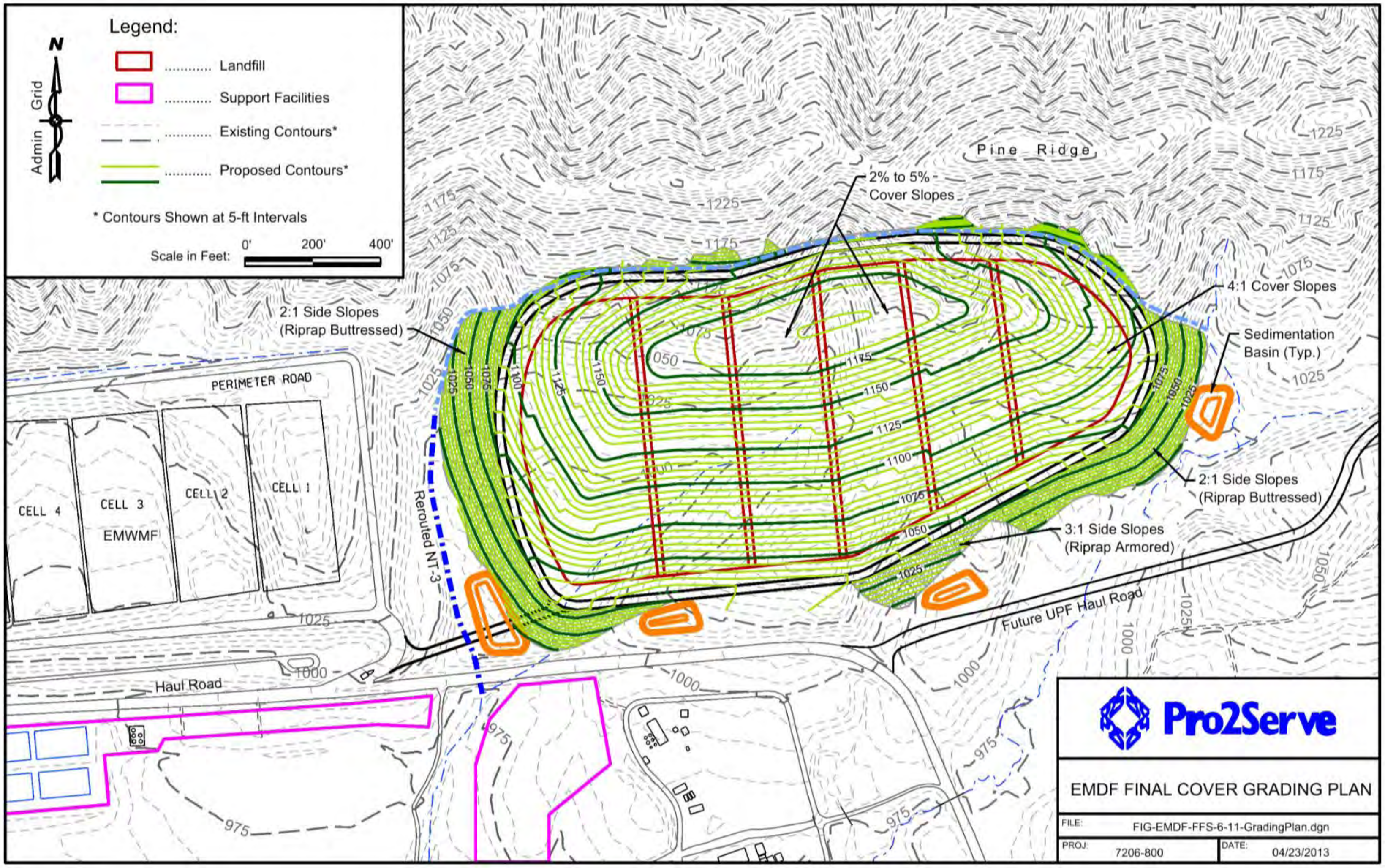


Figure 6-19. EMDF Final Cover and Grading Plan for EBCV Site Option

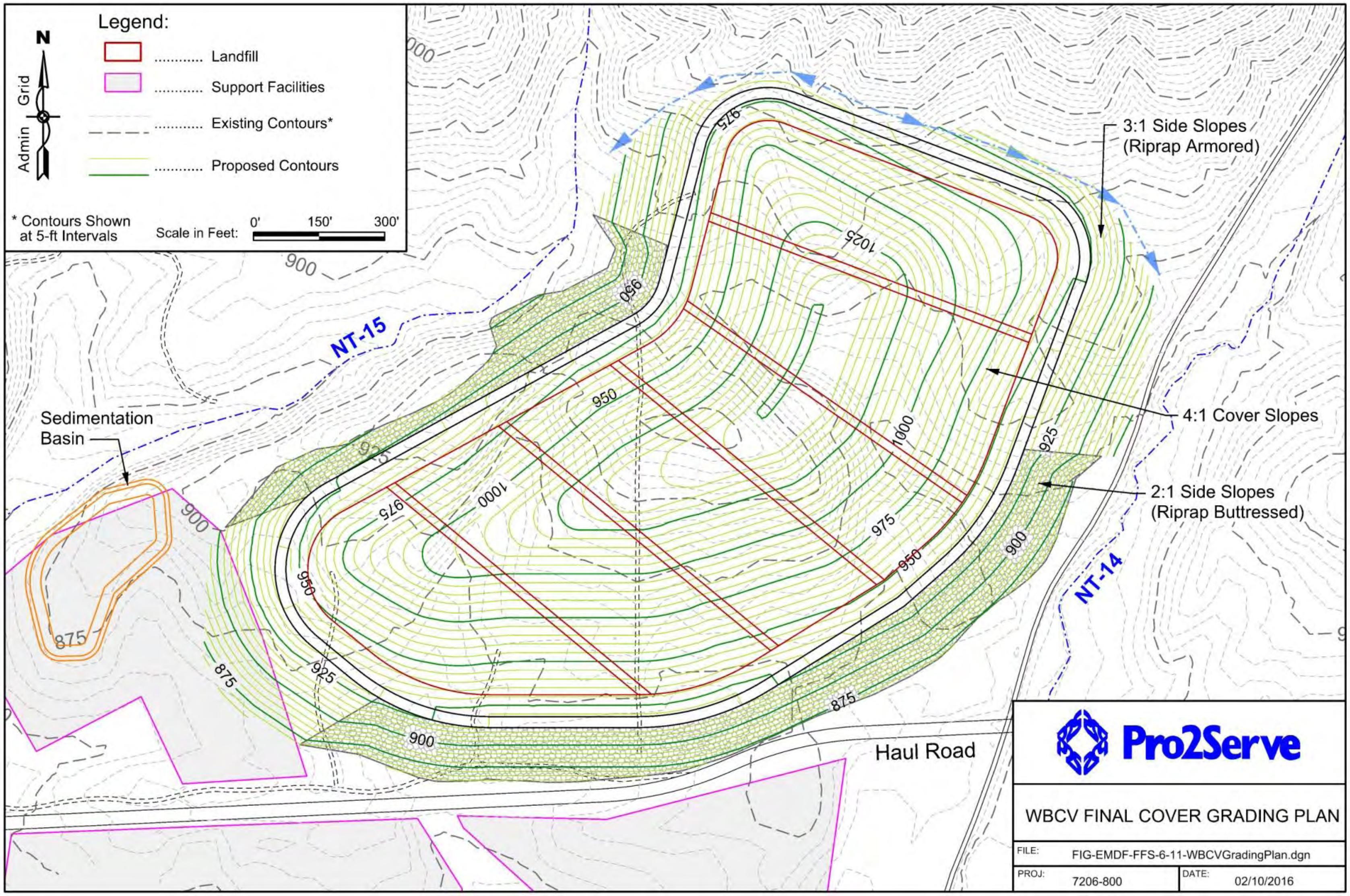
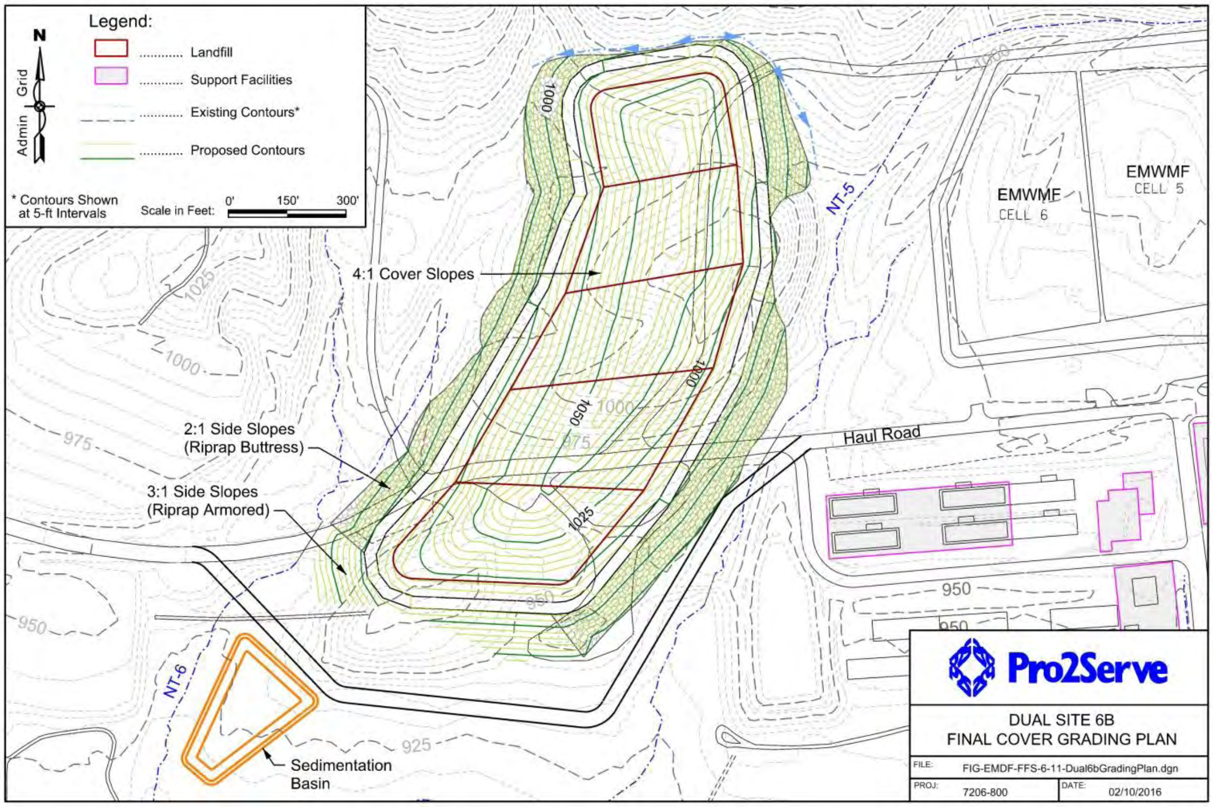


Figure 6-20. EMDF Final Cover Grading Plan for WBCV Site Option



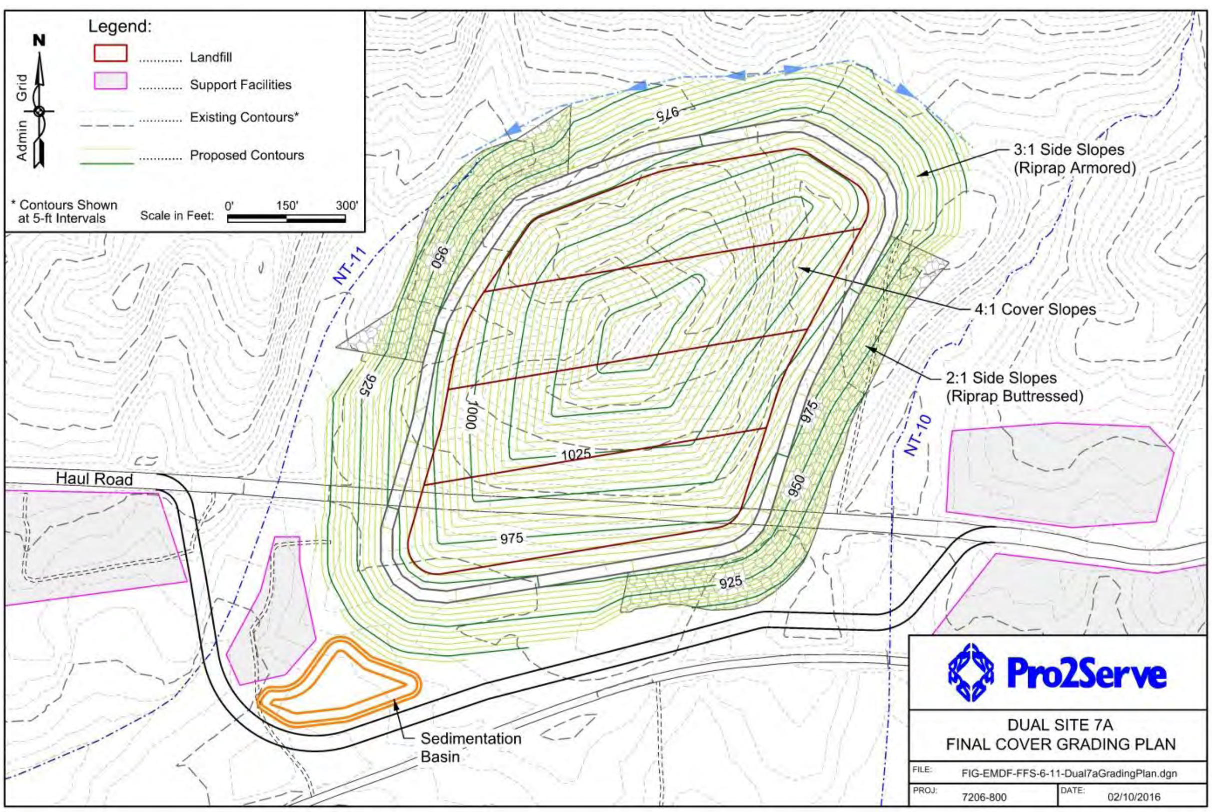


Figure 6-21. Dual Site Option (Sites 6b and 7a) Final Cover Grading Plans

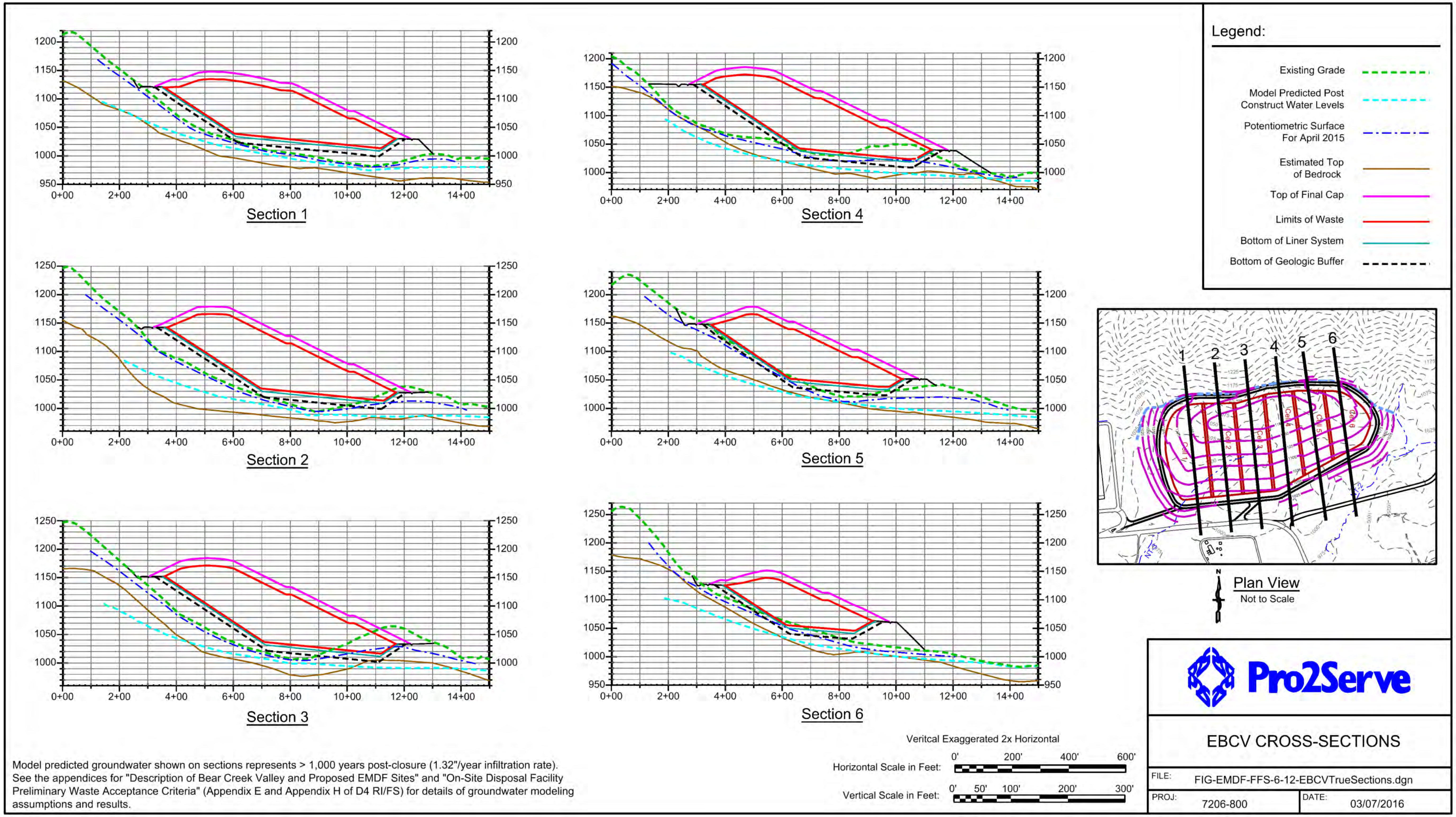


Figure 6-22. EMDF Cross-sections for EBCV Site Option

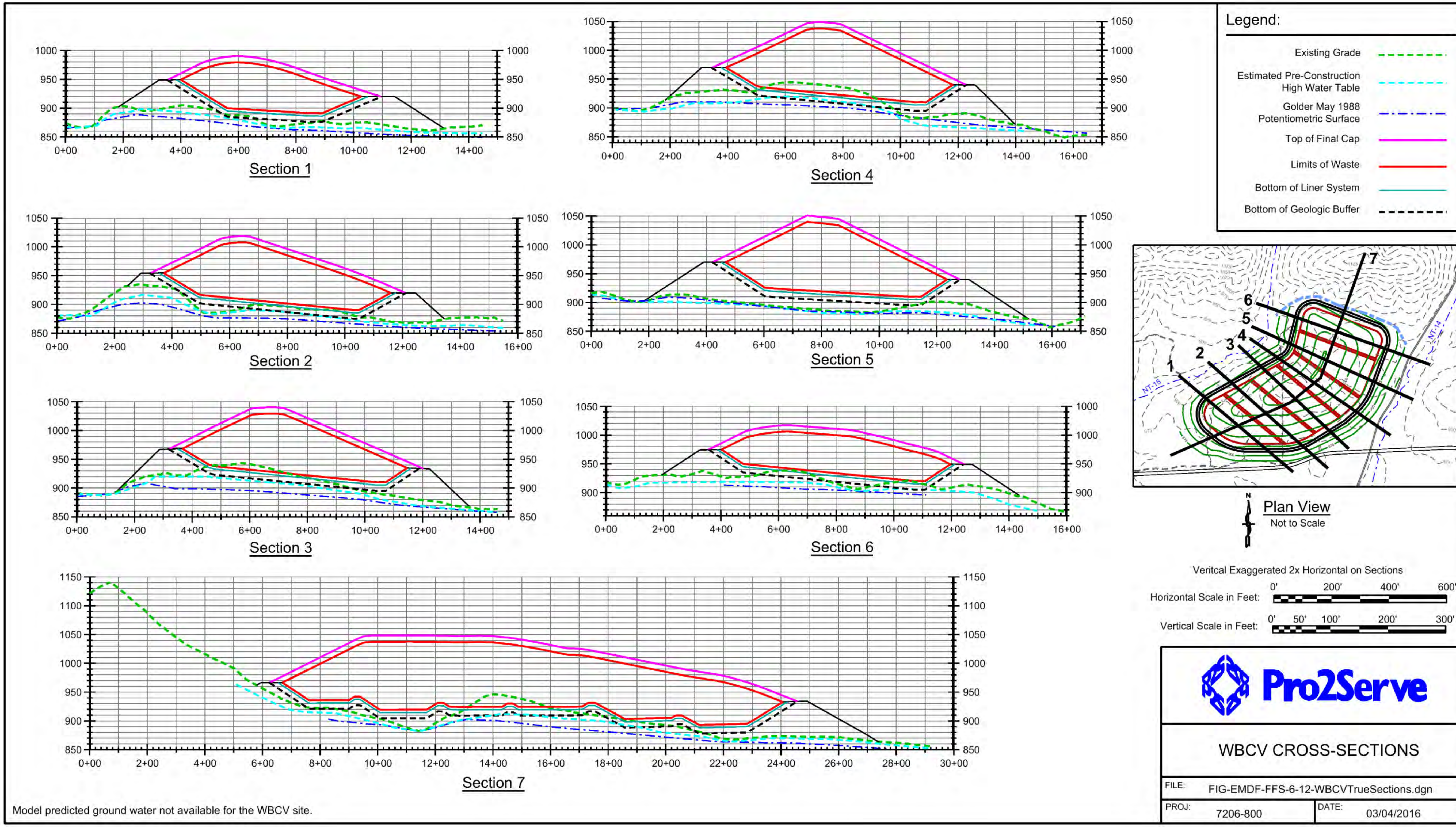


Figure 6-23. EMDF Cross-sections for WBCV Site Option

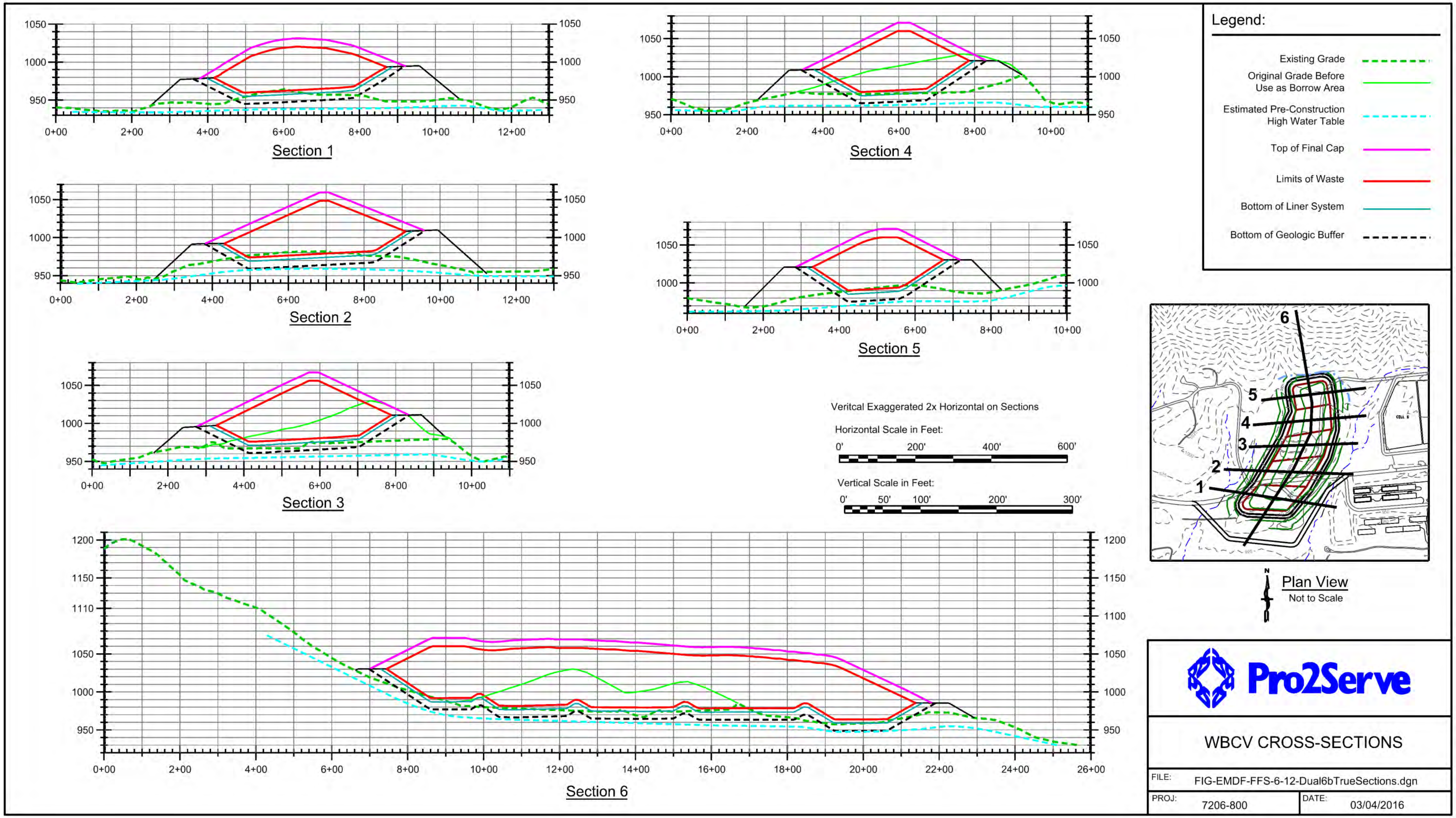


Figure 6-24. EMDF Cross-sections for Dual Site (6b) Option

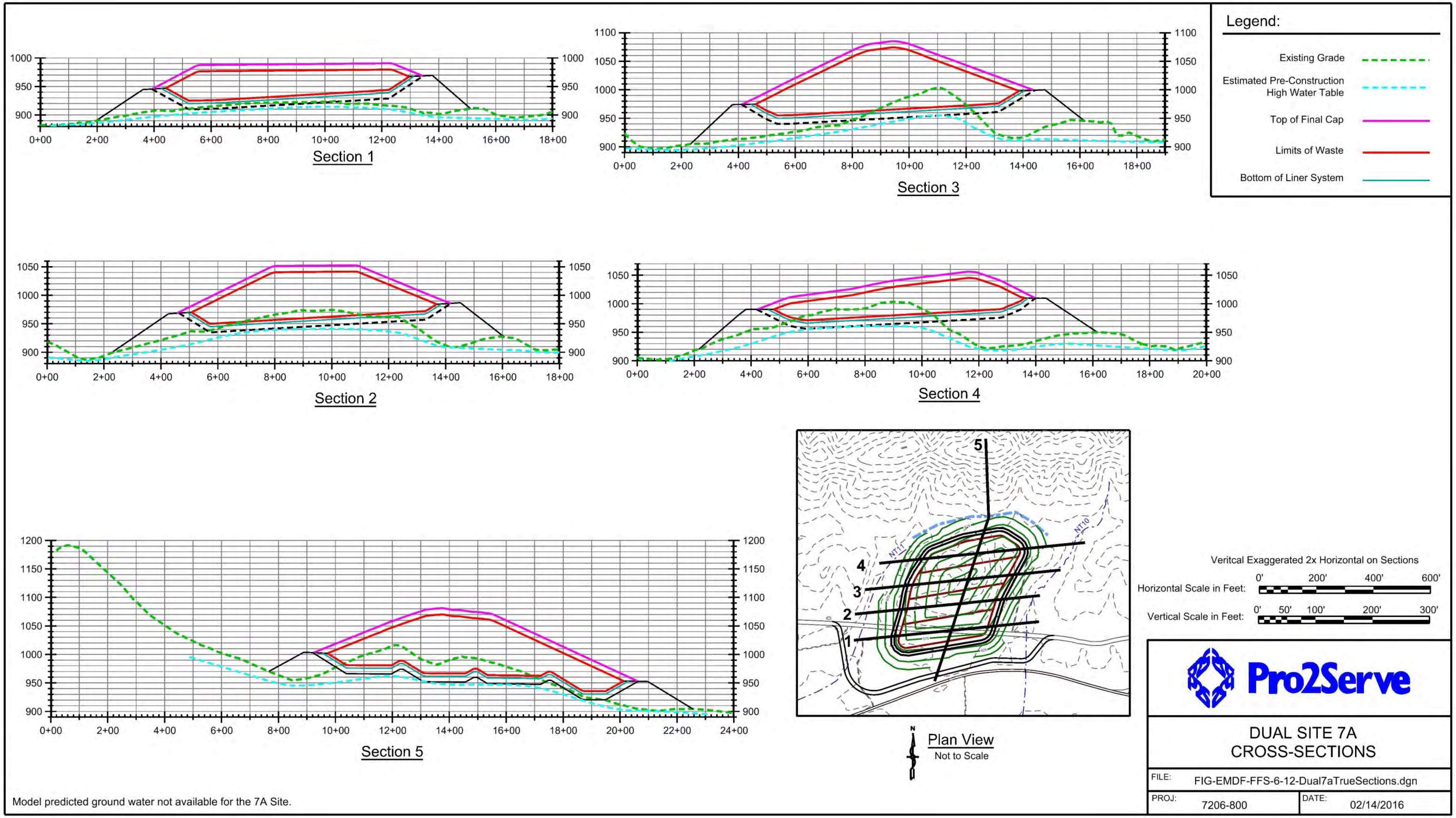


Figure 6-25. EMDF Cross-sections for Dual Site (7a) Option

This committed area would consist of the landfill (as delineated by the limits of grading), roads for accessing the landfill, and leachate management areas (see Figures 6-16 through 6-19). The remaining acres (difference between development acreage and permanent acreage) would provide for miscellaneous support facilities and spoils areas during active operations, and could be converted to meet other future project needs or be decommissioned and removed at landfill closure. The total area of disturbance at any point in time would be reduced by phased construction (only constructing 2 cells during each phase as opposed to the entire site footprint as one phase allows use of the future cell face for spoils storage etc.), reuse of construction spoil, implementation of BMPs to manage sediment and erosion during construction activities, and other detailed design considerations. Site specific accommodations are assumed at each location, for example, a new larger culvert would be constructed to carry NT-3 and runoff from the EMDF beneath Haul Road at the EBCV Site. Sediment basins would be constructed in phases along the sides of each landfill. Depending on the outcome of detailed storm water calculations performed during remedial design, one or more sediment basins may be retained as permanent storm water detention basins. Also, consideration would be given to converting the sediment basins to wetlands.

Vehicle access to EMDF at all sites would be provided from the existing Haul Road, although for Sites 6b and 7a (Dual Site Option) routing of the Haul Road around each footprint will be necessary. Existing or new access roads have been accommodated in each conceptual design and cost estimate. As shown in proposed site plans (Figures 6-2 through 6-5) and summarized previously in Table 6-2, existing support facilities are assumed to be utilized in some instances, and new support facilities would be located as needed, and are accounted for in estimates.

Detailed analysis of the various components of each landfill is outside of the scope of the conceptual design. Thorough calculations and development of proactive procedures will be performed as part of the final design and operations work plans for the landfill to ensure a safe and effective system is put into place. Table 6-3 summarizes topics that are considered in final design along with major considerations and calculations that will be performed.

Table 6-3. Final Design Topics and Considerations

Design Analysis Topic	Points of Consideration
Clean fill dike stability	• Incorporating site characterization data to set size and elevation of dike to maintain appropriate ground water buffer requirements for landfill • Calculating needed soil mass at landfill toe • Calculating maximum allowable slopes • Designing appropriate slope armoring • Setting compaction and lift placement requirements
Waste mass failure (during operations)	• Placing waste at appropriate slopes • Developing operational procedures and compaction requirements for filling voids • Ensuring proper drainage of water within cells
Liner stability	• Calculating maximum allowable slopes • Selecting appropriate geosynthectics for predicted site conditions • Following manufacturer's recommendations regarding design and installation • Designing appropriate anchor systems at landfill perimeter

Table 6-3. Final Design Topics and Considerations (Continued)

Design Analysis Topic	Points of Consideration
Liner leakage failures	• Conducting a thorough site characterization prior to design so that liner system is set at elevations to maintain appropriate ground water buffer requirements for landfill • Designing layer thicknesses, layer types, layer slopes, and collection piping so as to ensure appropriate liquid removal rates • Designing system to prevent clogging (e.g., materials used) • Design system using real data to supplement and validate model predictions • Utilizing an independent quality assurance/quality control program during construction
Wastewater Management System Failure	• Calculating appropriate leachate collection piping sizes • Calculating appropriate required on-site storage volumes • Designing for severe precipitation scenarios with appropriate safety factors • Incorporating redundancy and contingency into design • Incorporating operations practices that shed clean water away from contacting waste to reduce wastewater
Cap failure due to voids formation or differential settlement	• Calculating and designing appropriate cap layer thicknesses and slopes to ensure movement in waste can be tolerated by cap system without failing • Developing operational procedures and compaction requirements for filling voids
Underdrain failure	• Conducting a thorough site characterization prior to design so drainage system can be properly designed and sized • Ensuring all seeps and springs are captured with drainage system • Following natural surface water drainage flow paths with system • Creating redundancy to minimize effects of clogging • Using graded filtration to minimize effects of clogging • Excavating and removing unsuitable residual materials within drainage paths prior to construction of system
Upgradient ditch failure	• Conducting a thorough site characterization prior to design so drainage system can be properly designed and sized • Lining of ditches to inhibit surface water from entering into ground as water is diverted around landfill • Installing a shallow ground water intercepting French drain system • Allowing safety factors (sizing) ground water intercepting French drain system • Avoiding ditch bottom slopes that might lead to collection of water over time
Landfill failure due to earthquake	• Conducting a thorough site characterization prior to design to evaluate that geologic bedding planes are not earthquake sensitive • Adhering to TDEC Earthquake Evaluation Guidance Document • Evaluating the shear properties of landfill liner, landfill cap, and landfill waste mass

6.2.2.6.1 Layout Approach

A number of factors were considered when selecting and laying out the conceptual design of the EMDF landfill at the various location options, including its location adjacent to legacy waste management (brownfield) areas, proximity to EMWMF, and the area available to feasibly construct the facility (see Appendix E) and support structures.

EBCV Site Option

The proposed EMDF footprint at this site is located in Zone 3 of Bear Creek Valley, with Brownfield areas to the west (EMWMF), east/southeast (S-3 ponds), and south (BY/BY). Future land use designation of Zone 3 is DOE Industrial. The approach used to set the extents of the landfill waste and perimeter features was based on maximizing the disposal capacity that could be achieved while minimizing impacts to existing features such as site infrastructure and natural resources. Layout constraints for the disposal facility are described below:

- A 200 ft buffer between the waste and NT-2 was maintained and was set as the eastern constraint. Note this preliminary distance was selected to avoid wetlands and low-lying areas and may be adjusted up or down during the design process depending, in part, on the results of site characterization studies and ground water modeling. Design ground water modeling will demonstrate the landfill is sited a sufficient distance away from NT-2 to protect human health and the environment. Post-construction ground water and surface water monitoring will confirm the design is protective of human health and the environment.
- The southern constraint was set by the existing Haul Road and avoiding any impact to that road and associated overhead power line. Keeping the landfill footprint north of the existing Haul Road avoids shallower ground water, Bear Creek floodplains, and existing buried hazardous waste located to the south. It also avoids impact to areas designated for use by the planned UPF Project (see Figure 6-16).
- The western constraint was set by having an adequate drainage pathway between EMWMF and the new disposal facility to manage any surface water runoff around the two facilities, as this would become the rerouted location for NT-3. Final grading of the new landfill would divert some of the runoff that previously discharged to NT-3 over to NT-2.
- The northern constraint was set by the steep upper slopes of Pine Ridge which have typical slope ratios of two horizontal to one vertical (2:1) or steeper. Making cut slopes steeper than the natural slopes of Pine Ridge was avoided since it could cause the ridge slopes to become unstable. Also, it was necessary to somewhat match the existing slopes of Pine Ridge where the perimeter road and ditches would tie into existing grade along the north side of the landfill. Using a leveled backslope was undesirable since it would create an excessively high cut slope that would make it impossible to intersect any new grades to the existing grades near the crest of Pine Ridge. Another consideration for the north side of the landfill was to ensure the perimeter road that travels from the lower south side of the landfill up to the higher north side was not too steep for vehicles. A maximum roadway grade of 8% was set to control this and also controlled the elevation on Pine Ridge for the northern edge of the landfill.

WBCV Site Option

The proposed EMDF footprint at this site would be constructed in a Greenfield (Zone 1 of Bear Creek Valley), where the current designated future land use is Unrestricted. If this site is the selected alternative, a change to the future land use designation to DOE-Controlled Industrial would be required. The approach used to set the extents of the landfill waste and perimeter features was based on maximizing the disposal capacity that could be achieved while minimizing impacts to existing natural resources. The WBCV site offers the most area for adjusting the layout of the landfill. Layout constraints for the disposal facility are described below:

- The eastern constraint for the WBCV landfill was set based on an existing access road that roughly parallels the western edge of NT-14. This was done in order to take advantage of the existing access point to the site. This also provided a substantial buffer between the waste and NT-14 maintaining at least a 300 ft distance between the two edges.

- Like the EBCV site, the southern constraint was set by the existing Haul Road and attempting to avoid any impact to that road and the associated overhead power lines. This has the same benefit of avoiding the shallower ground water associated with the low lands around Bear Creek and ensuring that the landfill is well out of any floodplains.
- The western constraint was set using NT-15 and the existing slopes along this tributary so that any knoll areas could be used to buttress the perimeter of the landfill. Using the knoll side slopes ended up setting the minimum buffer distance between the edge of waste and NT-15 to 250 ft.
- The main three factors for setting the northern edge the WBCV landfill were to avoid cutting into the slopes of Pine Ridge, provide an acceptable slope along the perimeter road, and maintain drainage around the edge of the landfill for runoff from Pine Ridge.

Dual Site Option (Site 6b)

The proposed EMDF footprint at this site would be constructed with Brownfield areas to the west (BCBGs) and east (EMWMF). The current future land use designation of this site is DOE Industrial. The primary driver for setting the extents of the landfill waste and perimeter features for Site 6b was based on maximizing the disposal capacity that could be achieved while minimizing impacts to natural resources. Existing infrastructure impacts were less of a concern for laying out the extents of this landfill than for the WBCV and EBCV options. Layout constraints for the disposal facility are described below:

- The eastern constraint for Site 6b was set using existing knoll slopes while maintaining 200 ft between the edge of waste and NT-5. For a portion of the landfill, the side slopes of the old borrow area knoll were used as a buttress to set the eastern edge of the landfill. For the rest of the eastern edge, maintaining at least a 200 ft buffer between the edge of waste and NT-5 set the limits of waste.
- Due to the limited area in the east-west direction, the southern constraint for Site 6b was pushed further south than that for the EBCV and WBCV sites in order to achieve more volume. The southern edge of the waste was set so that an existing knoll could partially serve as a buttress at the south edge of the landfill, while still providing enough area to reroute the Haul Road and the associated overhead power lines. Using this knoll also maintained an adequate elevation to avoid the shallower ground water in the low lands near Bear Creek and provided some area for new support facilities.
- The western constraint was set by NT-6 so as to maintain 200 ft between the edge of waste and the tributary.
- Like all other options, the northern edge was set based on the slopes of Pine Ridge so as to avoid cutting into the side of the ridge, provide adequate perimeter road slopes, and promote drainage from Pine Ridge to travel around the landfill edges and into existing drainage channels.

Dual Site Option (Site 7a)

The proposed EMDF footprint at this site would be constructed in a Greenfield (Zone 2 of Bear Creek Valley), where the current designated future land use is Recreational and the future land use is Unrestricted. If this site is the selected alternative, a change to the future land use to DOE-Controlled Industrial would be required. The approach used to set the extents of the landfill waste and perimeter features at Site 7a involved minimizing impacts to Bear Creek tributaries while maximizing disposal capacity. Impacting existing infrastructure was a secondary consideration. It is noted here that Site 7a is quite similar to Site 7b, and if selected, a detailed examination of both (adjacent) locations would be made to select the best site. Layout constraints for the disposal facility are described below:

- The eastern edge of the landfill was set so that new grades would best tie to the existing grades at the site. This resulted in a minimum 300 ft buffer between the edge of waste and NT-10.

- Like Site 6b, the proposed southern edge of the landfill would require relocation of the Haul Road and overhead power lines in order to maximize volume. The southern boundary was set to avoid impacting Bear Creek Road with the relocated segment of the Haul Road. In this area of the valley, Bear Creek Road is located in close proximity to the Haul Road.
- The western edge of the landfill was again set so that new grades would best contour into existing grades while maintaining a minimum 200 ft buffer between the waste and NT-11.
- The northern edge of the landfill for Site 7a varies slightly from the other three options. The objectives of avoiding cutting into Pine Ridge, providing the proper slopes around the perimeter road, and maintaining drainage around the landfill perimeter were the same, but the approach to achieve these objectives was not. In order to avoid filling in a particularly severe ravine above the proposed landfill site, the landfill perimeter was pulled to the south and fill was used to build up the berm along the northern edge of the landfill. For the other sites, the northern perimeter of the landfill better followed the existing contours of Pine Ridge.

6.2.2.6.2 Phased Construction Approach

All EMDF conceptual designs allow for construction of the landfill to be completed in phases over the cleanup timeframe. Cost estimates assume this phased construction approach. The landfills would have multiple cells and it is anticipated that each phase would construct two or three cells (with the exception of Site 6b, which is constructed fully in a single phase). This approach promotes using gravity drainage for piping systems and consolidates brownfield areas if later phases of the landfill construction are not needed. It accommodates the uncertainty in waste volume estimates; as cleanup progresses and uncertainty in waste volumes decrease a smaller final landfill may easily be the result for any of the proposed sites.

For the EBCV Site, building over NT-3 would be an important consideration as part of the detailed design and phased construction approach. The conceptual design assumes that the entire NT-3 underdrain system would be constructed as part of Phase I (Cells 1 and 2). Phase I would then also include part of the rough grading that would be required to complete Phase 2 construction (Cells 3 & 4). The rough grading would direct surface water runoff away from Cells 1 & 2 and toward the NT-2 drainage area. The conceptual design indicates that cells would be constructed from west to east, but there is flexibility in how the phases can be executed. It likely may be advantageous to construct Cells 3 and 4 and associated underdrain first, followed by Cells 1 and 2 in the subsequent phase. As the design evolves, alternative phased approaches may prove to be more appropriate.

Similarly, for other sites considered, underdrain features and site topography and hydrology would need to be carefully considered in terms of the phased construction.

6.2.2.6.3 Predicting Seasonal High Ground Water Elevations

Just as important as surface constraints to design layouts as described in the approach above, is the constraint set by the ground water table under any site. The EBCV and WBCV Sites have enough monitoring data available to give a reasonable indication of the seasonal high water table elevations at those sites, but this information is lacking for Sites 6b and 7a. Detailed descriptions of existing site characterization efforts performed for the sites can be found in Appendix E.

Understanding expected seasonal high ground water levels is a key element to designing a landfill. The goal of the EMDF conceptual design was to begin the process of establishing landfill base elevations that would ensure long-term protection from ground water intrusion, a process that would be continued and refined as more data is collected at each site. The intent in the conceptual layout is to establish the lowest allowable elevation of the EMDF landfill bottom and still maintain a minimum 10 ft buffer between the bottom of the liner system and the estimated seasonal high ground water elevations. Technical experience at EMWMF has given the opportunity to implement improved practices for setting landfill elevations at the new sites. A pneumatic piezometer located below the waste on the north side of EMWMF has measured a rise in pressure in that location. While the cause has not at this time definitively been identified, the occurrence has highlighted the need to carefully consider ground water elevations in design.

How the water table would be altered over time with landfill construction was also a consideration. Upgradient drainage and the landfill itself will cut off a large amount of recharge within the footprint. A detailed description of this effect is discussed in Appendix E Section 2.9 and Chapter 3. Southern knoll areas at each site will likely see drastic decreases in water table levels once the impermeable layers of the landfill have been constructed. EMWMF likewise has a southern knoll area, which has not had any indication of the water table impinging on the buffer system.

EBCV Site Option

Estimating seasonal high ground water elevations for the EBCV site has been an iterative process. The first iteration of the this landfill conceptual design was done prior to the Phase 1 site characterization and was based on a potentiometric surface estimated from a combination of data obtained from *The Y-12 Ground Water Protection Program Location Information Database* (B&W 2012) and data used to build the BCV hydrogeologic conceptual model for Bear Creek. Originally there were no wells or boring data within the proposed EMDF footprint; however, wells and ground water data in adjacent areas east, west, and south of the site were available. Seasonal high ground water contours were estimated based on maximum water elevations measured for wells near the site and elevations of existing seeps, springs, and tributaries near and within the site. The locations of the existing drainage ways within the proposed EMDF site were assumed equal to the top of the ground water table during seasonal high conditions (i.e. the drainage ways would be a ground water discharge point). For the higher elevations of the proposed site, the seasonal high ground water elevations were predicted by assuming that the depth to ground water would be similar as seen in nearby wells at the same ground surface elevation and in the same geologic formation. Evaluation of the available data demonstrated that ground water could be very shallow within the EMDF footprint during certain times of the year, which lead to the conceptual design grades being set above the existing grades for a majority of the landfill footprint area. Once the first iteration of the landfill conceptual design was finalized, the resulting proposed elevations for the key landfill layers were provided for comparison with model predicted ground water table elevations, to ensure the conceptual design did not infringe on the predicted ground water table.

After these first efforts were conducted, limited Phase I characterization was performed. This provided ground water elevations for five well locations within the footprint, and a seasonal high water table was predicted based on this limited Phase I site characterization study data. The bottom (geobuffer and liner system) of the first iteration of the landfill design was then compared to these new ground water surfaces. This comparison showed areas where the predicted ground water levels intruded into the geobuffer layer of the first iteration of the landfill design. For the area of the landfill constructed into the knoll in the southern portion of the site it is anticipated that construction activities and landfill components can effectively manage the water table in this area by eliminating recharge and diverting water. (See Section 2.9 and Chapter 3 of Appendix E for a detailed discussion for site specific water level data and how landfill construction will affect the water table.) The area that was cause for concern was the area along the side slopes of Pine Ridge. Phase I characterization demonstrated how ground water could be quite shallow in this area. The geologic buffer for the first iteration of the EMDF appeared to intercept this shallow water table where the cell floors abruptly turned into the cell side slopes. Refer to the EMDF cross-sections for the EBCV option in Section 6.2.2.6 (Figure 6-22) for illustration. While the water table is expected to be substantially lowered in the long-term, post-construction site conditions will still allow for recharge from Pine Ridge to travel towards the landfill so a second iteration of the landfill conceptual design was created to raise the bottom of the landfill. The purpose of this was to ensure that it was feasible to construct the landfill such that it could provide long-term protection against ground water intrusion in the geobuffer. Trying to fit the bottom of the landfill into the natural bowl shape of the site without intercepting the ground water table traveling down Pine Ridge required that the landfill be mostly built above existing grades. This can be seen in the cross sections by comparing the bottom of the geologic buffer (the black dashed line) to the existing ground surface (the dashed green line). This resulted in the need for a considerable amount of fill material across the site for this conceptual design, and is accounted for in the cost estimate presented in this document.

WBCV Site Option

A substantial amount of ground water data already exists for the WBCV site and is discussed in Chapter 6 of Appendix E. Golder and Associates created two potentiometric maps of the WBCV site in the late 1980s. One map presented water levels for August of 1987 and one map represented water levels for May of 1988. The water levels for May of 1988 show the ground water table at slightly shallower elevations than the August 1987 map therefore the May 1988 potentiometric map was used as a starting point for estimating the seasonal high water table at the WBCV site. These maps can be found in the above referenced chapter of Appendix E. Since the water levels used to create the May 1988 map were monitored for a fairly brief time period, additional water data were examined to judge how the water table might fluctuate with seasonal changes. These additional water level readings were extracted from the *The Y-12 Ground Water Protection Program Location Information Database* (B&W 2012) and tabulated for comparison to the Golder levels shown on the May 1988 map. Additionally, the Phase 1 characterization for EBCV and how the water table fluctuated across that site was considered. It was assumed that the similar geology and topography should result in similar behavior of the water table in response to seasonal changes in the weather. It was concluded that the May 1988 potentiometric surface was likely not representative of seasonal high water levels for some areas of the site and a more elevated water table was conservatively created to set the bottom of this landfill. See the EMDF cross-sections (Figure 6-23) for the WBCV site for the estimated seasonal high water table used in the conceptual design process.

Dual Site Option: Site 6b (also Hybrid Disposal Alternative Site)

With the exception of Pine Ridge bordering it to the north, Site 6b has features that differentiate it from the other sites considered for the EMDF. Its use as a borrow area for the EMWMF has resulted in a much flatter area than the other sites which results in a flatter water table. Comparison of topography from before borrow activities began against design drawings of proposed final excavation grades results in a volume change of over 300,000 yd^3 with changes in elevation reaching as much as 60 ft at the highest pre-excavation elevations. Existing site characterization for Site 6b is very limited and is discussed in Chapter 4 of Appendix E. Several sets of well clusters are located at the perimeter of the proposed edge of waste, but none exist near the center. Seasonal high water levels were assumed to average about 15 ft deep across the site with some areas having closer to 20 ft of depth and some areas having as little as 5 ft of depth. This was based primarily on monitoring data from wells GW-372 and GW-373 which had recorded minimum depths to water of 12.5 ft and 15.7 ft (B&W 2012).

The water level used to set the bottom of the landfill for the Site 6b conceptual design can be seen on the cross-section in Section 6.2.2.6, Figure 6-24. The pre-excavation surface is also shown for information. The relatively flat nature of the site actually results in the least buffer between the bottom of the waste and the seasonal high ground water table than at any of the other sites. This is because at the sites where the terrain is more variable, the location where the water table is the highest drives the overall cell floor which means most of the remaining area of the floor is elevated well above the water table. However, more fill material is required at the other sites to achieve the needed buffer.

Dual Site Option: Site 7a

Similar to Site 6b, almost no site-specific data are available for Site 7a for estimating a seasonal high water table. What data do exist for this site are discussed in Chapter 5 of Appendix E. Engineering judgment was used to estimate a seasonal high water table for Site 7a based on high water levels observed at similar sites such as EBCV and WBCV and the same assumption of the tributaries representing the top of the water table during seasonal high conditions (i.e. the drainage ways would be a ground water discharge point. The high water table used in the conceptual design of this landfill is shown on the EMDF cross-section for Site 7a (Figure 6-25).

6.2.2.6.4 Data Gaps and Uncertainties

Varying extents of data exist for the proposed sites; all sites will require more extensive characterization, if selected. Well and boring data within the EBCV Site are limited to those contained in the Phase I Site Characterization Report, and areas immediately adjacent to the site have been well characterized. Also documented in the Phase I report is one year of hydrology monitoring in the proposed footprint of the EMDF in EBCV. T&E Species and Stream and Wetland Delineation Surveys were completed for the EBCV Site, although some confirmatory information remains to be collected. The WBCV Site was extensively studied and reported on in 1980 – 1990 timeframe (Golder 1988a/b/c/d, and 1989a/b/c). Some of that information would be applicable to all sites, as they are all located roughly along geologic strike with one another and in areas of generally similar topography. Site 7a (and 7b) has the least documented characterization; while some data exist for Site 6b, as it is the borrow area for EMWMF.

The conceptual design for the EMDF at each site is based on ground water, geologic, and geotechnical data obtained in the vicinity of the sites and within footprints if available. These data are sufficient for formulating a conceptual level design for the EMDF at each site and assessing the feasibility of constructing a CERCLA disposal facility. If one of the sites in the On-site Disposal Alternative is selected for implementation, a formal site characterization effort would be conducted as an early action in support of detailed design, building onto the information gained and lessons learned during Phase I characterization at the EBCV Site. The process of collecting, analyzing, and applying site specific data will continue into the final design to ensure that ground water buffer requirements are met.

6.2.2.7 Process Modifications

Based on future engineering studies and additional data on subsurface conditions, waste types, and volumes, process modifications may be incorporated into the final design. Process modifications or techniques could be used to maximize effectiveness and efficiency of EMDF.

Process modifications that may be considered for EMDF include geochemical immobilization technologies designed to retard movement of contaminants; in-cell solid waste treatment to enhance waste stability/reduce leachability, meet LDRs, and reduce waste transportation costs while increasing safety considerations; and a modified cap vegetation strategy to enhance cap stability and reduce long-term maintenance costs. The process modifications discussed in this section are not included in the base conceptual design. If these enhancements are deemed to be beneficial and feasible, they could be added to the landfill design or operational procedures, as appropriate, to enhance the implementability, performance, or cost effectiveness of the project.

6.2.2.7.1 Geochemical Immobilization

PreWAC are presented in this RI/FS based on conceptual facility design and assumed receptor exposure conditions (see Appendix H) for the EBCV Site design. For calculating the PreWAC, wastes are conservatively assumed to be disposed of throughout the waste layer without segregation. However, geochemical immobilization of soluble waste radiological constituents with long half lives or other hazardous contaminants and an innovative waste placement strategy could enhance the performance of the landfill by reducing or limiting long-term migration of contaminants.

Immobilization technologies could be used to reduce solubility of uranium or other constituents in waste. Uranium immobilization technologies include:

- Performing pretreatment of soluble uranium (U^{6+}) to immobilize it as an insoluble mineral.
- Using Apatite II™ and zero-valent iron as reactive barriers or geochemically reactive fill additives in the waste disposal layer.

In terms of hazardous constituents, an example would be mercury. Although not very mobile in most soil environments, mercury immobilization can be improved by adding sulfur or sulfur-containing compounds to fill soil when disposing of mercury-containing materials to promote formation of highly insoluble mercury sulfide or cinnabar. Wastes containing mercury below specific limits and not considered hazardous would be the target of this type of treatment. Toxicity characteristic wastes contaminated with mercury (D009 waste) must be treated to meet LDRs prior to disposal (See Appendix C). Waste to be immobilized could be disposed in one area in the landfill to reduce the area needed for application of geochemical immobilization technologies. Sustainable immobilization requires compatibility with the regional biogeochemistry.

6.2.2.7.2 On-site Waste Treatment

For some waste streams, it may be advantageous to reduce leachability or meet WAC by implementing some type of stabilization at the EMDF site. In the case of waste treated by grout stabilization (e.g., mercury macroencapsulation), the additional weight of wastes grouted at the generation site greatly increases the costs and risk associated with transporting the treated waste from the generator site to the disposal facility. Mobile processing equipment would be available at EMDF and located adjacent to the active disposal cell to allow for grouting to be carried out within the landfill. Treatability studies and other quality assurance steps would be implemented to ensure effective waste treatment. An example of this is in-cell macroencapsulation for mercury-contaminated debris, which is discussed in more detail in Appendix C.

6.2.2.7.3 Cap Vegetation

As an alternative post-closure strategy, the long-term maintenance costs could be reduced and the long-term stability of the EMDF cover system could be enhanced by early establishment of a controlled forest cover. The uppermost layer of the EMDF landfill cover system will be vegetated to protect underlying layers, reduce erosion, enhance evapotranspiration, and reduce infiltration. The mix of vegetation must be appropriate to regional climate and cap soil conditions. Grasses are commonly selected for cover vegetation because they can be rapidly established and grow shallow but dense root systems that stabilize the cap's surface. However, long-term maintenance of a grass cover requires periodic mowing to prevent colonization by shrubs and trees. It is expected that mowing would cease following the active institution control period.

One of the performance requirements for the EMDF cap is that it survive intact for more than 1,000 years with little or no maintenance. Assuming that climate remains temperate and no building occurs on the landfill, it is inevitable that the cap will undergo natural reforestation. It would therefore seem prudent to design the cap with eventual reforestation in mind. Perhaps the best means to do this is to use the expected post-closure maintenance period for the controlled establishment of a forest, so that a healthy stand of climax trees species is present when maintenance ceases. A forest will accomplish the same hydrologic goals of reducing infiltration, promoting run-off, and preventing erosion as well or better than grasses, and has the added benefits of requiring little or no maintenance and better prevention of inadvertent intrusion by making the site less attractive for use/clearing if administrative control is lost.

Objections to the establishment of forests on landfill caps include root penetration and pitting caused by wind-throw (i.e., the holes where the tree's roots have been pulled up). While the tap roots of some eastern forest trees, such as hackberry and certain hickories, can extend more than 3 m (10 ft) into the soil and could thus potentially disrupt cap layers, most common trees, such as oaks, poplar, walnut, most hickories, and cherry, root within the upper 1 m of the soil. These shallow root systems would be beneficial by creating a zone of increased permeability that fosters rapid run-off as storm-flow, yet would not impinge upon the synthetic and engineered cap layers. Further, the dense mat of interwoven roots form an effective barrier to erosion and mass wasting.

Wind-throw of a shallow-rooted forest would create a pit-and-mound micro-topography that influences soil formation and natural plant restoration in a manner that would be beneficial to cap stability. Pit-and-mound topography slows erosion by acting to trap sediments and regenerate soil profiles within the root plate area (Bormann, et al. 1995; Clinton and Baker, 2000; Ulanova 2000; Hancock, et al. 2011). Trapping of sediments and organic matter restores soil productivity and, by providing fertile seeding sites, increases plant diversity. If the cap forestation effort is managed to prevent the establishment of species with deep tap roots, forestation of the cap would appear to be at least as beneficial, and possibly more beneficial, than the typically accepted strategy of long-term protection via native grass/vegetation growth.

6.2.3 Waste Acceptance Criteria

A negotiated WAC attainment process was developed for the EMWMF (DOE/OR/01-1909&D3), which involves the designation of four separate categories of WAC requirements (DOE 2001b) to define and limit acceptable wastes. For a future on-site facility, similar tri-party negotiations would result in a WAC attainment or compliance process that will be documented in a primary FFA document, the WAC Attainment (Compliance) Plan. EMWMF WAC include four categories:

- **Auditable Safety Analysis (ASA)-derived WAC:** Derived from facility authorization basis documentation for the EMWMF.
- **Physical WAC:** Derived from operational constraints and contractual agreements for EMWMF operations.
- **Administrative WAC:** Derived from ARARs in the EMWMF ROD (DOE 1999), and from other agreements between DOE, EPA, and TDEC.
- **Analytic WAC:** Derived from the approved risk assessment model in the EMWMF RI/FS and RI/FS Addendum (DOE 1998a, DOE 1998b) for the EMWMF.

The first two WAC categories are not addressed in this RI/FS, but will be developed during design stages as safety basis documents and operations plans are developed and appropriate waste limits incorporated into the WAC Attainment (Compliance) Plan. The first category, ASA-derived WAC, controls disposal of radionuclides based on a maximum credible release of material that might occur during an extreme wind event at the operating facility. These limits are separate from and in addition to analytic WAC considerations. These WAC thus mainly address short-term external exposure risk to workers. The second category, Physical WAC, address the physical form of acceptable waste items such as length of piping, waste containers size and weight, dimensions of concrete rubble, addresses voids, etc. that are manageable from a facility operations point of view. It is expected that on-site facility WAC limits/definitions within these two categories will be similar to the EMWMF ASA-derived and physical WAC.

The third WAC category, administrative WAC, includes excluded waste streams and limits on waste streams as a result of ARARs or other policy issues. For example, the administrative WAC prohibits disposal of transuranic waste, high-level waste, spent nuclear fuel, and Atomic Energy Act of 1954 Section 11e(2) byproduct waste. Figure 6-26 is a flowchart that summarizes exclusions under a preliminary Administrative WAC, for an on-site facility. Excluded waste streams include physical forms (liquid, gas) or defined waste streams (non-CERCLA/non-ORR waste, listed RCRA waste, etc.).

Further waste exclusions based on definitions (e.g., greater than Class C and transuranic waste) have quantitative limits. These preliminary Administrative WAC limits are summarized in Table 6-4. Other Administrative WAC will be added in the development of a WAC Attainment (Compliance) Plan (e.g., possibly mercury depending on treatment method identified), or adjustments to these preliminary Administrative WAC limits may be necessary. Finalization of the Administrative WAC is part of the primary FFA document development.

The third step in the WAC flowsheet (Figure 6-26) introduces the analytic WAC limits. These limits are risk-based, numerical contaminant limits developed by applying fate and transport analysis based on site hydrogeology and using conceptual design elements of the EMDF at the EBCV location. Appendix H presents the modeling completed to determine PreWAC for this site, considering protection of human receptors, surface water resources, and ecological receptors as defined in the RAOs. Although only a single site is incorporated into the development of the PreWAC, other site PreWAC limits would be expected to be similar. PreWAC developed in Appendix H are given in Table 6-5 for the EBCV Site Option.

Table 6-4. Preliminary Administrative Waste Limits for an On-site Disposal Facility

Radionuclide	Class C Limits TDEC 0400-20-11-.17(6)(c)	
	(Ci/m^3)	(pCi/g) [a]
Long-lived radionuclides for administrative WAC compliance [b]		
C-14	8	4.7E+06
C-14 in activated metal	80	4.7E+07
Ni-59 in activated metal	220	1.3E+08
Nb-94 in activated metal	0.2	1.2E+05
Tc-99	3	1.8E+06
I-129	0.08	4.7E+04
Alpha emitting transuranic nuclides with half-life greater than five (5) years [c]	100 nCi/g	1.0E+05
Pu-241	3,500 nCi/g	3.5E+06
Cm-242	20,000 nCi/g	2.0E+07
Short-lived radionuclides for administrative WAC compliance [b]		
Ni-63	3.5	4.1E+08
Ni-63 in activated metal	3.5	4.1E+09
Sr-90	0.04	4.1E+09
Cs-137	1	2.7E+09

[a] A density conversion of 1.7 g/cm^3 is assumed.

[b] Concentration limits are applied using the sum of fraction (SOF) rule (sum of individual waste isotopic concentration divided by isotopic limit) for long-lived radionuclides and repeated for short-lived radionuclides. For waste with both long- and short-lived nuclides, the more restrictive SOF of the two determines if waste exceeds Class C.

[c] Concentration limit of 100 nCi/g applied to each transuranic isotope with half-life greater than 5 years. For waste with more than one transuranic isotope, SOF rule is applied.

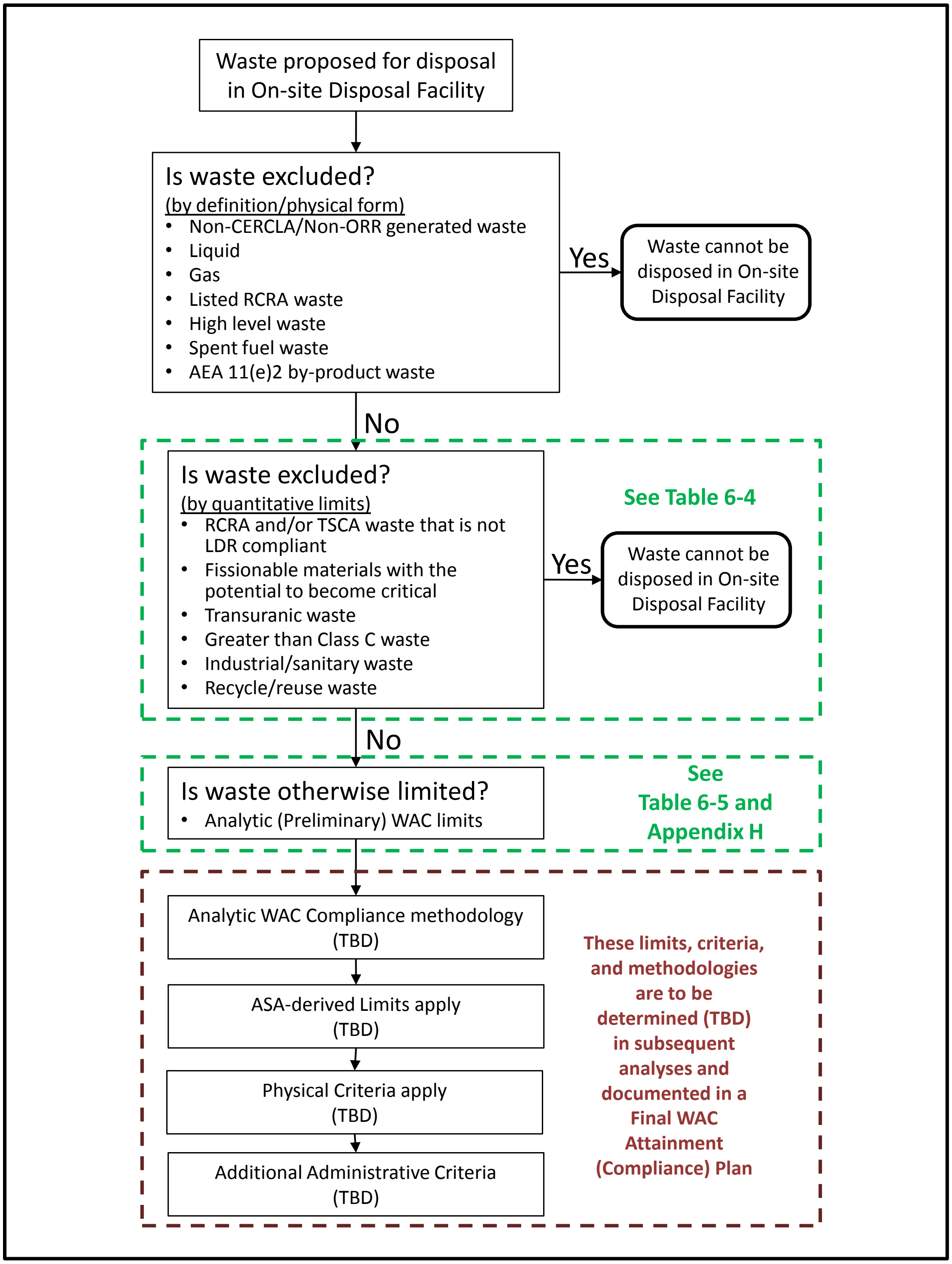


Figure 6-26. Waste Acceptance Flowchart for an On-site Disposal Facility

Table 6-5. Preliminary Analytic Waste Limits (PreWAC) for an On-site Disposal Facility Located at EBCV Site Option[a]

COPC	Carcinogenic PreWAC (pCi/g)	COPC	HI PreWAC (mg/kg)
Am-241	5.13E+06	2,4-D	3.21E+00
Am-243	4.74E+03	2,4,5-T[Silvex]	7.82E+00
C-14	6.89E+01	Acetone	1.07E+02
Cf-249	8.53E+04	Acetonitrile	6.19E-01
Cf-251	7.21E+08	Acetophenone	1.37E+01
Cl-36	3.49E+00	Acrolein	5.19E-02
Cm-244	4.95E+03	Acrylonitrile	4.52E-01
Cm-245	3.48E+03	Benzoic acid	4.13E+02
Cm-246	1.32E+04	Benzyl alcohol	1.15E+01
Cm-247	6.05E+02	Bromodichloromethane	1.14E+00
Cm-248	1.58E+02	Bromomethane	1.58E-01
H-3	9.70E+15	Carbon disulfide	1.99E+01
I-129	1.10E+02	m-Cresol	6.92E+00
K-40	1.37E+04	p-Cresol	1.37E+01
Nb-94	1.14E+06	Di-n-butylphthalate	1.02E+01
Ni-59	8.00E+10	Dibromochloromethane	1.66E+00
Np-237	1.05E+03	1,2-trans-Dichloroethylene	1.75E+00
Pa-231	1.31E+05	Dichlorodifluoromethane	1.68E+02
Pu-238	3.28E+03	1,2-Dichloropropane	9.19E-02
Pu-239	9.27E+02	Dimethylphthalate	4.51E+02
Pu-240	4.87E+03	2,4 Dinitrotoluene	1.74E+00
Pu-241	5.13E+06	2,6 Dinitrotoluene	2.67E+00
Pu-242	5.04E+02	1-Hexanol	4.50E+00
Pu-244	4.78E+02	2-Hexanone	5.62E-01
Re-187	4.62E+04	Methanol	2.07E+02
Se-79	1.79E+06	Methylcyclohexane	1.01E+03
Si-32	1.10E+14	Methyl Isobutyl Ketone	8.35E+00
Sn-126	9.37E+04	Methyl Methacrylate	1.54E+02
Tc-99	4.56E+01	Nitrobenzene	3.02E-01
U-233	3.25E+03	Propylene glycol	2.07E+03
U-234	3.23E+03	Pyridine	1.08E-01
U-235	3.04E+03	1,1,2,2-Tetrachloroethane	8.41E-01
U-236	3.05E+03	1,2,3-Trichloropropane	6.53E-01
U-238	3.17E+03		
Zr-93	1.32E+05		
	Units below (mg/kg)		
Acrylonitrile	2.10E-02		
Bromodichloromethane	1.88E-01		
Chloromethane [Methyl chloride]	9.51E-01		
Dibromochloromethane	2.02E-01		
1,2-Dichloropropane	4.17E-01		
2,4 Dinitrotoluene	3.06E-01		
2,6 Dinitrotoluene	4.84E-02		
1,1,2,2-Tetrachloroethane	8.81E-02		
1,2,3-Trichloropropane	5.92E-04		

[a] The PreWAC reported here were determined from site-specific/facility-specific modeling for the EBCV Site Option. It is expected that other siting options would result in similar PreWAC. Details regarding PreWAC modeling and development are given in Appendix H.

6.2.4 Construction Activities and Schedule

Figure 6-27 shows the conceptual sequence of design, construction, operations, and closure actions for a single on-site disposal facility (e.g., one located at EBCV or WBCV Sites). In practice, alternative construction sequencing could be implemented by the construction and operations contractor(s). For the Dual Site Option, this schedule would be more complicated, with a longer design timeframe (or two separate design phases), and one additional construction phase (e.g., two construction phases are planned for each footprint). These modifications in the schedule of the Dual Site Option are taken into account in the cost estimate for that alternative.

The on-site disposal facility construction elements include those described in Section 6.2.2. Ground water monitoring wells and surface water weirs would be installed as part of the early actions to support remedial design, as has been done in Phase I for the EBCV Site. Site development activities would be performed as a separate early phase of construction prior to construction of the landfill. Site development activities would include constructing access roads to the landfill site; preparing additional parking, laydown, spoil, and staging areas; creating/expanding wetlands as required; extending utilities to the landfill site; if necessary, relocating the Y-12 229 Security Boundary or rerouting the Haul Road and installing new guard stations; clearing and grubbing for site development activities; installing initial sediment and erosion controls for site development activities; upgrading/installing a new weigh scale; and setting up construction trailers.

Subsequent to site development, the disposal cells would be constructed in phases consistent with waste generation schedules. For the EBCV and WBCV Sites the conceptual schedule used to support the RI/FS cost estimate assumes that the landfill would be constructed and operated in three phases. Phase I would include site preparation for construction of Cells 1 and 2; construction of the NT-3 underdrain and part of the rough grading for Phase II; construction of support facilities; and construction of the first two disposal cells, including clean-fill dike, perimeter road and ditches, upgradient shallow French drain, geologic buffer layer, liner system, and leachate collection and detection systems and piping. Operational readiness and startup would be part of Phase I construction. Waste disposal would begin after Phase I construction is completed. Phase II would include additional site preparation and construction of Cells 3 and 4 which would be ready to accept waste after the Phase I cells have been filled. Phase III would include additional site preparation, construction of Cells 5 and 6.

A conceptual schedule for the Dual Site Option would include two Phases of construction for each footprint for a total of four construction phases. Assumed modifications of the "base" schedule shown in Figure 6-27 include additional characterization and design efforts and durations. Overlap of two landfill operations would be necessary in closing the first site, and opening the second site. In addition, two landfill capping and closure activities are necessary. The cost estimate for the Dual Site Option takes these modifications into account.

A large volume of clay-rich soil from a borrow area would be used for construction of the geologic buffer, compacted clay liner, and compacted clay layers of the final cover system, regardless of which site is considered (site-specific volumes are provided in the cost estimate). Due to the conservative estimate of the seasonal high ground water table at each site, the conceptual design indicates that a large volume of structural fill will also be required from a borrow area for the EBCV, WBCV, and Site 7a conceptual footprints. A significantly smaller amount is required at Site 6b due to its smaller footprint and previous use as a borrow area, which has leveled the site. This is necessary to raise the bottom of the waste to maintain the appropriate buffer between the waste and the ground water table, and to provide a level footprint. This structural fill would be used for construction of clean-fill dikes, roadways, and placement of daily cover. Where available, excess cut from the landfill construction that was deemed suitable for reuse could be stockpiled on-site and reused as structural fill. For estimating purposes it was assumed that all structural fill would be purchased from an off-site source. However, as part of the final design process, it would be appropriate to evaluate on-site borrow source areas.

After completion of the construction phases and disposal operations, the final cap would be installed. Support areas (e.g., the temporary and permanent spoils areas) would be restored. Demobilization would include removal and disposal or reuse of unneeded support facilities and equipment.

6.2.5 Operations

EMDF operational scope includes activities being conducted for the time period between 2022 to 2043 when waste placement is being performed, as well as closure and post-closure activities after 2043. In 2022, both EMWMF and EMDF will be operated with waste being placed in EMWMF Cell 6 and in EMDF Cells 1 and 2. In 2024, EMWMF will be filled to capacity and EMWMF final capping operations will begin. Wastewater will be generated from both sites and collected for storage and treatment as necessary. For the Dual Site Option, there is an additional operations overlap (transition from Site 6b to Site 7a) which adds additional operations cost for a two year period. EMDF closure activities will involve construction of the final cap and post-closure will involve cap maintenance and continued leachate collection and management. Again, for the Dual Site Option, there will be two capping activities and corresponding monitoring and post-closure activities.

Operations are guided by ARARs contained in Appendix G, Table G-7. Operational Plans and Procedures will be developed for the EMDF that address these ARARs. As is done for EMWMF, a cross walk would be developed that indicated which operational plan or procedure addressed each ARAR.

6.2.5.1 Waste Placement

For the On-site Disposal Alternative, operations, including some personnel and equipment, would likely transition from the existing EMWMF operations to the new EMDF operations. Disposal operations would include waste receipt, inspection, WAC compliance, and recordkeeping; unloading waste into the disposal cell, placing the waste properly in the working area, compacting waste, and filling void spaces; maintaining work face; surveying incoming and outgoing trucks and containers and decontaminating as needed; dust control; management of wastewater; storm water management, etc.

EMDF facility maintenance would include providing daily cover over the emplaced waste, as required; maintaining roadways, buildings, equipment, utilities, and other facilities; and leachate management. Waste disposal operations would be similar to those at EMWMF.

6.2.5.2 Wastewater Management

The IWM FFS (UCOR 2016) evaluates in detail the management of wastewater at both the EMWMF and the proposed EMDF. The IWM FFS recommends treatment of wastewater that fails to meet discharge criteria[16], and Managed Discharge for wastewater that meets discharge criteria (e.g., sampling and discharge). As mentioned previously, the on-site (EMWMF/EMDF) alternative was the selected treatment alternative for management of wastewater; therefore, it is included in this RI/FS as part of each of the On-site Disposal Alternative Site Options. The lifecycle cost as presented in the IWM FFS is part of the RI/FS On-site Disposal Alternative lifecycle costs. Operation of an on-site system for treatment would be conducted as part of the landfill operations. Those costs are also included in each Site Option's On-site Disposal Alternative lifecycle cost.

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[16] Discharge criteria and locations are given in the IWM FFS. They are not repeated in this document to avoid inaccuracies in translation. These criteria will be stipulated in a future ROD that will incorporate the results of both the IWM FFS and this RI/FS document.

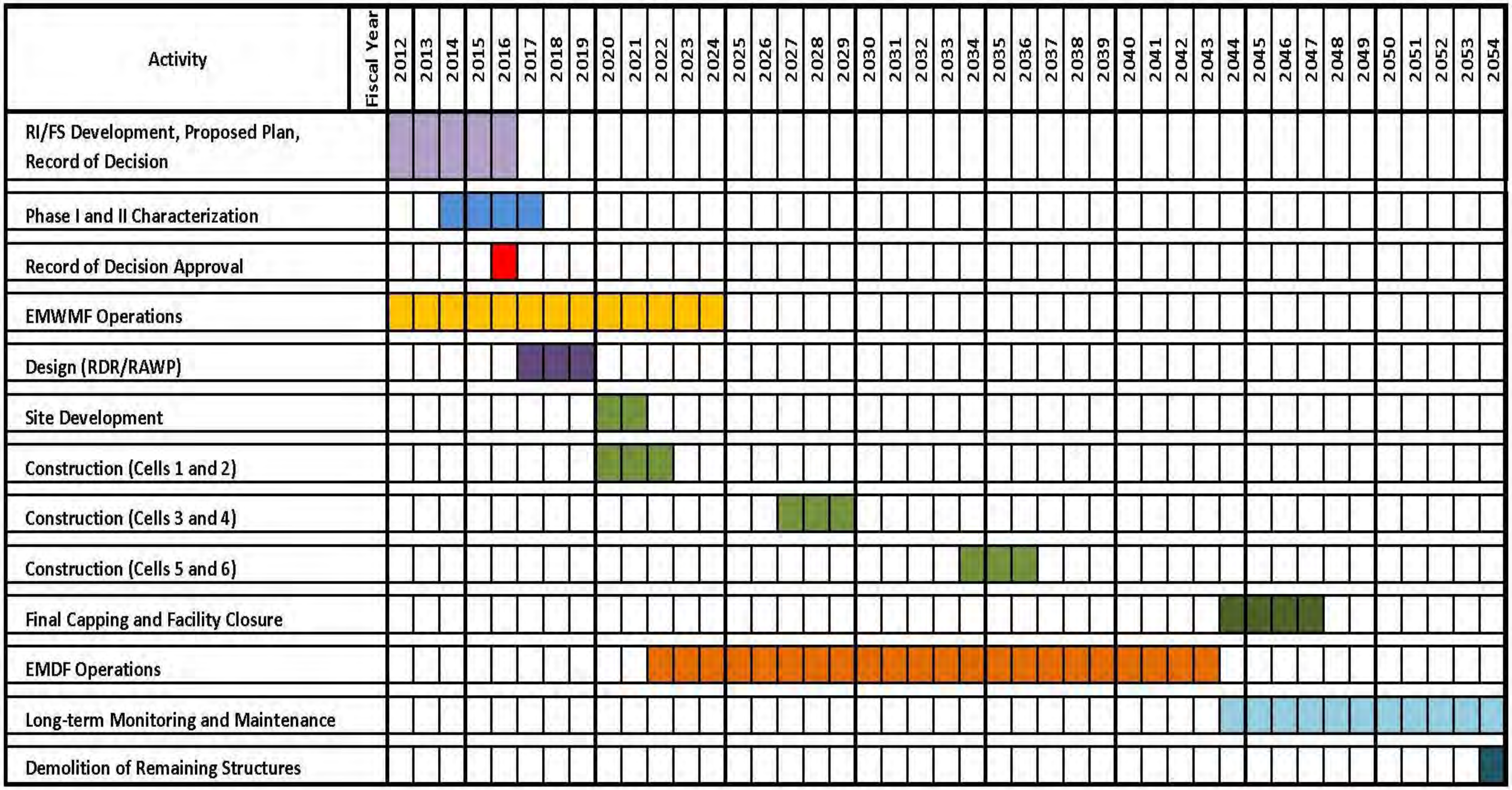

Figure 6-27. On-site Disposal Alternative Schedule

For details regarding the proposed treatment system and its operation, refer to the IWM FFS. ARARs associated with the IWM FFS are presented in that document as well as this RI/FS. It is intended that complete merging of conclusions reached in the IWM FFS and this RI/FS are addressed at the Proposed Plan stage. A single ROD will address the integrated alternative, and include ARARs from both the RI/FS and the IWM FFS. Therefore, necessarily, the coverage of the wastewater management in this RI/FS document is kept to a minimum. Costs for an assumed water treatment alternative, however, are entirely captured within the On-site Disposal Alternative Site Options in this RI/FS.

6.2.6 Engineering Controls, Construction Practices, and Mitigation Measures

Appropriate engineering controls and construction practices would be implemented during construction, operation, closure, and post-closure care of an on-site disposal facility to minimize the potential for adverse effects. It is assumed the EMDF would be constructed and operated similarly to EMWMF. ARARs that guide these activities are given in Appendix G.

Engineering controls, construction practices, and mitigation measures applicable to EMDF would include:

- Preparing and implementing worker health and safety plans.
- Implementing measures to protect air quality, such as wetting surfaces and using chemical dust suppressants and covers to control fugitive dust, and air quality monitoring to assess compliance with standards.
- Protecting aquatic and terrestrial habitat to the extent practical through appropriate planning and implementation of protective measures during construction, and restoring habitat, as needed, in consultation with appropriate state and federal agencies.
- Limiting the number of active working faces of exposed waste in the landfill to prevent contamination releases to air and reduce leachate generation.
- Use of appropriate construction practices in all excavation and construction areas to control surface water runoff and to minimize erosion and transport of sediment from exposed areas including:
  - Berms to direct the flow of surface water.
  - Silt fences to minimize the amount of sediment leaving the area.
  - Straw, mulch, riprap, membranes, or temporary vegetation mats in exposed areas.
  - Storm water detention basin(s) near the perimeter of the site (and at borrow areas, if needed) to protect surface water.
  - Segregating runoff from contaminated areas and clean areas.
  - Clearing during autumn or winter to protect the nests of migratory birds during breeding season, to the extent practical.
- Surface water, and ground water monitoring before, during, and after facility construction and operation and implementing appropriate contingency plans if any adverse effects were detected.
- Using double-walled piping for containment of leachate during transfers.
- Using waste soil for void filling to minimize clean fill requirement and conserve landfill capacity.
- For on- or off-site disposal, transporting waste in closed or covered containers or vehicles and providing contingency plans to address potential spills.
- Decontaminating and inspecting haul vehicles, construction vehicles, and containers before they leave any contaminated area.
- Grading, re-vegetating, and restoring disturbed areas.
- Preparing and implementing long-term monitoring and maintenance plans and contingency plans.

A lesson learned from EMWMF personnel is regarding the installation of the piezometers under the landfill to monitor ground water levels. Lack of redundancy in the piezometers has lead to confusion about how to interpret atypical water level readings. There are ongoing evaluations with respect to placement of these piezometers. Other methods of measuring ground water table beneath the landfill are being investigated, that would be more explicit, leaving less to interpretation of the data.

6.2.7 Management of Waste Exceeding WAC

Waste that exceeds the on-site disposal facility WAC would be shipped to an approved off-site facility for disposal by the generating contractor. If no off-site facility is identified that can accept the waste, the "no path for disposal" waste would be placed in interim storage pending the availability of treatment or disposal capabilities. Actions and decisions to manage waste that do not meet the criteria for on-site disposal will be carried out, documented, and managed under project-specific activities, and thus are not part of this CERCLA remedy evaluation.

6.2.8 Closure

After completion of waste disposal, closure activities would include final capping (i.e., construction of the final cover system). A final cap design would be part of the overall cell design prior to Phase I construction and documented in the RDR and RAWP, and follow the ARARs for design given in Appendix G, Table G-5. Several years before closure, any necessary updating of the detailed final cap design would be initiated. Closure of the facility will include continued wastewater collection and treatment as required by ARARs (Appendix G Table G-7), cap construction per ARARs (Appendix G Table G-6), and monitoring (closure and post-closure) per ARARs (Appendix G Table G-8). Leachate collection, storage, and treatment systems would be decommissioned after rates of leachate generation diminish. Contact water basins and other temporary support facilities would be removed and disposed of appropriately or plugged and abandoned in place, salvaging equipment and facilities to the extent practicable. The site would be restored to maximize beneficial reuse of the property in accordance with the designated land use.

DOE intends to retain ownership of the EMDF site in perpetuity. For those sites that currently have future land use designations of recreational or residential use (e.g., Site 7a and WBCV), a modification of the property's future land use designation will be required. In the unlikely event that DOE transfers the EMDF site out of federal control, DOE would comply with the requirements of CERCLA Section 120(h)(3), as applicable. This would include deed restrictions or covenants that would prohibit residential use of the property, construction of any facility that could damage the final cover system, or installation of ground water extraction wells for purposes other than monitoring and/or treatment. These deed restrictions would identify administrative controls necessary to protect the public and the integrity of EMDF and would be attached to the deed description and filed with the appropriate local government authority.

6.2.9 Post-Closure Care and Monitoring

Surveillance and maintenance (S&M) and performance monitoring would be performed during operation and after facility closure. The remedial design and subsequent documentation based on as-built conditions would include facility-specific S&M and monitoring plans including disposal facility performance goals, long-term S&M requirements, and performance monitoring requirements. The plans would identify required monitoring, features to be inspected, inspection frequency, and performance requirements. S&M and monitoring are assumed to be performed for a period of 1,000 years after facility closure. The on-site disposal costs cited in this document include costs for these post-closure activities, through the establishment of a perpetual care fee (see the next section for more on the fee). This fee, incorporated into the On-site Alternative cost estimate, makes no assumptions regarding the entity performing the long-term care. Its purpose is only to capture the cost of the activities. Determinations regarding the entity performing the work are beyond the scope of this document, but would necessarily be determined and incorporated into the ROD. Post-closure surveillance, maintenance, and monitoring is required per ARARs given in Appendix G Table G-8 (monitoring) and Table G-9 (closure and post-closure requirements).

6.2.9.1 Surveillance and Maintenance

Long-term S&M actions would be conducted to control erosion – repair cap settlement/subsidence, slope stability, repair run-on and run-off control systems, including the upgradient geomembrane-lined diversion ditch with shallow French drain, prevent rodent infestation, and prevent tree and other deep-rooted plant growth on the final cover and side slopes. S&M would also include maintenance of monitoring wells, fences, signs, access roads, survey benchmarks, and leachate collection, storage, and treatment systems. Collected leachate would be treated on a periodic basis and discharged to Bear Creek using appropriate discharge criteria. Leachate treatment system facilities are assumed to be demolished after a ten-year period following the end of waste operations (see the schedule in Figure 6-15). The facility will remain in DOE control in perpetuity. DOE is responsible for any non-routine maintenance that may be necessary in the future. An assumed $7 M per occurrence (two occurrences) of non-routing maintenance are accounted for in the estimate details. Details regarding the cost estimate assumptions for long-term care are given in Appendix I, where a comparison is made between a perpetual care fee and incorporation of the S&M costs post-closure. This comparison is made on a Present Worth basis, which indicates that a perpetual care fee as proposed is typically the higher cost (see Appendix I Section 3.3), and is therefore the cost included in the On-site and Hybrid Disposal Alternatives for long-term care.

6.2.9.2 Monitoring

Landfill performance monitoring could be accomplished by (1) monitoring leachate from the LCRS, (2) monitoring surface water in NT stream channels adjacent to the EMDF, (3) monitoring ground water seepage emanating from the facility underdrain, (4) monitoring ground water in wells up and downgradient of the site perimeter, (5) visual surveillance to detect erosion or indications of surface instability, and (6) periodic land surveys to monitor for settlement. Details about operational and post-closure monitoring would be specified in future post-ROD CERCLA documents that require regulatory approval. Available methodologies and technologies, such as real-time down-hole sensors and dedicated well purging/sampling options for ground water monitoring, would be considered and incorporated as appropriate. Determinations of whether to use high-flow or low-flow methods for well purging and sampling would be made with due consideration given to the potential for inducing contaminant flow from surrounding contaminated areas. Monitoring wells at the EMWMF currently use dedicated Well-Wizard™ bladder pump systems for low-flow purging and sampling. Similar equipment could be applied for EMDF ground water monitoring to facilitate uniformity and consistency for monitoring practices. Monitoring would support annual Remediation Effectiveness Reports and Five-year Reviews required by the FFA.

Routine monitoring of the leachate detection and removal system would provide an initial warning of liner failure. Periodic monitoring of ground water seepage emanating from the facility underdrain and surface water in NT stream channels adjacent to the site would serve as early indications of liner system failure. If a failure in the liner system occurred, some fraction of the leachate reaching the water table could migrate laterally toward and be captured in the underdrain system and be detected through monitoring at the underdrain outfall(s). Natural ground water flow paths in saprolite and bedrock also tend to occur along dominant strike parallel fracture systems that convey ground water toward cross-cutting NT tributaries, so that contaminants reaching shallow ground water can enter the NT streams as base flow. Monitoring of surface water along NT stream channels at locations near and downstream of such ground water discharge zones would provide an effective method of contaminant release detection in conjunction with the underdrain outfalls and monitoring well locations. Additional measures such as use of lysimeters within the final cover system may also be considered. Such devices could provide early warning that the final cover is not functioning as intended to limit infiltration. The relatively limited service life (as compared to the EMDF) and area of coverage for a typical lysimeter would need to be part of this consideration.

Current site characterization methods are limited in their ability to accurately define the complex three dimensional subsurface network of transmissive fractures in fractured rocks, but the combination of monitoring from stream channel locations, underdrain outfalls, and several cluster wells placed along the downgradient perimeter of the site will provide an effective means for release detection at the EMDF. One or more upgradient monitoring wells would complete the monitoring network to define water level and water quality conditions in uncontaminated areas upgradient of the site footprint, thus giving an accurate background data set.

The requirements for monitoring, recordkeeping, and reporting of ground water, surface water, storm water, leachate/contact water, and ambient air monitoring must be initially documented in site monitoring and operations plans and associated plans similar to those developed for the EMWMF (UCOR 2012a; UCOR 2012b). Substantive federal and state requirements of RCRA monitoring are given in Appendix G Table G-8. Baseline ground water conditions for a detection monitoring program must be documented before disposal facility operations start. Results from at least four consecutive quarters of water quality sampling and laboratory analysis must be reported to establish statistics for baseline water quality (See *Baseline Groundwater Monitoring Report for the EMWMF*, DOE 2003). Monitoring results during facility operations and the post-closure period are compared with the baseline statistical data as a basis for determining contaminant releases. Sites 7a and 14 are located in areas far beyond the influence of known waste sites and ground water contaminant plumes originating in EBCV. Of the two sites proposed in EBCV, only Site 6b appears to have the potential for some influence from existing contaminants at the adjacent BCBG. Site 5 appears to be located sufficiently upgradient of existing historical waste sites and ground contaminant plumes in EBCV to avoid potential problems with anthropogenic background contaminants. Use of low-flow purging/sampling methods and dedicated equipment would reduce the potential for inducing contaminant flow from neighboring areas in EBCV.

6.2.9.3 Lessons Learned Summary

Table 6-6 is a summary of lessons learned that were discussed in multiple previous sections. Lessons learned have been used throughout this RI/FS, in developing the conceptual designs, discussing the remedies, and planning for a future on-site disposal facility. Many of these lessons learned will be applicable throughout the process, if on-site disposal is the selected alternative.

6.3 OFF-SITE DISPOSAL ALTERNATIVE

This alternative would provide for the transportation of future CERCLA candidate waste streams off-site to approved disposal facilities and placement of the wastes in those facilities. The waste generator would be responsible for separation of materials for potential recycle or that meet the criteria for local disposal at the ORR Landfill, treatment required to meet the off-site disposal facility’s WAC, packaging of the waste at the point of origin, and local transportation. Wastes not meeting the WAC for any off-site facility would be placed in interim storage until treatment or disposal capacity becomes available.

DOE’s policy is to treat, store, and dispose of LLW at the site where it is generated, if practical, or at another DOE facility if on-site capabilities are not practical and cost effective. For CERCLA actions that transfer wastes off-site, appropriate permits are required to be held by the receiving facility. In general, the following conditions must be met to use an off-site receiving facility in accordance with the “Off-site Rule” at 40 CFR 300.440 and CERCLA Section 121(d)(3):

- The proposed receiving facility must be operated in compliance with all applicable federal, state, and local regulations; there must be no relevant violations at or affecting the receiving facility.
- There must be no releases from the receiving unit and contamination from prior releases at the receiving facility must be addressed, as appropriate.
- For mixed LLW/RCRA materials, off-site treatment, storage, or disposal facilities must have an approved Nuclear Regulatory Commission (NRC) license and RCRA Part B permit.

These procedures require confirmation by the regional EPA office with jurisdiction over the chosen disposal facility, that indeed the facility is acceptable for the receipt of CERCLA wastes.

6.3.1 Candidate Waste Streams

Wastes requiring disposal include LLW and mixed waste with components of radiological and other regulated waste (LLW/RCRA, LLW/TSCA). Table 6-7 lists the candidate waste stream volumes by waste type, material type, and off-site disposal facility for the Off-site Disposal Alternative. As described in Chapter 2, these volumes are based on the as-generated waste volume estimate from FY 2022 through FY 2043 with a 25% uncertainty applied.

6.3.2 Description of Representative Disposal Facility Options

As shown in Table 6-7, non-classified LLW and LLW/TSCA waste and classified LLW waste would be shipped to NNSS in Nye County, Nevada or Energy*Solutions*, Clive, Utah. Soil that is LLW/RCRA (in the currently referenced WGF,is attributed solely to mercury-contaminated soil/sediment from remediation projects at Y-12. LLW/RCRA (mixed) waste could be shipped for treatment and disposal at Energy*Solutions*, Clive, Utah, or WCS in Texas, although the cost for that treatment is outside the scope of this RI/FS (assumed to be covered at the project level). The disposal facilities are described in the subsections that follow.

Table 6-6. Summary of EMWMF Lessons Learned

Topic	Lesson Learned Description	Reference Section
Waste Hierarchy and Segregation	Characterization (and possibly some additional characterization) will allow for some waste lots to be disposed in ORR landfills as opposed to EMWMF/EMDF	5.1.5 Volume Reduction
Cumulative Risk	WAC Attainment volume-weighted sum of fractions approach is difficult to use. A new approach needs to be implemented for EMDF.	3 Risk Evaluations
Action Leakage Rates (ALRs)	Use actual site and material specific data when calculating this value and not the general EPA equations and guidance. The initial EMWMF ALR was estimated far too low due to using generic input parameters for calculations.	6.2.2.1 Remedial Design
Project Sequencing	Project sequencing must be improved to ensure maximum beneficial use of waste soil to replace clean fill during placement of debris and general landfill operations.	6.2.2.1 Remedial Design
In-Cell Void Space Fill	Appropriate ratios of soil to debris must be used to estimate the soil needed for use as void space fill to ensure landfill stability. Recognize that even with mindful project sequencing, soil-like waste will not always be available for use as void filling material and some quantity of clean soil fill will be required.	6.2.2.1 Remedial Design
Site Characterization	Performing a thorough site investigation for not only the project footprint, but also for borrow areas can reduce unforeseen construction costs and delays. EMWMF had issues with over-estimating the suitable borrow from the borrow site, underestimating how much unsuitable soils would require hauling off site, and underestimating the seasonal high ground water levels at the site.	6.2.2.2 Early Actions

Table 6-6. **Summary of EMWMF Lessons Learned (Continued)**

Topic	Lesson Learned Description	Reference Section
Planning and Constructing Upslope Diversion Channels	NT-4 was diverted during construction of EMWMF by filling and rerouting the channel along the northern perimeter. A portion of the channel continues to provide surface water into EMWMF area. Careful consideration needs to be given as to how, and with what materials, the diversion along Pine Ridge-side slopes are handled in design and construction.	6.2.2.4.2 Upslope French Drain and Diversion
Protective Soil Layer	The EMWMF design for the protective soil layer defines it as being a native soil with permeability lower than the granular leachate collection layer. This was specified in order to collect the in-cell runoff as clean before it mixed with the potentially contaminated leachate within the liner system. Actual operations of EMWMF have shown the difficulty of inhibiting the contact of the storm water with the waste, and, therefore, the contact water collected in the landfill cells has had to be managed as being potentially contaminated until it can be tested and deemed suitable for discharge. In some instances it has required shipment of contaminated contact water to the PWTC at ORNL for treatment prior to discharge.	6.2.2.4.3 Liner System
Underdrains	Underdrains can be successfully utilized in managing existing ground water at sites, but should be appropriately designed in advance of landfill operations. The materials of the various components of the underdrain system and backfill should be carefully selected to ensure drain longevity. Underdrains should be part of the ground water monitoring plan for the facility. All drainage features of a facility should be maintained post-closure (see Section 6.2.2.4.5 for indepth discussion of underdrain design, monitoring, and longevity)	6.2.2.4.5 Facility Underdrain
Storm Water Management	The design basis for EMWMF used a 25-year, 24-hour storm event for sizing storm water management features. Final design for the EMDF should take into consideration the need to manage multiple back-to-back events and also consider that this is a more specialized construction project than what is typically being evaluated. In 2003, nearly 70 inches of rain was received in one year. Use of enhanced operational covers to reduce amount of landfill water generated.	6.2.2.5.3 Storm Water Management
Management of landfill water capacity	This is an important step in operations. Need to manage capacity as efficiently as possible, to maintain available capacity.	6.2.5 Operations
Protective Materials used over Liner; Protection of Liner from Accidents	Protective materials should be used where possible to protect liner (e.g., transite). Use heavy waste/waste that does not require working/fill. Liner was torn during operations. This has resulted in improved education on landfill systems (e.g., liner) for workers; improved visual communications tools for pre-job briefings regarding special requirements; and enhanced controls for excavation activities occurring within 4 ft of the landfill protective layer.	
Waste with Mobile Contaminants	Contamination migration into landfill wastewater is minimized by placing waste with higher concentrations of mobile contaminants into areas with limited water contact. As an example, at EMWMF the waste with higher levels of Tc-99 was placed within a bowl constructed of waste with less mobile constituents.	
Piezometers for ground water monitoring	Placement of the pneumatic piezometers under EMWMF has caused questions about the applicability and accuracy of the data collected. Installing pneumatic piezometers under the landfill in pairs completely within the specific zone to be monitored will provide better confidence in readings. In addition, methods of measuring the ground water table beneath the landfill will be investigated that are more explicit, leaving less to interpretation.	6.2.6 Engineering Controls, Construction Practices, Mitigation Measures

Table 6-7. Candidate Waste Stream As-generated Volumes by Waste Type, Material Type, and Disposal Facility for Off-Site Disposal Alternative with 25% Uncertainty

Off-site Disposal Facility	Waste Type	Material Type	Volume (yd^3)
NNSS (Non-Classified) and/or Energy*Solutions*	LLW	Debris	1,151,440
	LLW and LLW/TSCA	Soil	540,115
	LLW/RCRA	Soil[a]	67,353
		NNSS (Non-Classified) SUBTOTAL	**1,758,908**
NNSS (Classified)	LLW and LLW/TSCA	Debris	40,233
		NNSS (Classified) SUBTOTAL	**40,233**
Energy*Solutions* and/or WCS	LLW/RCRA	Debris[b]	149,418
		Other SUBTOTAL	**149,418**
		TOTAL	**1,948,559**

[a] This soil is assumed to be treated by the remediation project prior to transfer to off-site disposal such that it is no longer considered hazardous. It is not included in the cost estimate for off-site.

[b] This debris volume is expected to require treatment by the off-site facility prior to disposal. Cost of treatment is assumed to be covered at the project level and is not included in the off-site estimate.

6.3.2.1 Energy*Solutions*, Clive Utah

Energy*Solutions* is located in Clive, Utah, approximately 75 miles west of Salt Lake City; the facility is licensed and permitted to receive the following waste types for disposal:

- Naturally occurring radioactive material/naturally accelerator-produced radioactive material
- Class A LLW per NRC regulations in 10 CFR 61.55
- PCB radioactive waste
- Asbestos contaminated waste
- Mixed waste
- AEA Section 11e.(2) Byproduct material (i.e., uranium and thorium mill tailings)

Energy*Solutions* receives radioactive waste in all forms, including, but not limited to, soil, sludges, resins, large reactor components, dry active waste, and other radioactively contaminated debris.

The facility is located in a remote Utah desert within a 100 square mile hazardous waste zone established by the state of Utah. The nearest population center is approximately 40 miles away. In addition to LLW disposal, Energy*Solutions* offers a variety of mixed waste treatment processing and disposal options.

6.3.2.1.1 EnergySolutions Waste Acceptance Criteria

As described in the WAC for Energy*Solutions* (Energy*Solutions* 2011), the facility is authorized to receive radioactive waste in the form of liquids and solids. Solid radioactive waste must contain less than

1% free liquid by waste volume. Generators shipping solid waste must minimize free liquid to the maximum extent practicable.

Soil must be greater than 70% by weight compactable material less than ¾ in. particle size and 100% compactable material less than 4 in. particle size. The maximum dry density of soil must be greater than 70 pounds per ft^3 (dry weight basis). Soil may be mixed with debris composed of materials that are less than 10 in. in at least one dimension and no longer than 12 ft in any dimension. Debris may include contaminated concrete, wood, bricks, paper, piping, rocks, glass, metal, slag, PPE, and other materials.

Radioactive waste that contains greater than 1% free liquid by waste volume (e.g., sludge, wastewater, evaporator bottoms, etc.) is solidified at Energy*Solutions*' Treatment Facility prior to disposal. Energy*Solutions* is also authorized to receive gaseous waste in accordance with Utah Administrative Code R313-15-1008(2)(a)(viii). Gaseous waste must be packaged at an absolute pressure that does not exceed 1.5 atmospheres at a temperature of 20° C and the total activity of any container shall not exceed 100 Curies.

The following waste types are prohibited from disposal at Energy*Solutions*:

- Sealed sources (e.g., instrument calibration check sources, smoke detectors, nuclear density gauges, etc.).
- Radioactive waste which is classified per NRC 10 CFR 61.55 as Class B, Class C, or Greater Than Class C waste.
- Solid waste containing unauthorized free liquids.
- Waste material that is readily capable of detonation, of explosive decomposition, reactive at normal pressure and temperature, or reactive with water or air.
- Waste materials that contain or are capable of generating quantities of toxic gases, vapors, or fumes harmful to persons transporting, handling, or disposing of the waste.
- Waste materials that are pyrophoric (pyrophoric materials contained in wastes must be treated, prepared, and packaged to be nonflammable).
- Waste materials containing untreated biological, pathogenic, or infectious material including contaminated laboratory research animals.

The following mixed wastes are not acceptable for treatment or disposal at Energy*Solutions*:

- Hazardous waste that is not also a radioactive waste.
- Wastes that react violently or form explosive reactions with air or water (without written approval by Energy*Solutions*).
- Pyrophoric wastes and materials (without written approval by Energy*Solutions*).
- DOT Forbidden, Class 1.1, Class 1.2 and Class 1.3 explosives.
- Shock sensitive wastes and materials.
- Compressed gas cylinders, unless they meet the definition of empty containers.
- Utah waste codes F999 and P999.
- Aerosol cans that are not punctured or depressurized.

6.3.2.1.2 Waste Treatment

Waste shipped to Energy*Solutions* for treatment or liquid solidification prior to disposal is managed at Energy*Solutions*' Treatment Facility. The Treatment Facility is designed for radioactive waste that requires treatment for RCRA constituents and for liquid radioactive wastes requiring solidification prior to disposal. Energy*Solutions*' mixed waste treatment and solidification capabilities include:

- Chemical Stabilization – Including oxidation, reduction, neutralization and deactivation.
- Amalgamation – For the treatment of elemental mercury.
- Macroencapsulation – For the treatment of radioactive lead solids, RCRA metal-containing batteries, and characteristically hazardous radioactive debris.
- Microencapsulation – To reduce the leachability of hazardous constituents in mixed wastes that are generally dry, fine-grained materials such as ash, powders or salts.
- Liquid Solidification – For the solidification of radioactively contaminated liquids such as aqueous solutions, oils, antifreeze, etc., to facilitate land disposal. Mixed waste liquids can also be treated and solidified at the Treatment Facility.
- Vacuum Thermal Desorption of Organic Constituents – For the thermal segregation of organic constituents from wastes including wastes with PCBs. Waste containing PCB liquids is also acceptable for Vacuum Thermal Desorption treatment.
- Debris Spray Washing – To remove contaminants from applicable hazardous debris.

6.3.2.1.3 EnergySolutions Waste Packaging

Energy*Solutions* receives waste for disposal either in bulk or in non-bulk packages. The packaging used must be authorized for the specific material being shipped by the DOT Hazardous Materials Regulations. Each generator is responsible for ensuring that the packaging used meets the appropriate regulations.

Energy*Solutions* receives various bulk packages, including gondola railcars with either hard-top lids or super-load wrappers, intermodals and other cargo containers, roll-offs, etc. Bulk packages are unloaded at Energy*Solutions* and then decontaminated, surveyed, and returned. Non-bulk packages (disposal containers) include boxes, drums, super sacks, etc. The disposal container is generally disposed of with the waste contents and will not be returned to the generator.

6.3.2.1.4 Transportation to EnergySolutions

Energy*Solutions* is capable of receiving both truck and rail shipments. The existing rail spur at the ETTP truck-to-rail (transload) facility is available for use for rail shipments.

6.3.2.1.5 EnergySolutions Documentation and Characterization Requirements

A waste profile record is required for disposal of wastes at Energy*Solutions*. The profile record provides information related to the following areas:

- Generator and waste stream information – generator contact information, general overview of the type of waste, physical characteristics, transportation and packaging, identification of specific radionuclides, and the average and range of radionuclide concentrations.
- Chemical and hazardous waste characteristics – chemical properties of waste relative to RCRA regulations.
- Special Nuclear Material exemption – radiological information to evaluate waste containing Special Nuclear Materia.l
- PCB certification – information about the type of PCB waste included.

For waste streams requiring treatment or solidification, a pre-shipment sample is required for a treatability and/or solidification study.

6.3.2.2 NNSS

The NNSS (formerly known as the Nevada Test Site), is located in Nye County, Nevada, approximately 65 miles northwest of Las Vegas, NV. The facility is licensed and permitted to receive the following waste types for disposal:

- LLW
- LLW containing PCBs
- Pyrophoric waste that has been treated, prepared, and packaged to be nonflammable
- Radioactive sources
- LLW containing asbestos
- Radioactive animal carcasses (unless preserved with formaldehyde)
- Beryllium waste
- Classified waste

NNSS receives waste in solid form. Wastes containing liquids or fine particulates must be stabilized to minimize their presence to the maximum extent practicable.

6.3.2.2.1 NNSS Waste Acceptance Criteria

As described in the WAC for NNSS (DOE 2011b), the facility is authorized to receive LLW, mixed waste, or U.S. Department of Defense classified waste in solid form. Solid radioactive waste must contain less than 1% free liquid by waste volume. Generators shipping solid waste must minimize free liquid to the maximum extent practicable. Liquid waste and waste containing free liquids should be processed to a solid form or packaged with sufficient sorbent material. Compressed gasses are not accepted for disposal at NNSS.

The following waste forms are prohibited from disposal at NNSS:

- Hazardous waste regulated under RCRA
- LLW containing pathogens, infectious wastes, or other etiologic agents
- LLW containing chelating or complexing agents greater than 1% (unless stabilized)
- Waste containing un-reacted explosives

6.3.2.2.2 Waste Packaging

NNSS receives waste for disposal either in bulk or in non-bulk packages. The packaging used must be authorized for the specific material being shipped by the DOT hazardous material regulations. Each generator is responsible for ensuring that the packaging used meets the appropriate regulations.

The preferred packaging at NNSS for containers to be disposed are those that are easiest to handle and stack, although alternative packaging will be accepted with prior approval. Bulk packages that are requested to be returned to the generator are also accepted, as are bulk items with no packaging (i.e., large equipment and machinery). Bulk items with no packaging are evaluated on a case-by-case basis.

NNSS has specific criteria for waste received in intermodals that are to be returned after emptying. Intermodals must use an inner liner with 18 mil thickness for debris and 12 mil thickness for soil. Intermodals may not weigh more than 44,000-lb gross weight and there must be an 18 in. clearance between the top of the waste and the bottom of the header brace near the door end of the container (this limits the waste volume within the intermodal to about 18 yd^3). Only soil, gravel, concrete rubble, scrap metal, and building rubble are acceptable for packaging and delivery in this manner. Debris items must not have a dimension greater than 3 ft in any direction. Soil must not contain debris or large rocks. Additional container design requirements, radiation dose, and radiological inventory limits also apply.

6.3.2.2.3 Transportation to NNSS

NNSS is only capable of receiving truck shipments; however, a portion of the shipment can be made by rail to a transfer station in Kingman, Arizona, and then transferred to trucks for final delivery to NNSS. The existing rail spur at the ETTP is available for rail shipments.

6.3.2.2.4 NNSS Documentation and Characterization Requirements

All waste disposed of at NNSS must be evaluated to ensure compliance with DOE O 435.1, "Radioactive Waste Management." The generator is required to develop, implement, and maintain the following documents:

- Quality Assurance Program Plan
- NNSS WAC Implementation Crosswalk
- Waste Profiles (summarize waste form, characterization data)
- Certification Personnel – list identifying the site waste certification officials

NNSS may require that a split sample be collected from a waste stream based on the annual volume, the potential for finding hazardous components, or the scope/complexity of the sampling process for the waste stream. If required, samples are collected by the generator under the observation of NNSS personnel.

6.3.3 Waste Control Specialists, Texas

WCS is a waste processing and disposal company that operates a permitted 1,338-acre treatment, storage and disposal facility near Andrews, Texas. WCS offers management of radioactive waste, hazardous waste, and mixed waste. Evaluation of the WCS disposal alternative, assuming that disposal fees are comparable to Energy*Solutions*, indicates that WCS would be the lower cost option due to lower rail and truck transport costs. This assumes that the federal disposal site at WCS is available and bulk transport of debris is allowed with non-containerized disposal. Non-containerized disposal of debris at WCS is currently not allowed and will require approval of a license amendment. For this reason, WCS is not considered a viable alternative for the majority of LLW to be generated as containerizing that debris would be cost prohibitive.

WCS capabilities include:

- Treatment
- Storage
- Repacking/consolidation
- Decontamination and free release of materials
- Disposal

WCS can accept mixed Class A, B, and C LLW and has a separate Federal Waste Disposal (FWD) facility with a current capacity of 964,000 yd^3. WCS is licensed and permitted to perform treatment of mixed waste and RCRA/TSCA materials, including the following treatment technologies:

- Chemical oxidation, reduction, neutralization, and deactivation
- Macro- and micro- encapsulation

- Stabilization and solidification
- Treatment of water-reactive materials

Within the FWD, waste may be delivered in containerized or bulk form. Only bulk soil and containerized waste (debris, other) is acceptable in the FWD at the present time. License amendments are in progress to gain approval for acceptance of non-containerized bulk debris. Containerized waste materials such as debris must fit into a concrete canister known as the Modular Concrete Canister (MCC). Cylindrical MCCs are 6 ft, 8 in. diameter with a height of 9 ft, 2 in. Typically 14, 55-gallon drums fit in a cylindrical MCC. Rectangular MCCs are 9 ft, 6 in. long × 7 ft, 8 in. wide × 9 ft, 2 in. tall. Typically four B-25 boxes fit in a rectangular MCC. There are other limitations on Federal waste at the present time, but license amendments are in progress to allow additional waste types and compositions. General requirements for containerized waste include the following:

- Class A, B, or C.
- Depleted Uranium (DU) - Containerized waste streams containing DU in concentrations <10,000 pCi/gram are authorized.
- License Amendment currently under review with the Texas Commission on Environmental Quality to allow acceptance of any depleted uranium, except for uranium hexafluoride.
- Free liquids - must pass Paint Filter Liquids Test, SW-846, Method 9095; no visible free liquids are allowed in bulk waste shipments; containerized waste packages must have <1% free liquids.
- Mixed LLW is acceptable.
  - F020, F021, F022, F023, F026 and F027 (Dioxins & Furans) prohibited.
  - LDR notification required.
- TSCA regulated waste at FWD.
  - Containerized LLW and mixed LLW containing asbestos.
  - Request for TSCA authorization to accept PCBs submitted to EPA.
- Non-containerized bulk waste (soil only).
  - Class A only.
  - Less than 100 mR per hour at 30 cm.
  - Contains isotopes with half-lives less than 35 years.
  - Transportation by highway only.
  - DU and TRU isotopes not allowed.
  - Soil must be <1% debris per container.
- Bulk Debris (Debris & Rubble) for In-Cell Constructed Enclosure (when license amendment is approved).
  - Class A only.
  - Meets RCRA definition of debris and also includes monoliths (concrete-like forms generated by stabilization of waste).
  - Dose rate of waste <100 mR per hour at 30 cm.
  - Each container >50% debris.
  - Average organic content <5% for the entire waste.

The facility is accessible by rail or highway and has on-site rail and truck off-loading capabilities. The distance from the Oak Ridge Office (ORO) to Andrews, Texas is approximately 1,177 miles compared to about 2,290 miles for Energy*Solutions* and about 2,616 miles to NNSS. Consequently, WCS transportation costs may be about half of those for Energy*Solutions* or NNSS. DOE recently entered into a contract with WCS. If disposal rates are comparable to Energy*Solutions*, WCS overall off-site disposal costs would be competitive with other off-site facilities. However, based on the limited FWD capacity, WCS does not currently provide sufficient capacity to make it a viable option in this analysis for the large volume of LLW considered, leaving it as a process modification for that waste stream. It is considered here as a viable option for treatment and disposal of mercury-contaminated mixed waste debris.

6.3.4 Size Reduction Processing

Transportation is the most important cost element for the Off-site Alternative; therefore, it is important that materials be shipped efficiently through maximizing the quantity of waste material per shipment. For waste materials that are low in bulk density due to high void fraction, the quantity for shipment in a transport container is limited by the size and not the weight of the material. Transportation costs could be reduced substantially by reducing void volume through size reduction (as demonstrated in Appendix B); therefore, it is assumed that size reduction capability would be provided for this alternative (Option 1 only, see Appendix B). A centralized size reduction facility (SRF) would be constructed and operated to size reduce selected materials to increase the mass of waste material per shipment.

6.3.5 Off-site Disposal Alternative Description

Figures 6-28 and 6-29, respectively, show the off-site disposal activities and responsible entities for waste shipments to Energy*Solutions* or WCS and NNSS. Non-classified waste LLW and LLW/TSCA waste would be shipped by rail followed by truck transport to NNSS using a transload facility in Kingman, Arizona (Option 1). All classified waste LLW shipments to NNSS would be by truck transport, and LLW/RCRA (mixed) waste would be shipped by rail for treatment and disposal at Energy*Solutions*, Clive, Utah, or WCS in Andrews, Texas (Option 1 or 2). Non-classified waste LLW and LLW/TSCA waste could also be shipped to Energy*Solutions* for disposal (Option 2). Appendix I contains the cost estimate and additional assumptions for the Off-site Disposal Alternative Options 1 and 2.

The waste generator would be responsible for waste removal; waste characterization, preparation of waste profile and certification; waste segregation; treatment as necessary to meet disposal facility WAC; packaging with exceptions as noted in Sections 6.3.5.2 and 6.3.5.3; local waste transport; and interim storage, as required, for waste not meeting disposal facility WAC.

6.3.5.1 Characterization and Treatment

The waste generator would review all existing waste characterization information to determine compliance with the characterization requirements and the WAC of the designated disposal facility. Wastes with inadequate characterization data would be sampled and analyzed as necessary. The WAC documents for each of the off-site disposal facilities provide detailed information related to the required analyses for waste streams.

6.3.5.2 Packaging of LLW and Classified Waste

Packaging requirements for wastes originating at each generator site would be determined based on waste form (e.g., treated or untreated soil, debris, miscellaneous solids, personal protective equipment /trash, sediment/sludge), waste type (e.g., LLW, mixed waste), transportation mode, destination, and other considerations. Generators would be responsible for waste packaging to reach the ETTP transloading station.

Intermodals are easy to load, are consistent for the projected waste streams, and, when sealed, can be loaded onto trucks and transferred from trucks to railcars with ease. Intermodals are also commonly used at ORR and the disposal facilities are familiar with their use. The intermodal containers would be dedicated to one or more DOE generator sites and would be recycled throughout the waste disposal process, unless used for classified LLW waste disposal at NNSS. Classified waste shipped to NNSS is assumed to be disposed in non-returnable containers.

6.3.5.3 Packaging of Mixed Waste

Two disposal facilities have been identified as possible off-site treatment and disposal options for the management of mercury-contaminated debris expected to result from the demolition of mercury-use facilities at Y-12. Those are Energy*Solutions* and WCS. Those facilities provided vendor quotes for management of this waste stream; however, that information is provided in Appendix C as information only and not included in the off-site alternative costs. Both facilities were assumed to receive the waste prior to treatment, in appropriate packaging, via rail. The volume to be treated and disposed, as defined in Chapter 2 and again in Table 6-7 of this chapter, is nearly 150,000 yd^3, which includes a 25% contingency.

6.3.5.4 Local Transportation

Local transportation methods would be determined at the waste generator site-specific level. There is little difference in local transportation costs between the On- and Off-site Disposal Alternatives because the average distance from the generator sites to either the on-site disposal facility or the transload facility at ETTP would be similar. Local transportation is considered the responsibility of the generator, and costs are not evaluated in the detailed analysis.

All waste containers would be loaded onto a truck at the generator site. The waste containers would be manifested and placarded appropriately for on-site transportation before placement on the trucks. LLW/RCRA waste would be transported to the transload facility at ETTP for rail shipments to Energy*Solutions* or WCS. Non-classified LLW and LLW/TSCA waste would be transported to the transload facility at ETTP for rail shipment to Kingman, Arizona, and subsequent transfer to trucks for transport to NNSS.

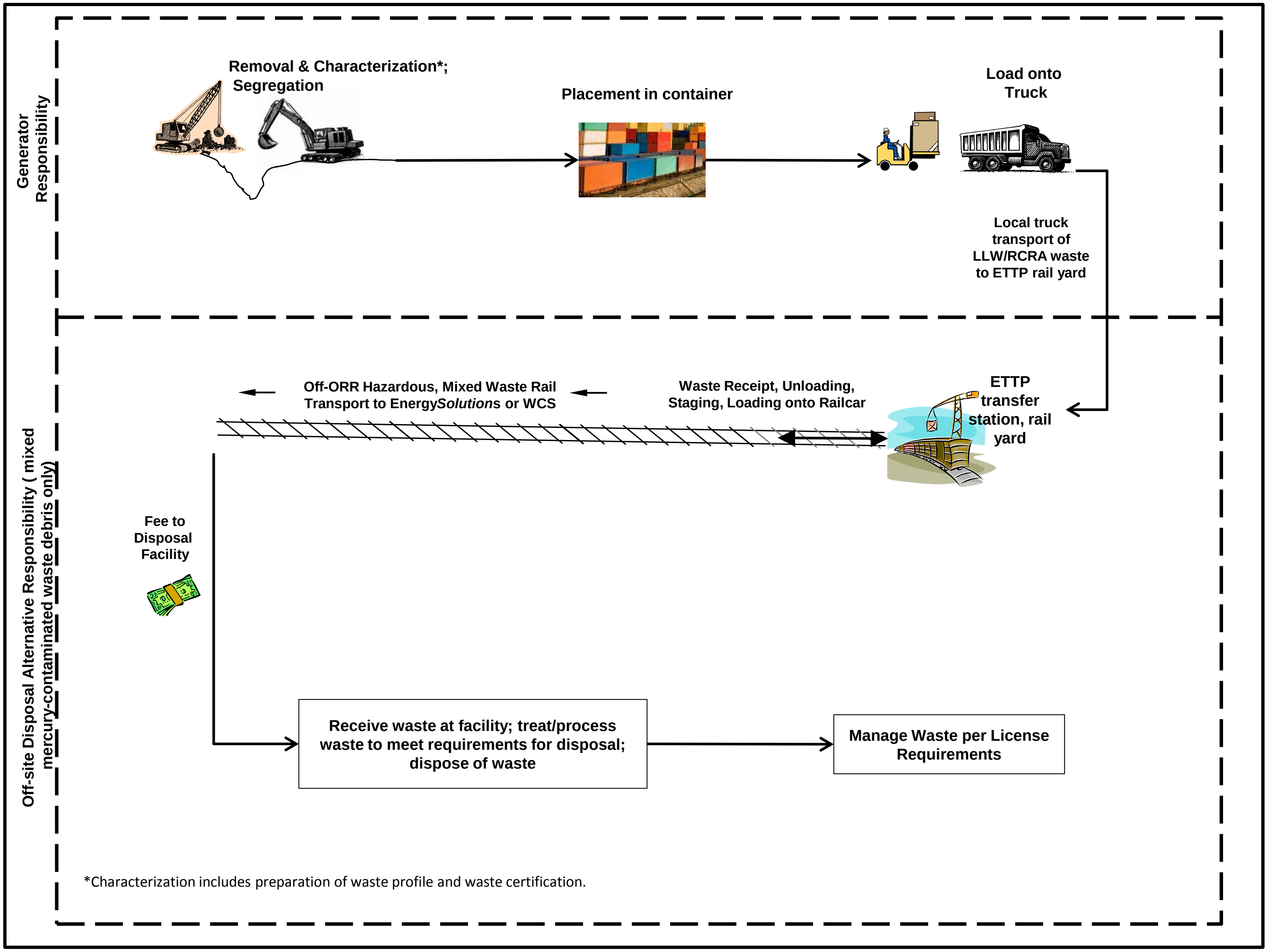

Figure 6-28. Schematic of Responsibilities for Waste Shipments to Energy*Solutions* or WCS for Off-site Disposal Alternative

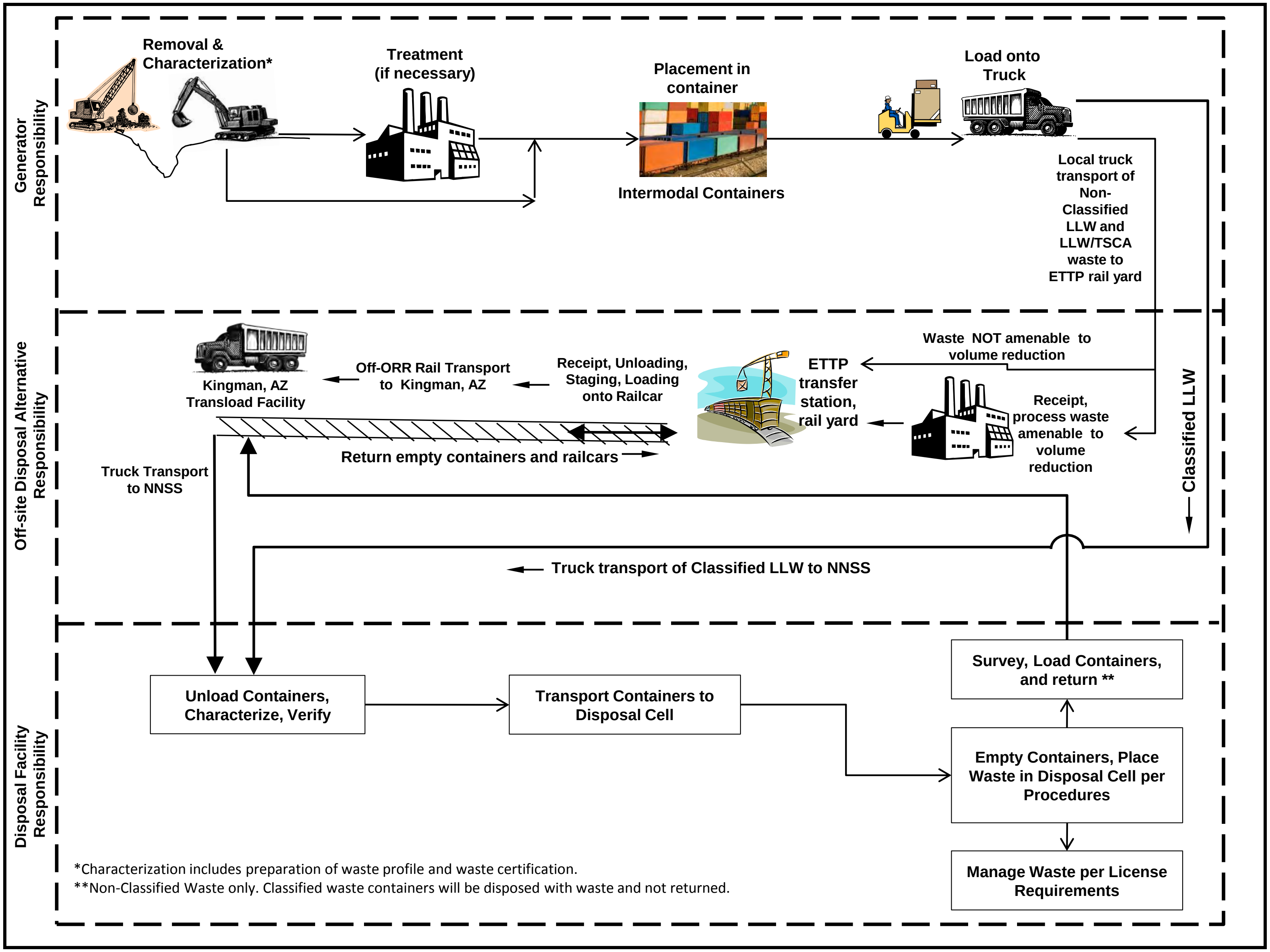

Figure 6-29. Schematic of Responsibilities for Waste Shipments to NNSS for Off-site Disposal Alternative

6.3.5.5 Transload Facility at ETTP

Rail transportation of waste is assumed for all non-classified waste being shipped for off-site disposal. The existing transload facility at ETTP would facilitate the transfer and staging of waste containers from trucks to railcars. Wastes delivered by truck from generator sites would be staged in intermodal containers at an existing docking area for rail shipment. Wastes that require size reduction would be processed prior to loading the intermodal containers and staged in similar fashion. The intermodals would be loaded onto articulated bulk container railcars using forklifts, access ramps, and overhead or mobile cranes. These railcars would be moved on this rail spur by a locomotive. When ready for shipment, one or more railcars would be transferred from the rail spur to the CSX system.

Some upgrades to the transloading facility, and maintenance for the term of the cleanup would be expected. Additionally, a contractor would have to operate the transloading facility. Activities would include exterior radiation scanning/control of incoming/outgoing containers; environment, safety, and health activities; waste manifesting and placarding; reporting; and management as well as actual transfer/loading of waste intermodal containers. The cost of transfer/loading of waste is assumed to be included in the transportation costs.

For Option 1, an estimated 116,216 intermodal containers would be transported from the individual remedial sites to the transload facility at ETTP. Each railcar would carry eight intermodal containers resulting in 1,037 railcar loads (mixed waste) to Energy*Solutions* in Clive, Utah, and 13,252 railcar loads to Kingman, Arizona, for truck transfer to NNSS. Classified waste is trucked in intermodals (1,898 shipments) to NNSS. Option 2 would include transport of the 116,215 intermodals in gondolas, by rail to Energy*Solutions* in Clive, Utah.

It is assumed that DOE would purchase dedicated returnable intermodal containers for transporting non-classified waste. Incoming intermodal containers could be staged directly on the cars until one or more cars could be transferred to the main line and shipped. This eliminates the need for construction of additional staging facilities or payment of demurrage fees for holding time at ORR or the disposal facilities.

6.3.5.6 Size Reduction Facility at ETTP

The plan for the Off-site Alternative (Option 1) involves constructing and operating a size reduction facility (SRF) located in close proximity to the ETTP transload station. Waste targeted for size reduction would be transported by dump truck to ETTP and unloaded into the size reduction unit feed systems for processing. Space for staging waste materials would be available, but would be minimized through scheduling and coordination with SRF operators. Processed material would be loaded by conveyor or excavator into intermodals that would be staged for loading onto railcars.

The SRF would be an enclosed facility that would occupy about 6,400 ft^2, not including space for outdoor staging of waste materials. The facility would include industrial shearing and shredding machines designed for size reducing materials such as heavy gauge steel and structural beams, large and small diameter piping, sheet metal, siding, roofing materials, flooring, and other materials with high void fraction. Excavators and conveyors would be utilized for managing the feed and processed materials. The SRF enclosure would be equipped with the necessary ventilation controls and exhaust filters to provide for worker safety and contamination control. Materials that do not benefit from size reduction, and would not undergo processing, include concrete and masonry type materials that are limited by weight rather than volume for transportation. Appendix B includes details regarding size reduction equipment, facility requirements, operational characteristics, and estimated costs.

About 393,000 yd^3 as-generated debris volume could be processed for the baseline evaluation. This percentage includes only debris considered amenable to size reduction and does not include concrete or other debris that does not benefit from processing. Based on cost estimate sensitivity analysis, the minimum quantity of debris processed that would result in a cost reduction that equals the cost of SRF implementation (break-even) would be about 30% of the forecasted debris quantity.ARARs for VR are included in the Off-site Disposal Alternative, Appendix G.

6.3.5.7 Off-ORR Transportation

Non-classified LLW and LLW/TSCA waste being shipped to NNSS by rail would be unloaded from trains at a transload facility at Kingman, Arizona.[17] The assumed rail route to Kingman, Arizona, (see Figures 6-30 and 6-31) involves three major railroads (CSX, Union Pacific, and Burlington Northern Santa Fe [BNSF]) and is approximately 2,402 miles (3,866 km) long. The shipment would be originated by CSX railroad, the rail service provider at ETTP. From ETTP the route continues on the CSX main line west through Tennessee into Memphis. In Memphis, the cargo transfers to the Union Pacific line and continues west through Little Rock, Arkansas; Dallas, Texas; El Paso, Texas; and Phoenix, Arizona. In Phoenix, the cargo transfers to the BNSF line and continues north through Flagstaff, Arizona, before arriving in Kingman, Arizona. Based on 13,252 railcar loads to Kingman, Arizona, approximately 31.8 M railcar miles (40 M railcar km) would be traveled between Oak Ridge, Tennessee, and Kingman, Arizona.

At Kingman, Arizona, intermodals would be transferred from railcars to trucks for the trip to NNSS in Nye County, Nevada. The assumed truck route from Kingman, Arizona, to NNSS (see Figure 6-31) is approximately 214 miles (343 km) long. Based on 116,216 truckloads, approximately 24.9 M truck miles (35.6 M truck km) would be traveled between Kingman, Arizona, and NNSS. On the return trip, trucks would carry empty intermodals back to Kingman, Arizona, for transfer to railcars and the return trip to Oak Ridge, Tennessee. A 40-day round trip is assumed for rail transportation to Clive, Utah, or Kingman, Arizona.

For classified LLW waste, truck transportation is assumed for the trip from Oak Ridge, Tennessee, to NNSS. There are various approved routes for shipments of classified waste. A representative route approximately 2,056 miles (3,309 km) long was used for purposes of the RI/FS analysis. Based on 1,898 truckloads, approximately 4 M truck miles (6.4 M truck km) would be traveled between Oak Ridge, Tennessee, and NNSS.

From Oak Ridge, Tennessee, the intermodals would be loaded onto trucks and the trucks routed to Nashville, Tennessee. From Nashville, the truck would proceed thru West Memphis, Arkansas, and Oklahoma City, Oklahoma. After passing thru Oklahoma City, the truck would pass through Vega, Texas; Kingman, Arizona, and then arrive at Amargosa Valley, Nevada.

All LLW/RCRA (mixed) waste would be transported by rail and disposed at the Energy*Solutions* facility in Clive, Utah, and/or WCS in Andrews, Texas. The assumed rail route to Energy*Solutions* (see Figures 6-30 and 6-31) involves three major railroads (CSX, Indiana Harbor Belt [IHB] Railroad, and BNSF Railway) and is approximately 2,290 miles (3,686 km) long. This route was analyzed in the transportation risk, since it is the bounding case. The shipment would be originated by CSX railroad, the rail service provider at ETTP. From ETTP, the route continues on the CSX main line north into Corbin, Kentucky, through southern Ohio, north through Indiana, and into Illinois near Chicago. Here the cargo transfers to the IHB rail line for 16 miles and then transfers to the BNSF line at La Grange, Illinois. The

[17] The transloading station in Kingman, Arizona has been replaced with a transloading station in Parker, Arizona. This document remains with the Kingman, Arizona location because the difference between the two locations amounts to only a 30 mile difference; one is has a bit longer rail route, the other a bit longer truck route with the total difference between the two whole routes only 30 miles in length.

route continues west through Illinois and crosses into Iowa at Burlington. The route continues through Lincoln, Nebraska; Denver, Colorado; and Grand Junction, Colorado; before arriving in Clive, Utah.

Similar to the rail route taken to get to NNSS, the rail route to Andrews would be originated by CSX railroad, the rail service provider at ETTP. From ETTP, the route continues on the CSX main line west through Tennessee into Memphis. In Memphis, the cargo transfers to the Union Pacific line and continues west through Little Rock, Arkansas; Dallas, Texas; and to Andrews where WCS is located.

6.3.5.8 Disposal

Energy*Solutions*, WCS, and NNSS facilities are familiar with and equipped for the unloading of intermodal waste containers. The intermodal containers would be transferred to the facility's dedicated trucks/equipment, taken into the appropriate disposal cell, and emptied per approved procedures. The waste would be placed in the facility according to approved procedures. Empty containers for LLW and LLW/TSCA waste shipped to the disposal facilities would be surveyed at the disposal facility for release and return to ORR. It is assumed for purposes of this RI/FS that no decontamination of the containers would be required prior to their return. LLW/RCRA waste shipped to Energy*Solutions* and/or WCS for treatment/disposal is based on reuse and limited decontamination of containers as provided in quotes by the vendors. Classified LLW shipped to NNSS for disposal is assumed to be packaged in purchased (non-returnable) intermodal containers.

Table 6-7 provides the estimated volumes that would be disposed at Energy*Solutions* and/or WCS and NNSS. There is currently no disposal fee charged to DOE sites for waste disposal at NNSS; however, DOE costs for NNSS disposal are accounted for through applying a rate of \$14.51 per ft^3 for estimating purposes (NNSA 2008).. Fees at Energy*Solutions* for disposal of LLW and LLW/TSCA waste are per the current Indefinite Delivery/Indefinite Quantity contract (Energy*Solutions* 2012).

6.3.5.9 Management of Waste Exceeding Off-site Disposal WAC

All waste disposed of under the Off-site Disposal Alternative would be required to satisfy the appropriate facility WAC. For wastes not meeting the designated facility's WAC or regulatory requirements regarding transportation or land disposal, the generator would be responsible for appropriate treatment in order to render the waste acceptable at an off-site disposal facility.

If an off-site facility is not identified that can accept a certain waste stream even with treatment, that waste stream would require interim storage until treatment or disposal capacity is identified and/or becomes available.

As discussed in Section 2.1.3, the expected volumes of waste exceeding WAC or shipped off-site for other project-specific factors are small and are comparable for both the On- and Off-site Disposal Alternatives. Those volumes are not considered as part of this RI/FS analysis.

6.3.5.10 Process Modifications

Process modifications could be used to maximize effectiveness and efficiency of off-site disposal. Process modifications that may be considered include disposal at a WCS facility in Texas, transportation by gondola, and transportation by truck. If deemed beneficial and feasible, these process modifications could be incorporated into the Off-site Disposal Alternative.

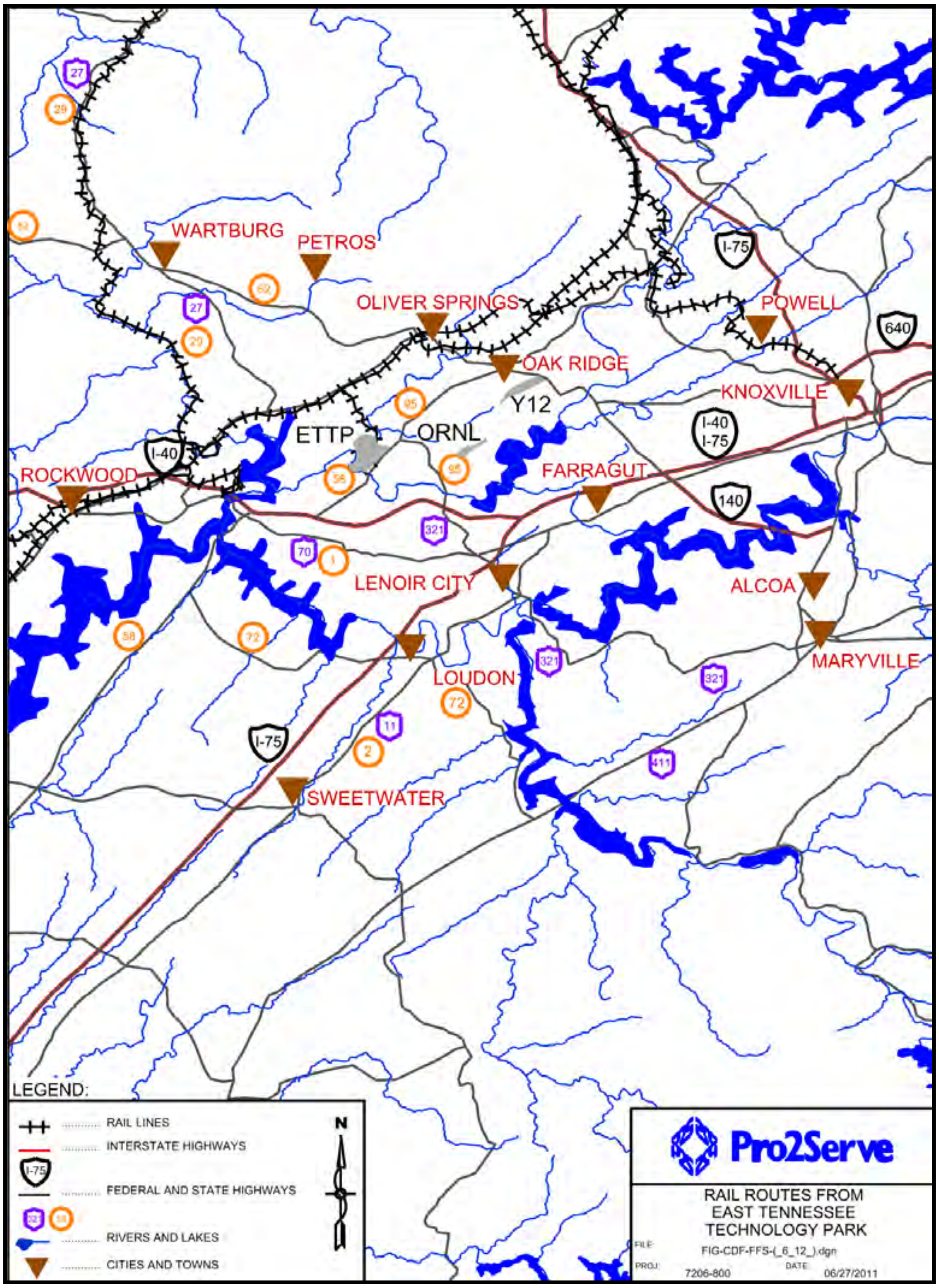

Figure 6-30. Rail Routes from ETTP

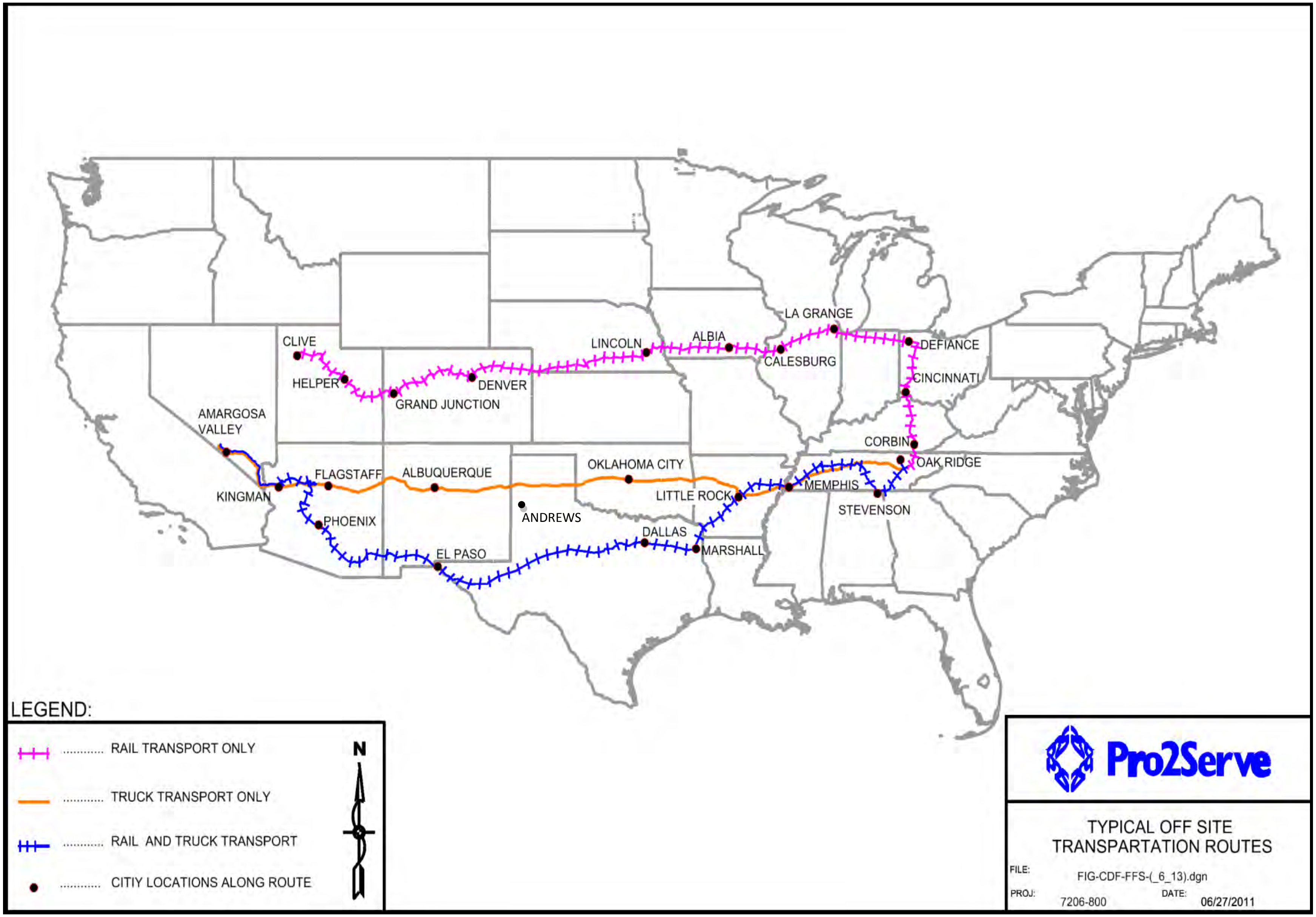

Figure 6-31. Typical Off-site Transportation Routes

6.3.5.10.1 Disposal at WCS

As discussed earlier, WCS is a waste processing and disposal company that operates a permitted 1,338-acre treatment, storage and disposal facility near Andrews, Texas. WCS offers management of radioactive waste, hazardous waste, and mixed waste. As noted previously, WCS is not considered a viable alternative for the large volumes of debris expected to be generated in the future CERCLA cleanup on the ORR due to limitations in place concerning the receipt of debris waste (must be containerized). Additionally, the size of the facility (964,000 yd^3) precludes it from receiving the large volumes of waste predicted in future cleanup activities. The facility is kept as a process modification, for future consideration if the facility is expanded and/or debris may be received in bulk form. It is considered a viable option and included in the analysis for off-site treatment (treatment cost is the generator's responsibility) and disposal of the mercury-contaminated debris that will be generated when Y-12 mercury-use facilities are demolished.

6.3.5.10.2 Transportation by Gondola

Standard gondolas have a volume capacity of about 100 yd^3 and supergondolas have a volume capacity of about 230 yd^3. Only Energy*Solutions* at present has the capability to receive and unload gondolas for placement of the waste. The volume of waste per gondola may be limited by the bulk density of the waste material as the weight capacity is about 100 tons.

6.3.5.10.3 Transportation by Truck

Preliminary cost analysis indicates that cost savings by using rail shipment versus truck shipment would be approximately 11%. However, truck transportation to NNSS and/or Energy*Solutions* may be more favorable than rail in some cases (e.g., small projects where there is not enough material to justify rail shipments). Off-site waste shipment by truck provides a more direct mode of transport and more flexibility than rail and can be more economical depending on the project. However, on a cumulative basis, truck transport is much more costly than providing comprehensive rail shipment of waste.

6.4 HYBRID DISPOSAL ALTERNATIVE

Hybrid disposal refers to significant disposal at both on-site and off-site disposal facilities using elements of both the On-site Disposal Alternative and Off-site Disposal Alternative. As with the other alternatives, the starting waste volume for the Hybrid Disposal Alternative is that waste volume produced by CERCLA actions on the ORR that could theoretically be disposed on-site. The Hybrid Disposal Alternative proposes consolidated disposal of future-generated CERCLA waste exceeding the capacity of the existing EMWMF in a newly-constructed, much smaller capacity, engineered waste disposal facility (i.e., landfill) on ORR, referred to as the EMDF. Waste volumes that exceed the capacity of the facility – regardless of whether those wastes meet the on-site disposal WAC – would be disposed off-site. A single on-site disposal option is analyzed (Site Option 6b, one of the two sites included in the Dual Site Option) with components (e.g., buffer, liner, berms, cells, final cover) the same as that discussed under the On-site Disposal Alternative (Section 6.2).

Construction of the on-site facility at Site Option 6b is planned to be conducted in a single phase. The on-site portion of the alternative includes designing and constructing the landfill, support facilities, and roadways; developing plans and procedures, personnel training and supervision; receiving waste that meets the WAC; unloading and placing waste into the landfill; surveying and decontaminating as needed any containers, equipment, or vehicles leaving the site; closing the landfill; and managing the waste and the landfill during the construction, operations, closure, and post-closure periods. All these elements were discussed in detail in Sections 6.2.1 to 6.2.10. Due to the limited capacity of the on-site disposal element of this alternative, a size reduction facility to reduce disposal volumes has been added to the on-site portion of the Hybrid Alternative and is discussed in Section 6.4.1.2 below.

The off-site portion of the alternative includes the same elements that were discussed in detail for the Off-site Disposal Alternative, Sections 6.3.2 to 6.3.5, for Option 2 (bulk of waste is sent to Energy*Solutions* in Clive, Utah).

6.4.1 On-site Portion of Hybrid Disposal Alternative

As stated, the on-site portion (disposal of CERLCA waste in a newly constructed on-site landfill) details are presented under the On-site Disposal Alternative (particularly design of the facility) and are not duplicated here. Elements that differ from the on-site alternative are presented in the following sections.

6.4.1.1 Proposed On-site Location

The on-site landfill location selected for inclusion in the hybrid alternative was constrained by the following two criteria:

- The landfill location must meet the minimum capacity that allows on-site disposal to be more cost effective than off-site disposal.
- The landfill location must minimize hydraulic connections between ground water and surface water (e.g., minimize underdrain construction).

A brief analysis was completed to determine at which volume on-site disposal is no longer cost effective compared to off-site disposal. This analysis is necessarily approximate, because the on-site disposal cost is reliant on the specific site selected. Off-site disposal cost per cubic yard is constant — ~\$824/yd^3 (see Figure 6-32, including the notes), representing a straight line. The unit cost of \$824/yd^3 is essential a fixed-unit-rate that is independent of volume—whether its 500,000 yd^3 or 2,000,000 yd^3. In contrast, the cost per cubic yard for disposal on-site varies: the greater the volume disposed, the lower the cost per cubic yard. Unit costs were evaluated for a series of as-disposed volumes ranging from 440,000 yd^3 to roughly 2 million yd^3. The resultant cost per cubic yard disposed ranged from roughly \$1,262 to \$400, respectively. The volume at which the off-site and on-site costs are essentially equivalent, i.e., the breakeven volume, is roughly 750,000 yd^3. At this volume, the unit cost for on-site and off-site disposal is \$824/yd^3.

In summary, for waste volumes less than 750,000 yd^3, off-site disposal appears to be less expensive per cubic yard disposed. For waste volumes greater than 750,000 yd^3, on-site disposal appears to be less expensive per cubic yard. As waste volumes approach 2,000,000 yd^3, the unit rate for on-site disposal is roughly half the cost of off-site disposal.

Based on meeting the first criterion, the on-site landfill should provide in excess of 750,000 yd^3 of capacity. All small footprints examined (Sites 7a, 7b, and 6b) with the exception of Site 6a, fulfilled this criterion (see Appendix D). The second criterion, to minimize as much as possible hydraulic connections between ground water and surface water, was best satisfied by Site 6b. Additionally, Site 6b is located immediately adjacent to EMWMF in an area dedicated to DOE waste management in the future. Therefore, this site, which provides 850,000 yd^3 of capacity, was selected as the hybrid alternative's on-site location.

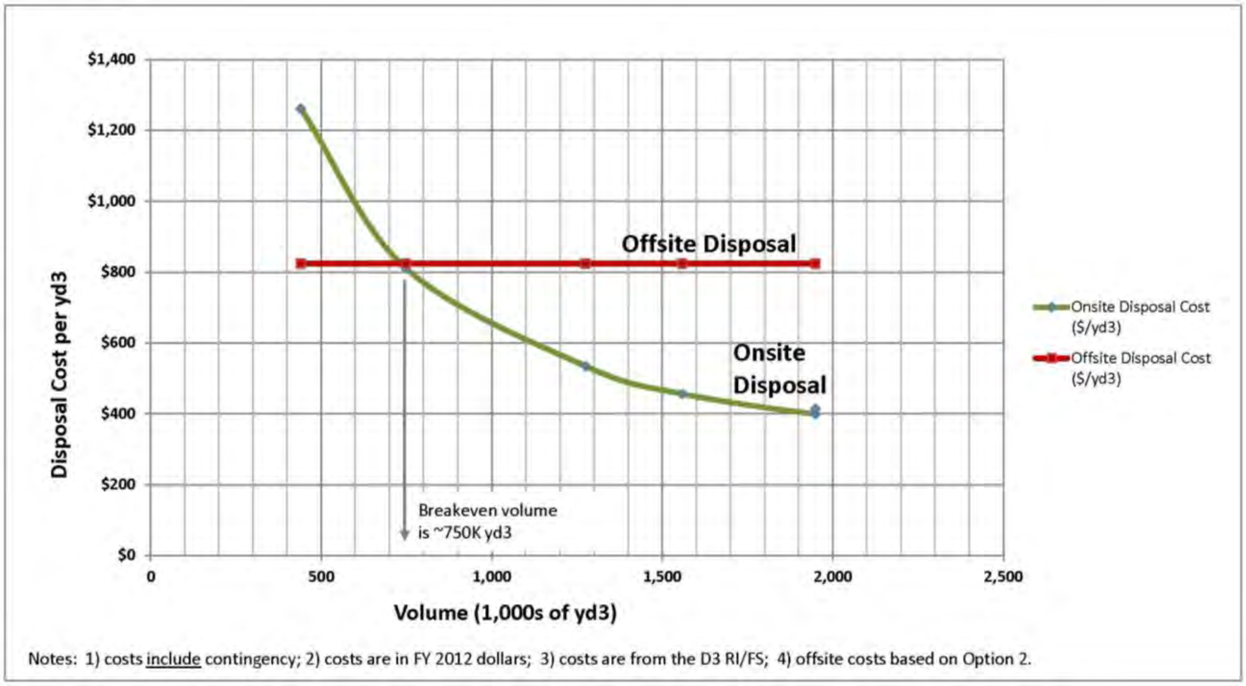

Figure 6-32. Estimate of Minimum On-site Capacity Required to Reduce $/yd^3 below Off-site Disposal Costs

6.4.1.2 Waste Volumes

Waste volumes to be disposed in the on- and off-site portions of the hybrid alternative are presented in Chapter 2. Those volumes are as follows:

Material Type	On-site Volumes by Material Type		Off-site Volumes by Material Type (As-generated, yd^3)
	(As-generated, yd^3)	(As-disposed, yd^3)	
Debris	490,706	244,132	582,166
Soil	77,566	59,666	408,409
Fill		492,073	(not applicable)
Volume preserved through VR		-144,838	
25% uncertainty		**198,968**	**247,644**
Total		**850,001**	**1,238,219**

The volumes for on- and off-site disposal were determined based on the sequencing of projects as given in Appendix A. As the split of volumes indicates, there is significantly more soil disposed in the latter half of the cleanup effort. This is due to the need to demolish buildings prior to remediation of soils. To develop an estimated schedule it is assumed that while the on-site facility is operational, 10% of debris is transported and disposed off-site. This is a reasonable assumption, and allows for an operational period of 12 years for the on-site facility before the capacity is reached (including the additional capacity provided through volume reduction). Assuming higher amounts of waste are initially disposed off site (e.g., 20 or 30%) just lengthens the operational period of the on-site facility by up to 3 years. The cumulative volumes to be disposed on-site versus off-site do not change significantly (some effect of soil sequencing is seen, but it is a very minor effect).

After 12 years of operation of the on-site facility, the remainder of waste must be disposed off site. As the figures in the table indicate, there is a larger portion of soil being disposed off site due to more soil being generated later in the cleanup program, after the buildings are demolished.

If this alternative becomes the selected alternative, a future WAC Attainment (Compliance) Plan may include provisions for supporting determinations concerning what would be disposed on- versus off-site. Some adjustments of sequencing might be possible, but are beyond the scope of this document to address or assume.

6.4.1.3 Volume Reduction

Volume reduction is assumed for the on-site portion of the Hybrid Disposal Alternative. Appendix B presents the VR analysis for the On-site Disposal Alternative and the Off-site Disposal Alternative. Based on the Appendix B analysis, the use of a centralized VR system at the Hybrid Alternative EMDF would provide an additional 145,000 yd^3 of disposal capacity in the on-site facility. This additional capacity results in a reduction in the number of off-site shipments necessary under this alternative at a cost of about $61.7 M. Operation of the VR facility at the EMDF would have an estimated lifecycle cost of $29.4 M (capital and operating, based on a 12 year operating life). The analysis demonstrates a net cost savings of approximately $32.3M (FY 2012 dollars) in off-site transportation and disposal costs. VR by mechanical means was therefore incorporated as part of the Hybrid Disposal Alternative.

The VR facility would be located near the EMDF (see Figure 6-33). The VR system (facility, throughput, etc.) is as described in detail in Appendix B; however, this facility would be operating for a shorter time period (but at the same rate as described in Appendix B). ARARs for the VR system are included in Appendix G, Table G-7. Cost information is taken from Appendix B, and adjusted for the expected operating period. See Appendix I for a detailed examination of the costs assumed.

6.4.1.4 Operations

Based on the assumption of 10% of debris disposed off site while the on-site facility is operational, and with additional capacity freed up by mechanical VR, the lifecycle of the facility is 12 years. Operations will be conducted identical to those described under the On-site Disposal Alternative. The smaller size of the landfill does not result in any needed operational changes. Capping and closure of the facility will take an additional two years.

6.4.2 Off-site Portion of Hybrid Disposal Alternative

Disposal of waste to off-site facilities will occur for the entire lifecycle of the project; however, the initial 12 years of operation will see much less waste (only 10% of debris) being disposed under this portion of the alternative. It is unlikely that a small portion of waste disposal such as this would need a fully functioning transloading facility. Thus use/operation of transloading facility is assumed to begin in the 13th year of operation when all waste begins to be shipped off site for disposal. However, rail transport is still assumed for the entire lifecycle. Off-site disposal of *all* waste occurs for years 13 through 22, at which time the cleanup program has completed generation of waste.

Option 2 of the Off-site Disposal Alternative, disposal of the bulk of the waste to Energy*Solutions* in Clive, Utah, is the assumed pathway for the off-site disposal portion of the hybrid alternative. Elements of this option are identical to the Off-site Disposal Alternative. It is assumed that classified waste generated while the smaller EMDF is operational would be disposed on site if the WAC is met. But classified waste generated that does not meet the WAC or is generated once EMDF is closed would be disposed at NNSS consistent with the description in the Off-site Disposal Alternative.

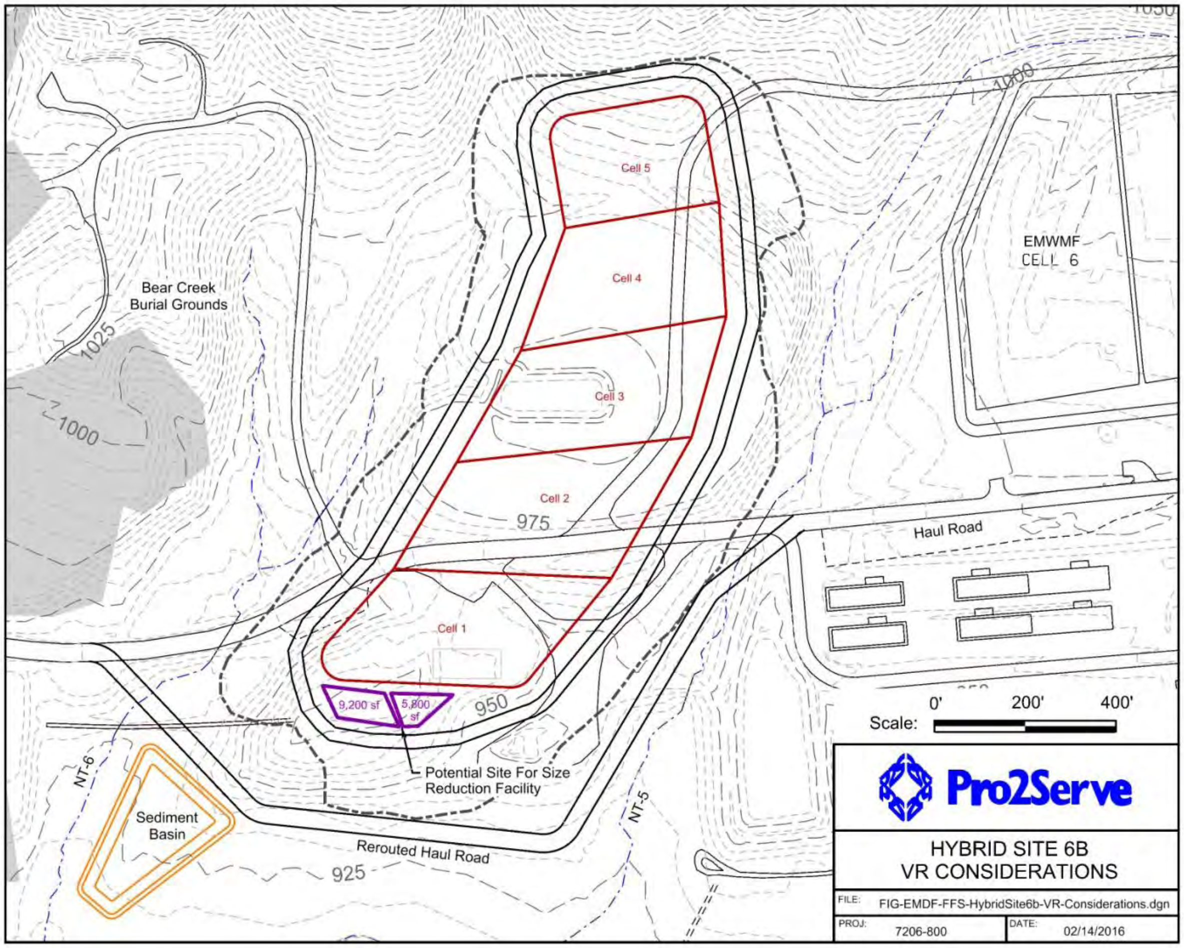

Figure 6-33. EMDF Layout for Site 6b of the Hybrid Disposal Alternative, Showing VR Facility Location

7. DETAILED ANALYSIS OF ALTERNATIVES

This chapter provides detailed analysis of the No Action Alternative, the On- and Off-site Disposal Alternatives, and the Hybrid Disposal Alternative described in Chapter 6. Relevant information is presented and assessed to provide the basis for identifying the preferred alternative in the Proposed Plan and the selected remedy in the ROD.

The detailed analysis consists of individual and comparative analyses. Building on the technology screening, alternative development, and detailed alternative descriptions, the individual analysis provides an in-depth evaluation of each alternative against the CERCLA threshold and primary balancing criteria identified in the National Oil and Hazardous Substances Pollution Contingency Plan (40 CFR 300.430). Following the individual analysis, the comparative analysis highlights the key advantages, disadvantages, and tradeoffs among the alternatives. NEPA values are incorporated into both the individual and comparative phases of the alternative analysis.

The CERCLA modifying criteria (state agency and community acceptance) are not addressed in the detailed analysis because these criteria rely on participation that has not yet occurred. In terms of the state agency input, this current RI/FS document has not been seen in its entirety by the state. The state has seen earlier versions of the RI/FS, which differ significantly from this version, and documenting the state's input on an earlier version could be misinterpreted as applying to the current document; their input is documented separately in submitted comments to which DOE has responded to in developing this RI/FS. While the Oak Ridge Site Specific Advisory Board (ORSSAB) has had some input into alternatives for disposal of CERCLA waste, their input is only a portion of public participation. The most significant public participation and feedback is gathered based on the Proposed Plan. The Proposed Plan, which documents the evaluation of remedial alternatives and presents the preferred alternative, will be issued for public review and comment subsequent to regulatory agency concurrence. Public comments on the Proposed Plan and any other components of the Administrative Record will be addressed in the ROD.

7.1 EVALUATION CRITERIA

CERCLA defines an approach that must be used to evaluate and compare alternatives. This approach uses nine evaluation criteria to facilitate comparison of the relative performance of alternatives and provides a way to identify their advantages and disadvantages. The nine criteria are divided into three categories – threshold criteria, balancing criteria, and modifying criteria.

Threshold Criteria: The two Threshold Criteria are minimum requirements that each alternative must meet in order to be eligible for selection in the ROD.

- Overall protection of human health and the environment
- Compliance with ARARs

Primary Balancing Criteria: The five Primary Balancing Criteria represent the primary technical, cost, institutional, and risk factors that form the basis of the evaluation and verify that the alternative is realistic.

- Long-term effectiveness and permanence
- Short-term effectiveness
- Reduction of contaminant toxicity, mobility, or volume through treatment
- Implementability
- Cost

The ability of alternatives to meet these criteria is evaluated in sufficient detail to enable decision makers to understand the significant aspects of each alternative and any uncertainties associated with the evaluation.

Modifying Criteria: The viability of the preferred alternative is evaluated on the basis of two modifying criteria:

- State acceptance
- Community acceptance

Alternatives are not evaluated against the modifying criteria in this RI/FS. Modifying criteria will be addressed in the ROD based on stakeholder participation (state and community) and feedback on the preferred alternative identified in the Proposed Plan.

In addition to these evaluation criteria prescribed under CERCLA, DOE policy directs that the substantive elements of analysis required under NEPA should be incorporated, to the extent practicable, into CERCLA decision documents (DOE 1994 and DOE 2010a). Elements common to both CERCLA and NEPA include protectiveness, long-term effectiveness and permanence, short-term effectiveness, and cost. Additional NEPA values are addressed for each alternative as described in Section 7.1.10.

7.1.1 Overall Protection of Human Health and the Environment

This evaluation criterion assesses each alternative's ability to achieve and maintain adequate protection of human health and the environment in accordance with RAOs. All alternatives except the No Action Alternative must satisfy this criterion.

The scope of this criterion is broad and reflects other evaluation criteria, especially long-term effectiveness and permanence and short-term effectiveness. This criterion addresses how site risks associated with each exposure pathway would be eliminated, reduced, or mitigated through treatment, engineering controls, or institutional controls. It also evaluates impacts to the site resulting from implementation of the remedial action.

7.1.2 Compliance with ARARs and To Be Considered Guidance

Appendix G presents a listing of ARARs and to be considered (TBC) guidance for the actions that would be taken to implement the On-site, Off-site, and Hybrid Disposal Alternatives. This criterion addresses compliance with federal and state environmental requirements and facility siting requirements that are either legally applicable or relevant and appropriate. In certain cases, regulatory standards may not exist that address the proposed action or the contaminants of potential concern. In such cases, non-promulgated advisories, criteria, or guidance developed by the EPA, other federal agencies, or states can be designated as potential requirements TBC. Other requirements that do not fall within EPA-established criteria for ARARs include DOE orders that pertain only to DOE facilities.

7.1.3 Long-term Effectiveness and Permanence

The long-term effectiveness and permanence criterion considers the degree to which the alternative provides sufficient engineering, operational, and institutional controls; the reliability of these controls to maintain exposures to human and environmental receptors within protective levels; and the uncertainties associated with the alternative over the long-term. Long-term environmental impacts evaluated include transportation impacts, air quality, wetland and aquatic resources, surface water resources, and ground water resources.

7.1.4 Short-term Effectiveness

Short-term effectiveness provides a means of evaluating the effects on human health and the environment at the site posed by the construction and implementation of the alternative. Potential impacts are examined, as well as appropriate mitigation measures for maintaining protectiveness for the community, workers, environmental receptors, and potentially sensitive resources. Short-term environmental impacts evaluated include transportation impacts, air quality, wetland and aquatic resources, surface water resources, ground water resources, T&E species, historical and cultural resources, noise, visual impacts, and duration of the alternatives.

7.1.5 Reduction of Toxicity, Mobility, or Volume by Treatment

This criterion considers the extent to which alternatives can effectively and permanently fix, transform, or reduce the volume of waste materials and contaminated media. The evaluation also considers the amount of material treated; the magnitude, significance, and irreversibility of the given reduction; and the nature and quantity of treatment residuals.

7.1.6 Implementability

Implementability refers to the technical and administrative feasibility of implementing the alternative. Administrative feasibility addresses the need for coordination with other offices and agencies, including the ability to obtain permits and regulatory agency approvals. Technical feasibility considers difficulties and uncertainties associated with construction and operation of a given technology; the reliability of the technology; the ease of undertaking additional future remedial actions; the ability to monitor effectiveness of remedial action; and the potential risk of exposure from an undetected release. Evaluation of the availability of services and materials includes consideration of the availability of necessary facilities, equipment, technologies, and specialists, and the effect of reasonable deviations on implementability.

7.1.7 Costs

Cost estimates developed to support the detailed analyses are based on feasibility-level scoping and are intended to aid in comparisons between alternatives. EPA guidance states that these estimates should have an accuracy of +50% to -30% (EPA 2000). The cost estimates for this RI/FS are based on the conceptual design and assumptions provided in the detailed alternative descriptions in Chapter 6 and Appendix I. No direct costs are associated with the No Action Alternative. The cumulative disposal costs from cleanup of individual sites under the No Action Alternative cannot be accurately estimated because they depend on independent actions at individual sites. Therefore, these costs are addressed qualitatively. For the On-and Off-site Disposal Alternatives, the following costs are addressed:

- Capital costs (direct and indirect)
- Operations costs, including long-term monitoring and maintenance costs
- Contingency (applied per EPA Guidance [EPA, 2000], see Appendix I) at 22% for the On-site Disposal Alternative total cost, 27% for the Off-site Disposal Alternative total cost, and 22% (on-site portion) and 27% (off-site portion) for the Hybrid Disposal Alternative total cost

Capital costs are those expenditures required to initiate and perform a remedial action, mainly design and construction costs. Capital costs consist of direct and indirect costs. Direct costs include design and construction (e.g., material, labor, and equipment), service equipment, buildings, and utilities. Indirect costs are mark-ups for fixed-price construction to cover expenses incurred by the subcontractor as described in Appendix I.

Operations costs include (1) long-distance transportation costs and fees paid to off-site disposal facilities; (2) waste handling and placement, facility maintenance, and monitoring during on-site disposal operations; and (3) costs for long-term monitoring and maintenance activities that would occur after closure of the on-site disposal facility. S&M costs for off-site disposal are assumed to be included in the disposal fees paid to the off-site facilities.

Present worth costs for the alternatives were calculated based on EPA guidance (EPA 2000) using a real discount rate of 1.5% according to the Office of Management and Budget (OMB) Circular No. A-94 (OMB 2016). The present worth costs are based on discounting costs given in 2012 dollars (base estimate) that have been escalated to FY 2016 dollars per the Consumer Price Index estimate of inflation over the 2012 to 2016 time frame. Present worth costs are reported in FY 2016 dollars. The full estimates are given in Appendix I.

7.1.8 State Acceptance

State acceptance of alternatives will be evaluated in the Proposed Plan issued for public comment. At that time, state input will have been finalized. Feedback received on the preferred alternative identified in the Proposed Plan will be documented in the ROD. Therefore, this criterion is not considered in this RI/FS because state input thus far addresses only previous versions of alternatives, and does not reflect the acceptance of current versions presented in this document.

7.1.9 Community Acceptance

Community acceptance of alternatives will be evaluated in the Proposed Plan issued for public comment. Community feedback, in terms of formal public comments to be received on the preferred alternative (identified in the Proposed Plan) will be documented in the ROD. Therefore, this criterion is not considered in this RI/FS. DOE is currently updating their Public Involvement Plan as is routinely accomplished. This update, due May 30, 2016 to the regulators as a D1 version, will document completed and planned efforts to engage the community on the alternatives presented in this RI/FS. The ORSSAB is participating in the review of that document.

Recommendations received from the ORSSAB regarding disposal of CERCLA waste (ORSSAB 2011, ORSSAB 2014) included the following:

- Evaluate and propose disposal capacity necessary to support current EM scope and potential additional cleanup waste streams.
- Analyze and compare the life-cycle costs and impacts of off-site disposal of expected waste streams versus those of a second on-site disposal cell.
- Reevaluate and update the original siting studies.
- Continue with planning for additional on-site disposal capacity for low-level radioactive and chemically hazardous contaminated waste, and continue ongoing efforts to minimize the need for additional on-site capacity.
- Ensure that the proposed new disposal facility will have sufficient capacity to accept all appropriate future generated waste from DOE activities through cleanup of the ORR.

These items are all taken into account in this RI/FS document.

7.1.10 NEPA Considerations

DOE policy (DOE 1994 and DOE 2010b) directs that CERCLA documents incorporate NEPA values, such as analysis of cumulative, ecological, and socioeconomic impacts, to the extent practicable. The NEPA process informs decision makers on a wider range of environmental and socioeconomic concerns than those specifically addressed under CERCLA. While this RI/FS incorporates NEPA values throughout, the evaluation of alternatives presented here highlights, as appropriate, values that are not specifically included in the CERCLA criteria: socioeconomic impacts, land use, environmental justice, irreversible/irretrievable commitment of resources, and cumulative impacts.

7.2 INDIVIDUAL ANALYSIS OF ALTERNATIVES

7.2.1 No Action Alternative Analysis

Evaluation of the No Action Alternative is required under CERCLA and NEPA to provide a basis for comparison with action alternatives. The No Action Alternative for this RI/FS assumes that no comprehensive strategy to address the disposal of waste resulting from any future CERCLA remedial actions at ORR would be identified or implemented. Under the No Action Alternative each CERCLA remedial action would be required to individually address the disposition of waste generated. Uncertainty about these future actions prevents specific identification of the impacts of no action. Efficiencies of consolidation and economies of scale would not be realized under the No Action Alternative.

7.2.1.1 Overall Protection of Human Health and the Environment (No Action)

Overall protection of human health and the environment would depend on the actions ultimately taken at individual sites. Risk reduction would have to be addressed by CERCLA decisions at the individual sites without the benefit of a comprehensive disposal strategy. The effectiveness of these controls at multiple sites would depend on local site conditions, the effectiveness of engineered controls enhancing local conditions, continued maintenance and monitoring, and security measures. Land use restrictions would be required at any sites where waste would be left in place, whether the waste was treated, contained, or disposed of in situ. The failure of these measures would increase human and ecological risks.

7.2.1.2 Compliance with ARARs (No Action)

Compliance with ARARs applies only to actions taken under CERCLA authority. No ARARs apply to the No Action Alternative which assumes no comprehensive disposal strategy for future waste generated by CERCLA actions. ARARs for remedial actions at individual sites that will generate future waste would be specified by separate CERCLA documents.

Under the No Action Alternative, there could be a future increase in the amount of stored waste due to a lack of readily available disposal capacity. Extended or indefinite waste storage could result in DOE being out of compliance with regulatory requirements and agreements.

7.2.1.3 Long-term Effectiveness and Permanence (No Action)

There would be no direct long-term adverse environmental effects under the No Action Alternative because no construction or operations activities would take place to implement a comprehensive waste disposal strategy. Long-term effectiveness and permanence would be determined in CERCLA actions at individual sites. While individual actions at the ORR could result in independent disposal capabilities that adequately prevent releases or exposure, the extent to which RAOs could be met would vary among sites. This alternative may not support timely cleanup or release of portions of ORR for beneficial use.

7.2.1.4 Short-term Effectiveness (No Action)

Similar to long-term effectiveness, there would be no direct short-term adverse environmental effects under the No Action Alternative because no activities to implement ORR-wide waste disposal would take place. However, risk at project levels, due to more waste transportation occurring by trucking (versus rail) to off-site disposal facilities, could be significantly higher. Short-term effectiveness would be determined in CERCLA actions at individual sites.

7.2.1.5 Reduction of Contaminant Toxicity, Mobility, or Volume by Treatment (No Action)

Reductions of toxicity, mobility, or volume would be determined in CERCLA actions at individual sites. If the lack of a coordinated disposal program under the No Action Alternative were to cause more waste to be managed in place, limitations on treatment activities could result in less overall reduction in toxicity, mobility, or volume of contaminated media.

7.2.1.6 Implementability (No Action)

No implementation would be required for this alternative. Activities associated with a comprehensive strategy for either on-site or off-site disposal of waste across projects would not be implemented.

7.2.1.7 Cost (No Action)

There would be no cost directly associated with implementing the No Action Alternative; however, analysis and implementation of disposal options on a site-by-site basis could result in high cumulative cost over time because of the lack of economies of scale and the need to procure disposal services on a project basis. Conversely, if the lack of a comprehensive disposal program resulted in most of the waste being managed in place, remediation costs at the individual sites and overall disposal costs could be lower.

7.2.1.8 NEPA Considerations (No Action)

There would be no direct NEPA considerations under the No Action Alternative because no construction or operations activities would take place to warrant a comprehensive waste disposal strategy. NEPA considerations would be determined in CERCLA actions at individual sites without the benefit of a coordinated disposal strategy. This could indirectly result in more wastes being managed in place, limited reuse of some land, more use of truck transportation with associated higher risk to human health, and greater residual risk.

7.2.2 On-site Disposal Alternative Analysis

The On-site Disposal Alternative proposes consolidated disposal of most future-generated CERCLA waste exceeding the capacity of the existing EMWMF in a newly-constructed, mostly above grade, engineered waste disposal facility (i.e., landfill) on the ORR, referred to herein as the EMDF. Wastes not meeting the EMDF WAC would be transported to off-site disposal facilities or placed in interim storage until treatment or disposal capacity becomes available. Section 6.2 gives a detailed description of this alternative and the sites considered. The On-site Disposal Alternative evaluates three proposed EMDF sites in BCV. Sites include the EBCV Site Option, the WBCV Site Option, and a Dual Site Option (Sites 7a/6b). Because much of this analysis is the same regardless of which site is considered, the analysis presented herein will note differences between sites when there is a known differentiator or when there is uncertainty in differentiators. Elements that do not differ between sites will be noted as well. Table 7-1 is a summary of pertinent features of each site that will be referred to throughout this analysis.

7.2.2.1 Overall Protection of Human Health and the Environment (On-site)

The On-site Disposal Alternative (all sites) would meet risk-based RAOs and protect human health and the environment by consolidating most future generated CERCLA waste exceeding the capacity of the existing EMWMF from the cleanup of ORR and associated sites into an engineered waste disposal facility, isolating the wastes from the environment. Additional protection would be provided indirectly by treatment of some waste streams to meet the EMDF WAC. Prior to placement in the EMDF, wastes would be evaluated for compliance with the facility WAC; placement of that waste would result in an overall net reduction of risks associated with environmental contamination at the ORR and associated sites.

A new on-site waste disposal facility would be designed to control releases to ground water, soils, surface water, and air, and to prevent inadvertent intrusion into the waste. The facility would be designed such that components would be operational and effective throughout operations and the post-closure periods, and containment would remain effective for 1,000 years to the extent practicable. Protection following closure also would be maintained by active institutional and engineering controls (including physical restrictions, ground water use restrictions, monitoring, and maintenance) and permanent restrictions on land use (e.g., ROD restrictions on land use and deed restrictions in the unlikely event of land transfer). While appropriate ROD restrictions on future land use for Sites EBCV and Site 6b of the Dual Site Option are in place, selection of either the WBCV Site or the Dual Site Option (Site 7a), would require ROD modifications to limit future use of those sites.

WAC that limit the acceptance of waste at the on-site facility will be determined such that they ensure the RAOs are met and compliance will all ARARs is achieved or achievable. PreWAC have been determined for the EBCV site, to demonstrate that RAOs are achievable. PreWAC for other sites would be expected to be similar. Certain waste streams may not meet the WAC for either the On-site EMDF or existing off-site disposal facilities. This waste, expected to be a relatively small volume, would be stored at compliant facilities with sufficient engineering controls and oversight to minimize the potential for exposure or release.

Monitoring of potential migration pathways would allow evaluation of the effectiveness of waste containment and would provide advance warning of any releases so that appropriate mitigative measures could be taken. If the presence of on-site disposal capacity encouraged removal of waste from individual CERCLA sites, environmental benefits could result at those sites depending on eventual land use. Environmental impacts at each of the EMDF sites would result from clearing, grading, construction, and operations conducted within the area designated as an Oak Ridge Environmental Research Park (ORERP). The ORERP encompasses 20,000 acres, the majority of the ORR (DOE 2011d). Approximately half of the EBCV Site is located within the ORERP. All other proposed sites are fully within the ORERP. Flora and fauna would be impacted by the permanent commitment of land to the disposal facility for all sites.

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Table 7-1. Summary of Proposed Site Parameters

Parameter		EBCV (Site 5)	WBCV (Site 14)	Dual Sites: (Sites 7a & 6b)[e]	Hybrid Site: (Site 6b)	Site 7a (not utilized individually)
Conceptual Design	**Capacity (yd^3)**	up to 2.5 M	up to 2.8 M	up to 2.25 M	up to 0.85 M	up to 1.4 M
	Cells	6 Cells 3-5 acres each	6 Cells 4-5.5 acres each	9 Cells 2-5 acres each	5 Cells 2-2.5 acres each	4 Cells 4-5 acres each
	Proposed Buildout (yd^3) (per RI/FS current waste volume estimate) [g]	2.2 M 5 Cells	2.2 M 5 Cells	2.25 M 9 Cells	0.85 M 5 Cells	1.4 M 4 Cells
	Acreage, extent of waste	30 acres	29 acres	32 acres	13 acres	19 acres
	Acreage, extent of cap	35 acres	34 acres	40 acres	17 acres	23 acres
	Acreage, development/operations [a]	71 acres [c]	94 acres	135 acres [c]	53 acres [c]	82 acres
	Acreage, disposal facility (footprint) [b]	48 acres	52 acres	68 acres	27 acres	41 acres
	Acreage, permanent commitment	70 acres	71 acres	109 acres	50 acres	59 acres
	Acreage, upland drainage area	10 acres	12 acres	42 acres	16 acres	26 acres
	Upgradient french drain/diversion drains (ft)	2,100 ft	1,470 ft	2,370 ft	950 ft	1,420 ft
	Acreage, wetlands (impacted by facility footprint) Acreage, wetlands (impacted by support facilities)	1.38 acres 0.20 acre Total: 1.58 acres	1.66 acres 0.87 acres Total: 2.53 acres	5.31 acres 0.48 acres Total: 5.79 acres [d]	0.0 acre 0.0 acre Total: 0 acre	5.31 acres 0.48 acre Total: 5.79 acres [d]
	Underdrain size (ft^2) Trench drain Blanket drain	43,219 253,893	18,997 240,471	21,165 110,462	3,047 24,309	18,118 86,153
	Infrastructure	Existing (EMWMF proximity)	Construction needed	Construction needed Requires Haul Rd reroute	Existing (EMWMF proximity) Requires Haul Rd reroute	Construction needed Requires Haul Rd reroute
Geology	**Proximity to Maynardville Limestone in Bear Creek Valley floor, ft (m)**	1270 ft (387 m)	656 ft (200 m)	593 ft (181 ft)	597 ft (182 m)	593 ft (181 ft)
Proximity to Water Resources	**Distance, edge of waste to Bear Creek, ft (m)**	1,270 ft (387 m)	1,160 ft (354 m)	565 ft (172 m)	565 ft (172 m)	990 ft (302 m)
	Distance, average, bottom of waste to top of current/estimated seasonal high water table, ft (m)	27.9 ft (8.5 m)	28.1 ft (8.6 m)	19.2 ft (5.6 m)	19.2 ft (5.6 m)	31.9 ft (9.7 m)
	Distance, edge of waste to nearest surface water, ft (m)	200 ft (61 m)	240 ft (73 m)	165 ft (50 m)	165 ft (50 m)	190 ft (58 m)
Future Land Use and Proximity to Public	**Future Land Use**	DOE-Controlled Industrial	Unrestricted [f]	Recreational/Unrestricted [f]	DOE-Controlled Industrial	Recreational/Unrestricted [f]
	Proximity to Public **Proximity to nearest resident:** **(all ~0.75 mi from DOE Boundary)**	0.84 mi to nearest resident	1.1 mi to nearest resident	.79 mi to nearest resident	1.14 mi to nearest resident	.79 mi to nearest resident

[a] Area for development, including temporary construction activities, existing and new support facilities, and spoils areas.

[b] Area of disposal facility footprint, computed to the outside edge of grading for perimeter clean-fill dike, perimeter berm slopes.

[c] An additional 21 acres is already developed and being used to support EMWMF operations.

[d] If Site 7b were used, 1.7 acres of wetland would be impacted (as noted throughout, Sites 7a and 7b are quite comparable, and if selected, a detailed screening of both sites would be necessary to decide between them).

[e] For the Dual Site Option, the most restrictive parameter of the two sites is tabulated. See separate site parameters in table for individual site statistics.

[f] Sites will require a change to future land use designation if selected.

[g] EBCV and WBCV would both see reductions in extent of waste, extent of cap, development acreage, etc. with a reduction in size from a 6 cell design to a 5 cell design commensurate with the reduction in capacity (12% for EBCV and 18% for WBCV). No wetland acreage would be affected.

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Human-health and environmental risks from transport of waste, disposal activities, and storage would be maintained as low as reasonably achievable (ALARA) through compliance with ARARs, DOE orders, and health and safety plans. Risk would be minimized through selection of appropriate transport routes, compliance with DOT requirements, and adherence to project-specific transportation safety, spill prevention, and cleanup plans. These activities would minimize the likelihood of an accident as well as the severity of a release should an accident occur, maintaining exposures ALARA. See Section 7.2.2.4 for a discussion of transportation risk for the On-site Disposal Alternative.

7.2.2.2 Compliance with ARARs (On-site)

The On-site Disposal Alternative (all proposed sites) would comply with chemical-, location-, and action-specific ARARs and pertinent TBC guidance. In general, waste generators at remediation sites would be responsible for treating wastes, if required, to ensure that wastes meet on-site EMDF WAC.

7.2.2.2.1 Chemical-specific ARARs

Chemical-specific ARARs provide health- or risk-based concentration or discharge limitations in various environmental media (i.e., ground water, soil, and air) for specific hazardous substances, pollutants, or contaminants. Because no specific sites or media would be remediated under this action, no chemical-specific ARARs for contaminant cleanup levels would apply. Chemical-specific ARARs that address radiation protection would apply to this alternative. Radiation protection standards that limit exposure of the public and limit the release of radionuclides into the air are presented in Appendix G, Table G-1. Further radiation protection standards are addressed by DOE orders. The EMDF, at all proposed sites, would meet these standards through control measures detailed in Section 6.2.

7.2.2.2.2 Location-specific ARARs

Location-specific ARARs and TBC guidance establish restrictions on permissible concentrations of hazardous substances or operational requirements to minimize damage to special or sensitive locations (e.g., wetlands, floodplains, critical habitats, historic districts, streams). TDEC substantive requirements for Aquatic Resource Alteration Permits would be triggered by construction of a road crossing a streambed, wetlands or stream alteration, or dredging. For the EBCV Site, construction of the EMDF would require modification of NT-3 (i.e., construction over a portion of NT-3 using an underdrain system and intercepting and rerouting upgradient surface flow that contributes to the stream). All sites will require improvements and potential construction of new culverts that would impact existing wetlands. Actual design considerations would determine the potential impact to the aquatic environment. In addition, 10 CFR 1022 requires that detrimental effects to wetlands or a floodplain be evaluated and avoided wherever possible. All proposed sites, with the possible exception of Site 6b, will require some mitigation of wetlands. Table 7-1 summarizes the area of wetlands currently thought to be impacted by development at each proposed site.

If the On-site Disposal Alternative is chosen as the preferred alternative for CERCLA waste disposal, wetlands and stream assessments would be completed as necessary at the selected site(s), and results would be incorporated into planning and implementation, including mitigation of adverse impacts. There are currently no identified federal- or state-listed T&E species in the proposed EBCV site area; however, further reconnaissance regarding the Northern Long-eared bat may be required. WBCV and Sites 7a and 6b have not had recent T&E species surveys completed. Should any of these species be identified in the proposed site area(s), consideration of the requirements of endangered, threatened, or rare species ARARs would be triggered before initiation of the action.

7.2.2.2.3 Action-specific ARARs

Action-specific ARARs for on-site disposal address siting, construction, operation, closure, and post-closure care of the EMDF. The On-site Disposal Alternative, as described in this RI/FS, invokes CERCLA provisions for exemption from permitting requirements, although DOE could choose to permit the facility. The variety of wastes disposed of on-site under this alternative would trigger requirements for RCRA-hazardous waste, radiological waste, and TSCA waste. No set of regulations is specifically tailored to the combination of waste forms, types, and constituents anticipated in these wastes. Action-specific ARARs include siting criteria and design components for a disposal facility appropriate to the EMDF, and are based on the overriding priority to dispose of wastes in a manner protective of human health and the environment over both the long- and short-term. These ARARs include substantive requirements drawn from RCRA, TSCA, and TDEC regulations. In terms of siting requirements, the most extensive are those from NRC regulations in 10 CFR 61 *Licensing Requirements for Land Disposal of Radioactive Waste* that TDEC, as an NRC Agreement state, administers. The following bullets list these siting requirements that are relevant and appropriate, and information regarding how the proposed sites meet those requirements.

- **TDEC 0400-20-11-.17(1)(b) Disposal site shall be capable of being characterized, modeled, analyzed and monitored.** All sites selected for consideration meet this ARAR. All sites under consideration in this RI/FS as locations for an on-site disposal facility – EBCV Site, WBCV Site, Dual Site (Site 6b and Site 7a) – are located in BCV, which has been extensively characterized over the last 40-50 years. More than 1,000 ground water wells have been installed and monitored many of which continue to be monitored, multiple characterization events have been executed and documented, and over 900 acres of the valley are incorporated in the BCV model (see Appendix E and Appendix H). Additionally, an effort is underway within OREM to develop a more detailed ground water model of BCV outside of this RI/FS. The current BCV model, a porous media model, has been questioned in terms of its ability to adequately predict ground water movement in Bear Creek. Discrete fracture flow models have been suggested to be more applicable for this area. However, development of a fracture-based flow model would take a large amount of capital and time, without any guarantee of producing a successful accurate model. The scale of fractures compared to the scale of the current porous flow model grid is such that this approximation is appropriate, and modeling calibration efforts and results support that conclusion. See further discussions in Appendix H.
- **TDEC 0400-20-11-.17(1)(c) Within the region where the facility is to be located, a disposal site should be selected so that projected population growth and future developments are not likely to affect the ability of the disposal facility to meet performance objectives.** All sites selected for consideration meet this ARAR. This requirement is tied to the potential for future use of the site. All sites are within DOE boundaries. EBCV Site Option, Site 6b of the Dual Site Option (On-site Disposal Alternative), and the Hybrid Disposal Alternative (Site 6b) are located in Zone 3 of Bear Creek, with a future land use designation that is DOE industrial use, with restrictions on ground water usage and future development limited to industrial use only, in perpetuity per the Bear Creek Valley Phase I ROD (DOE 2000). WBCV Site Option is located in Zone 1 of Bear Creek, with a future land use designation as unrestricted use. However, if selected, this site will require a revision to the future land use designation. Site 7a of the Dual Site Option is located in future (long-term) land use designation of unrestricted usage as well, with a short term restriction for recreational use only. However, if selected, this site will require a revision to the future land use designation as well.

  Per the NRC's guidance document NUREG-0902 (NRC 1982), "*Disposal sites should be located in an area which has low population density and limited population growth potential. Disposal sites should be at least two kilometers from the property limits of the closest population centers.*" To further clarify, NRC Regulatory Guide 4.19 (NRC 1988) designates the "*property limits of the* *closest population center*" as "*residential property limits of the nearest existing urban community*". The U.S. Census Bureau classifies urban areas two ways: "Urbanized Areas" as areas with populations exceeding 50,000 and "Urban Clusters" as those areas with populations of at least 2,500 but less than 50,000 people. "Rural" encompasses all populations not included within an urban area. Oak Ridge is classified as part of the Knoxville Urbanized Area. The U.S. Census Bureau identifies a population center as a weighted observation, basically an "area" (area corresponding to the whole country, state, or county) is dissected by horizontal and vertical lines defined to set the population equal above and below/right and left of the lines. Perhaps most importantly, NRC Regulatory Guide 4.19 notes that this 2-km distance is not necessarily the distance to the nearest residence: "*However, the exact distance to the nearest residential property may vary depending on local land use and demographic conditions*."

The map given in Figure 7-1a shows that only the EBCV site does not meet a 2-km buffer guidance for siting an LLW disposal facility based on the Urbanized Area boundaries. However, the northern portion of the Urbanized Area that is within the 2-km circumference of the EBCV Site is a portion of land that is not developed, and has no residents as shown in the detail of Figure 7-1b. Note that Y-12 is also considered part of the Knoxville Urbanized Area. Of course, as part of DOE property, this "infringement" within the 2-km circumference is not relevant, and further demonstrates that portions of the Urbanized Area may be exceptions within this guidance.

A final point to be made regarding proximity of the public to the BCV proposed sites is the ground water divide that runs parallel between the sites and public property, provided by Pine Ridge. Ground water that contacts the sites flows in a southern direction within Bear Creek Watershed, and doesn't flow north toward nearby residents, who are located in a separate watershed. Therefore, there is no direct ground water/surface water pathway that links the public to these sites, as illustrated in Figure 7-1c.

- **TDEC 0400-20-11-.17(1)(d) Areas must be avoided having known natural resources which, if exploited, would result in failure of the cell to meet performance objectives.** All sites selected for consideration meet this ARAR. This requirement refers to natural resources such as minerals, coal or other hydrocarbon deposits, geothermal energy sources, timber, and water resources. No such resources are present at the proposed sites, nor if they were, would they be available for exploitation, because the land is owned by DOE.
- **TDEC 0400-20-11-.17(1)(e) Disposal site must be generally well drained and free of areas of flooding and frequent ponding, and waste disposal shall not take place in a 100-year floodplain or wetland.** All sites selected for consideration meet this ARAR. All proposed sites are generally well drained and free of areas of flooding and frequent ponding. The conceptual designs at each site ensure hydrologic/hydrogeologic conditions such that waste disposal will not take place in a 100-year floodplain. Moreover, all sites are located outside the 500-year floodplain as well. See Figure 7-2, which identifies the proposed facility locations with respect to the 100- and 500-year floodplains. This also demonstrates compliance with TSCA 40 CFR.761.75(b)(4).

  While limited wetlands are present within the footprints of all but one site (Site 6b), those wetlands if impacted will be mitigated, and thus waste disposal will not take place in wetland areas. The primary purpose in avoiding wetlands, per NUREG-0902, is to avoid habitat destruction. Wetland mitigation is an accepted replacement strategy for those habitats that are destroyed. Additionally, NUREG-1200 (NRC 2006) states "*When 10 CFR 61 was promulgated, the staff did not envision that small inconsequential areas could be designated as wetlands. The regulations intended to avoid the placement of waste in submerged and relatively large wetland areas, such as marshes, bogs, swamps, and tidal areas.*" Based on this interpretation, the relatively minor wetland areas identified in the proposed sites do not qualify as the wetland areas intended to be avoided by this siting criterion. See Table 7-1 for a summary of estimated wetland areas that will be mitigated at each proposed site.

Figure 7-1. Details of Residences and Boundaries Close to Proposed Sites in BCV

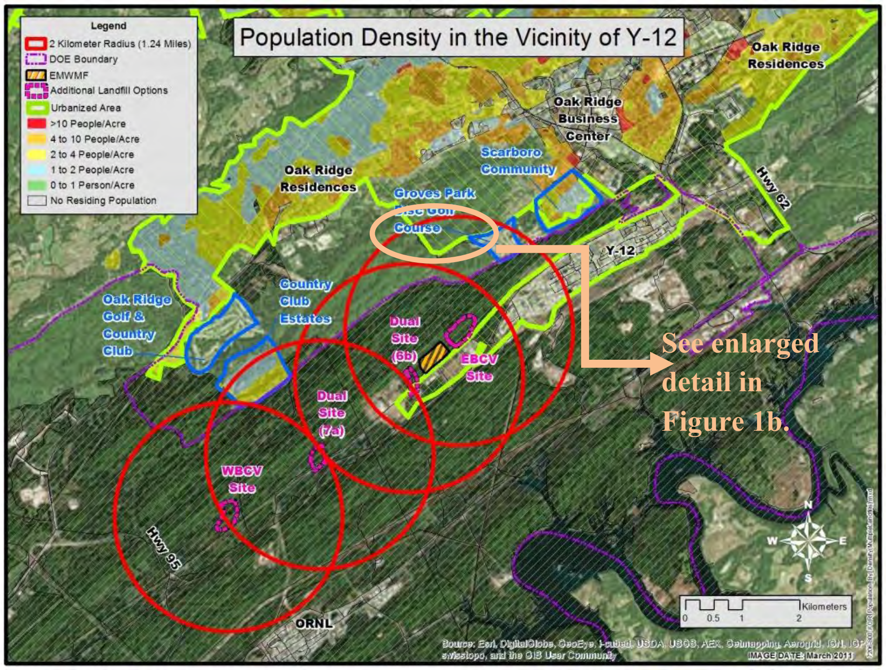

Figure 7-1a. Two Kilometer Circumferences around Proposed Sites

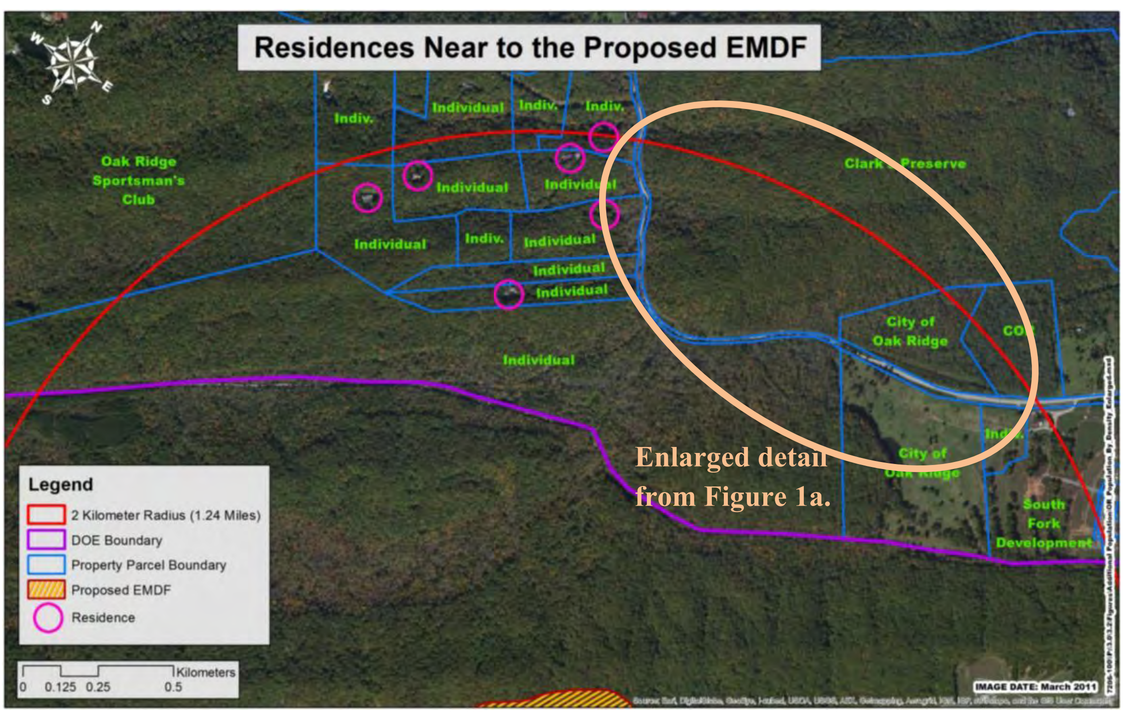

Figure 7-1b. Enlarged Detail from Figure 7-1a

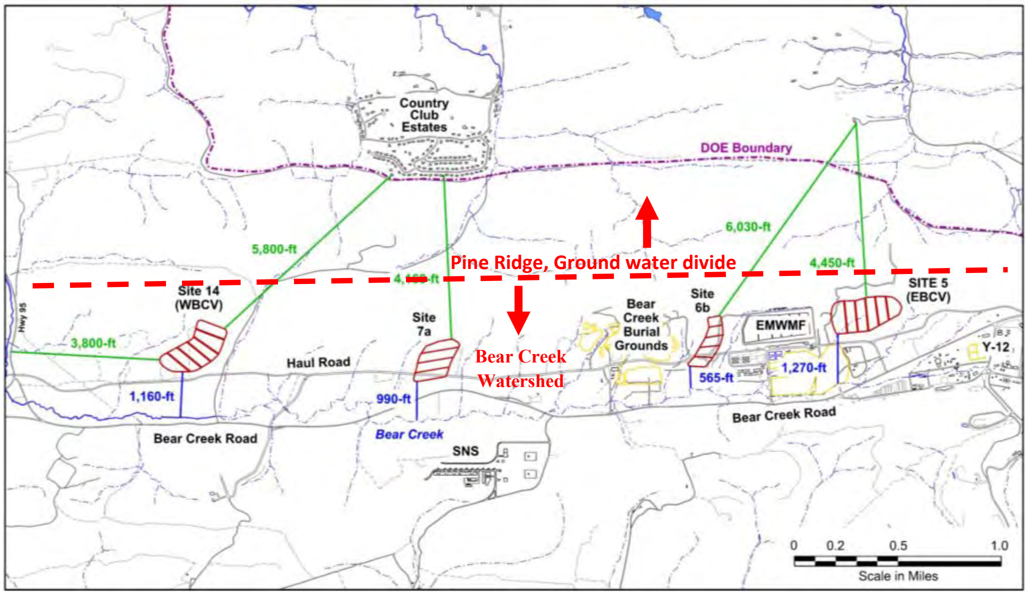

Figure 7-1c. Illustration of Water Divide along Pine Ridge, Separating Nearest Residents from Ground Water Contacting the Proposed Landfills

- **TDEC 0400-20-11-.17(1)(f) Upstream drainage areas must be minimized to decrease the amount of runoff which could erode or inundate waste disposal units.** All sites selected for consideration meet this ARAR. This requirement is related to drainage crossing the disposal site, and primarily applies to the disposal site after construction of the near-surface disposal facility per NUREG-0902. All proposed sites are situated such that upland drainage areas are minimized by locating the footprints as far upslope as possible. Upland drainage areas will remain forested, reducing surface runoff and reducing runoff velocity. In addition, runoff from Pine Ridge (which borders all proposed sites to the north) is diverted with surface ditches and French drains around the landfills' northern borders. French drains will be sized to accommodate extreme heavy rainfall. Drainage will be sized based on 100-year storm conditions. Materials will be used that resist degredation; design will accommodate long-term longevity, under assumptions that should be little to no long-term maintenance required (see Section 6.2.2.4.2 for more discussion). See Figure 7-2 and Table 7-1 for a comparison of upland drainage area estimated acreage for each of the proposed sites.
- **TDEC 0400-20-11-.17(1)(g) The disposal site must provide sufficient depth to the water table that ground water intrusion, perennial or otherwise, into the waste will not occur.** All sites selected for consideration will meet this ARAR upon complete construction. All sites have conceptual footprints that are planned to be built mostly above grade. Per NUREG-0902, this requirement indicates that near-surface disposal of low-level radioactive wastes should be in unsaturated soil deposits (regolith). However, the NRC guidance document notes that exceptions include structures completely below, partially below, or completely above natural site grade. In the case of both EBCV and WBCV sites, the majority of the footprints will be installed significantly above natural grade, therefore requiring a good amount of fill material.

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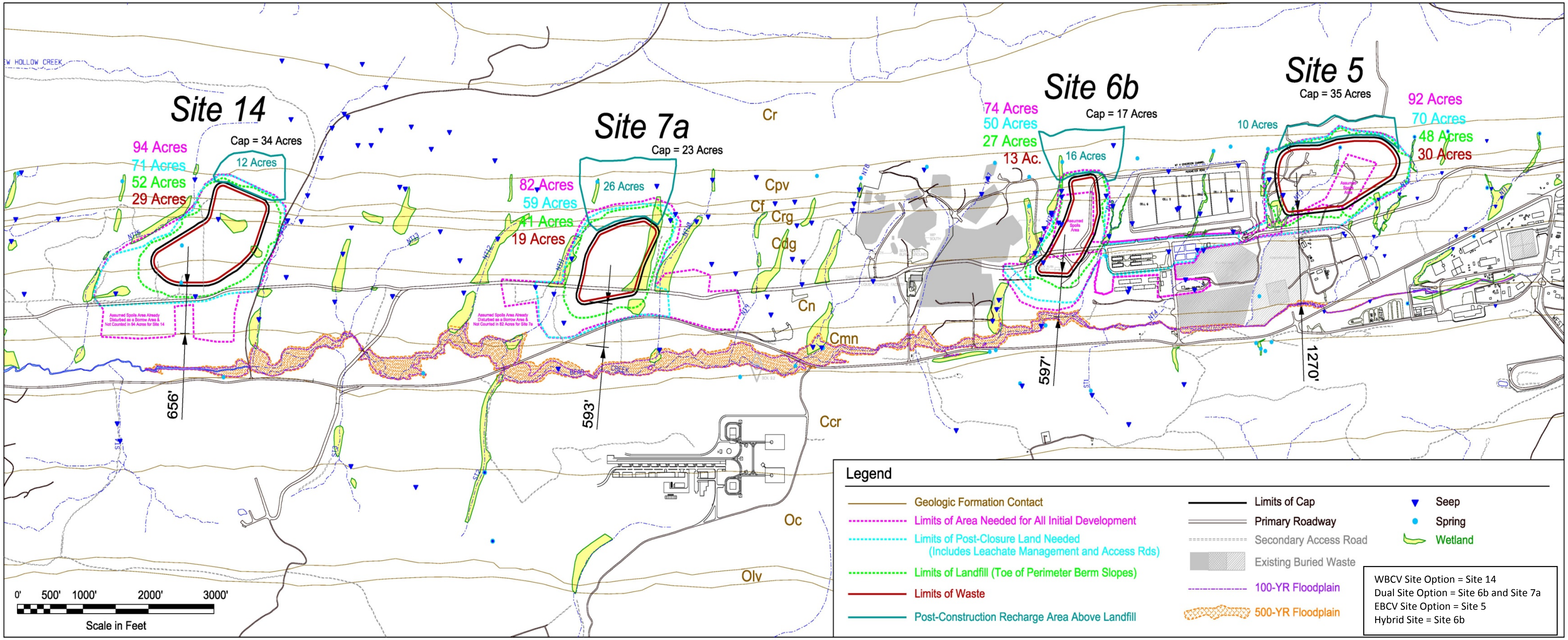

Figure 7-2. Proposed Sites in BCV, Associated Area Acreage, Floodplains, Wetlands/Seeps/Springs, and Distances to Maynardville Limestone Formation

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The calculated average depth (over the whole footprint) from the bottom of the waste to the current high water table (measured high water table at EBCV, estimated high water table at other sites) at each site is:

- WBCV Site Option: ~28 ft
- EBCV Site Option: ~28 ft
- Dual Site (Site 7a) Option: ~32 ft
- Dual Site (Site 6b) Option/Hybrid Site: ~19 ft

Modeling has been performed to validate the EBCV Site post-construction ground water table, and its position with respect to the waste, which ensures that this ARAR is met both short and long term (details are given Appendix E). It is expected that modeling results for other sites would result in similar conclusions. Should one of the other sites be selected as the remedy (WBCV Site, Dual Site [Sites 6b & 7a]), full, detailed modeling would be performed.

- **TDEC 0400-20-11-.17(1)(i) Areas must be avoided where tectonic processes such as faulting, folding, seismic activity may occur with such frequency to affect the ability of the site to meet the performance objectives.** All sites selected for consideration meet this ARAR. The nearest mapped fault to the EMDF sites in Bear Creek (the White Oak Mountain Thrust Fault) is on the northwest side of Pine Ridge. This fault is greater than 200 ft from the edge of all proposed disposal cell sites (see Appendix E of the RI/FS) and there is no evidence that this fault has had displacement in Holocene time. Information available at this time indicates that the EMDF, all locations, can comply with the seismic considerations in RCRA 40 CFR 264.18(a)(1) which is identified as an ARAR for the on-site facility and requires the facility "must not be located within 200 ft of a fault which has had displacement in Holocene time." Final design documents will demonstrate and record compliance with this ARAR after a seismic hazard evaluation is completed. In addition, there was such an evaluation conducted for EMWMF, also located in BCV in the vicinity of the proposed site, which demonstrated that this ARAR was met.
- **TDEC 0400-20-11-.17(1)(j) Areas must be avoided where surface geologic processes such as mass wasting, erosion, slumping, landsliding or weathering may occur with such frequency and extent to affect the ability of the disposal site to meet performance objectives or preclude defensible modeling and prediction of long-term impacts.** All sites selected for consideration meet this ARAR. As with the previous site selection criterion, this criterion relates to the stability of the site. Per NUREG-0902, this requirement is further described as "*the natural processes affecting the disposal site should be occurring at a consistent and definable rate. In addition, these processes should not occur at a frequency, rate, or-extent which can significantly change the stability of the site or the ability of the disposal site to isolate low-level radioactive wastes during the duration f the radiological hazard (approximately 500 years).*" Regarding the reference to defensible modeling, the guidance states that "*Changes which occur due to these processes should not invalidate the results of any modeling and prediction of long-term impacts.*"

  The existing natural slopes of Pine Ridge along Bear Creek Valley have not shown any indications of recent large-scale landslides or slumping. Characterization efforts such as test pits, boreholes, well drilling logs, and corresponding laboratory testing have occurred at various locations down the valley and demonstrate the stability of the existing terrain. Problems could arise if the existing slopes of Pine Ridge were excavated incorrectly, but this has been a design consideration in the conceptual designs of the proposed on-site options in the RI/FS. Avoiding undercutting along Pine Ridge was a primary driver in the conceptual designs for two reasons: 1) to avoid creating potentially unstable slopes above excavated areas and 2) to avoid intercepting any potentially shallow ground water traveling down the ridge.

Any new slopes constructed as part of any landfill will use standard allowable slopes which will then be validated through modeling and static slope stability analyses allowing adequate safety factors during detailed design. All of the landfills considered in the RI/FS use similar proposed slopes for the various phases of landfill construction. Slope failure is always a key issue in the design of any large earth structure, regardless of existing terrain. Landfill design involves rigorous seismic analysis and slope stability calculations. Volume 3 of the RDR for EMWMF (DOE 2001a), provides examples of the types of slope stability modeling and calculations that will be performed to ensure long-term stability, while Volume 1 of the RDR provides the quality assurance plans that are used to ensure that the landfill is constructed to the standards required to ensure long-term stability. The new facility will undergo this process as well as considering new seismic standards that have been implemented in recent years.

Landfill stability is also ensured as part of operations, during waste placement. For example, at EMWMF, most compactable waste is spread in a 8-inch lift and compacted with a minimum of 4 round-trip passes of a Caterpillar D-8 dozer. Containers of waste are typically flood grouted to eliminate voids. Pipes may be crushed, split open, or filled with grout. Waste placement is observed by a trained Field Engineering Technician who verifies the waste placement location, the number of passes of the dozer, and any evidence of unsatisfactory compaction (e.g., excessive rutting). The technician also runs compaction tests at a frequency of one test per every 1000 cubic yards of waste placed into the landfill. These procedures ensure that waste is compacted in place, voids are filled, are requirements met that ensure stability of the landfill long-term.

Finally, NRC Regulatory Guidance 4.19 states, when assessing a site's ability to meet criteria under TDEC 0400-20-11-.17(1)(i) and (j), ***"****Ideally, a site should be located near a drainage divide and must be generally well drained."*. The sites considered in BCV abut the drainage divide atop Pine Ridge, and, especially for the furthest site to the East (EBCV Site Option), are relatively close to the hydrologic divide between Bear Creek Watershed and Upper East Fork Poplar Creek Watershed.

- **TDEC 0400-20-11-.17(1)(k) The disposal site must not be located where nearby activities or facilities could impact the site's ability to meet performance objectives or mask environmental monitoring.** All sites selected for consideration meet this ARAR with the possible exception of Site 6b. The proximity of Site 6b (one of the sites in the Dual Site Option and the Site in the Hybrid Disposal Alternative) to BCBG and ground water contamination in the shallow (<100 ft depth) and intermediate/deep intervals (>100 ft depth) around Site 6b pose potential issues with environmental monitoring. With the limited information available, it is not possible to state emphatically that this site would require a waiver to this siting criteria; however, it is a consideration and would have to be further investigated if this site were selected.

  Preliminary characterization at the EBCV Site during the Phase I effort did not identify any contamination issues within the footprint. Concern has been expressed about the proximity of the EBCV Site to the EMWMF; however, previous modeling of the EMWMF and modeling of the EBCV Site (see Appendix H) predicted plumes, especially within the 1,000-year compliance period, do not indicate any significant overlap of those plumes, and certainly no interference at locations close to the landfill where environmental monitoring wells would be located. Based on the ground water model predicted plume directions for EMDF, contamination emanating from the S-3 Ponds area to the east and south of the EBCV Site would not interfere with environmental monitoring at that site.

  Site 7a of the Dual Site Option does not have available characterization within the proposed footprint. However, it is isolated, and is unlikely to have a situation in which environmental monitoring could be masked by other waste disposal facilities to the east. It is located approximately ¾ of a mile west of the BCBG.

  Significant characterization of the WBCV site was completed (Golder 1988a/b/c/d, and 1989a/b/c). No issues that would raise concern regarding the ability of the site to be monitored were reported. It is located in a Greenfield area, approximately 1.5 miles west of the BCBG. For more details see Appendix E.

One siting requirement, **TDEC 0400-20-11-.17(1)(h),** has been determined to be relevant but not appropriate. See Appendix G Section 4.3 for a discussion.

Waters contacting waste and collected during operation of the landfill and during the post-closure dewatering period will be collected and sampled. Alternatives for managing landfill wastewater are considered in the IWM FFS, and on-site treatment is included in this document as a place/cost holder. The IWM FFS provides details regarding alternative proposed treatment systems and their operation. ARARs from the IWM FFS have been incorporated in this RI/FS. It is intended that the conclusions reached in the IWM FFS and this RI/FS will be merged in the Proposed Plan. A single ROD will address the integrated alternative, and include ARARs from both the RI/FS and the IWM FFS.

Facility design would also incorporate TSCA requirements for a chemical landfill to accommodate wastes containing PCBs at concentrations ≥ 50 ppm. Most TSCA requirements parallel those of RCRA. Implementation of more stringent RCRA requirements would meet or exceed the protectiveness of the TSCA requirements in some instances. TSCA requirements regarding in place soils are identified at 40 CFR 761.75(b)(1) *The landfill site shall be located in thick, relatively impermeable formations such as large-area clay pans. Where this is not possible, the soil shall have a high clay and silt content with the following parameters:*

(i) In-place soil thickness, 4 ft or compacted soil liner thickness, 3 ft
(ii) Permeability (cm/sec), equal to or less than 1×10^{-7}
(iii) Percent soil passing No. 200 Sieve, >30
(iv) Liquid Limit, >30
(v) Plasticity Index >15

These requirements will be met. Detailed characterization efforts will determine soil properties as needed. If in place or borrow materials are lacking in the given specifications, soil will be either amended to meet the requirements or purchased.

Two TSCA technical requirements will require waivers; waivers will be sought as TSCA waivers. The first [40 CFR 761.75(b)(3)] is a technical requirement for chemical waste landfills used for the disposal of PCBs and PCB items and is a hydrologic condition requirement that states "*The bottom of the landfill shall be above the historical high ground water table as provided below. Floodplains, shorelands, and ground water recharge areas shall be avoided. <u>There shall be no hydraulic connection between the site and standing or flowing surface water.</u> The site shall have monitoring wells and leachate collection. <u>The bottom of the landfill liner system or natural in-place soil barrier shall be at least fifty feet from the historical high water table</u>.* ". As none of the proposed disposal sites in BCV meet two parts of this requirement (those two parts are underlined), and because the facilities can be designed without meeting these requirements and still be protective of human health and the environment, a waiver to this requirement is requested. Under 40 CFR 761.75(c)(4) *Waivers.* "*An owner or operator of a chemical waste landfill may submit evidence to the Regional Administrator that operation of the landfill will not present an unreasonable risk of injury to health or the environment from PCBs when one or more of the requirements of paragraph (b) of this section are not met. On the basis of such evidence and any other available information, the Regional Administrator may in his discretion find that one or more of the requirements of paragraph (b) of this section is not necessary to protect against such a risk and may waive the requirements in any approval for that landfill.* Appendix G Chapter 4 provides evidence and rationale in the following three categories to support this waiver: (1) PCB management and disposal practices on the ORR; (2) Equivalent or superior effectiveness of site soils and engineered features of the EMDF; and (3) Results of risk assessment and related fate and transport modeling for PCBs.

The second TSCA waiver that will be requested is applicable to the EBCV Site only, and is a requirement regarding topography, "*The landfill site shall be located in an area of low to moderate relief to minimize erosion and to help prevent landslides or slumping.*" [40 CFR 761.75(b)(5)]. The proposed disposal sites in BCV are all situated abutting the slopes of Pine Ridge but there is some question regarding whether the slopes of the EBCV Site meet the requirement as stated. The landfill in EBCV can be engineered to remain protective of human health and the environment, and will minimize erosion and help prevent landslides/slumping, thus a waiver is being requested. Evidence and justification is given in Appendix G, Chapter 4, and involves (1) PCB management and disposal practices on the ORR; and (2) equivalent or superior effectiveness of engineered features of the EMDF.

Other action-specific ARARs address management of stormwater runoff, fugitive dust emissions, leachate management, waste management and operations, facility closure, and post-closure maintenance and monitoring. These requirements would all be met for all site locations. Appendix G contains a more detailed discussion of ARARs for the On-site Disposal Alternative Site Options.

7.2.2.3 Long-term Effectiveness and Permanence (On-site)

For the On-site Disposal Alternative (all Site Options), the long-term period is considered to begin when all candidate waste has been disposed of or stored and the EMDF has been closed. Final capping and closure activities for this alternative are projected to be complete in FY 2047. Under this alternative, access to the EMDF would continue to be restricted. This evaluation does not address CERCLA remedial activities, waste, or residuals that would be left in place at remediation sites, non-candidate waste streams, or any treatment residuals from on-ORR processing of waste to meet WAC.

Residual Risk

Under this alternative, most future CERCLA waste, treated as appropriate, would be placed in an on-site engineered waste disposal facility designed to isolate waste from the environment and significantly reduce the possibility of intrusion or the migration of contaminants away from the facility. Residual risk would be represented by the in-place waste, which would be nearly equivalent for each Site Option – EBCV, WBCV, and the Dual Site Option since all sites are of sufficient capacity to accommodate the projected 1.95 M yd^3 of waste, and WAC limits for each site, although only calculated for the EBCV Site Option, are not expected to differ substantially. WAC will be developed for whichever site would be selected, and by design, meeting the facility WAC would ensure that the total ELCR from the EMDF would be less than 1×10^{-5}, and the total non-carcinogenic risk HI value would be less than one to a hypothetical future resident receptor living adjacent to the facility (see Appendix H) for a 1,000 year compliance period. Waste not meeting the EMDF WAC would either be shipped to off-site disposal facilities or stored by the generator pending availability of treatment or disposal options. The On-site Disposal Alternative (all Site Options) uses proven technologies to protect human health and the environment and meet risk-based RAOs. Reliance on proven technologies reduces uncertainty associated with this alternative. The on-site disposal facility and support facilities under this alternative incorporate three types of controls to ensure protectiveness: engineered controls, S&M, and institutional controls.

Engineered and Institutional Controls

Engineered controls would be built into the landfill and support facilities to prevent exposure to contaminants and to prevent, detect, and mitigate contaminant releases. Workers and the public will be protected from direct exposure by a landfill final cover system that would prevent airborne releases of, and direct contact with or exposure to the waste, as well as provide shielding for radiation, and most importantly will greatly reduce water contact with the waste. The EMDF conceptual design at all Site Options is essentially the same in terms of cover and liner design. Geomembrane liners of the landfill liner system at all sites would control releases of leachate to ground water for their design life (Koerner, et al. 2011, Rowe, et al. 2009a, Benson 2014). Both cap and liner systems contain geomembranes to reduce contact of water and waste. As described by Bonaparte et al. (2016), it appears that HDPE geomembranes of the type being used in some MLLW disposal facilities are relatively unaffected at total alpha doses of 5 megarad (Mrad), or more. These geomembranes are also reportedly unaffected by radiation from gamma and/or beta sources until total doses reach on the order of 1 to 10 Mrad, which are orders of magnitude over the doses that will be seen in this environment. Bonaparte et al. (2002) proposed three stages of HDPE geomembrane service life: 1) depletion of antioxidants; 2) induction, and 3) degradation of material properties. Despite the depletion of antioxidants in Stage 1 and oxidation induced-scission of polyethylene chains in Stage 2, there is no loss of performance during these stages. Stage 3, or degradation, occurs when the effect of oxidation induced-scission of polyethylene chains becomes measurable. Bonaparte et al. (2002) found that the approximate durations for each stage for a 1.5-millimeter (mm) HDPE geomembrane are: (i) antioxidant depletion (200 years), (ii) induction (20 years), and (iii) half-life (50% degradation) of an engineering property (750 years). This implies a service lifetime for an HDPE geomembrane of 800 to 1,000 years. Subsequent research conducted by Rowe et al. (2009b) found similar durations and concluded that HDPE liners may perform as designed for upwards of 500 to 1,000 years. Similarly, Phifer and Denham (2012) estimate that the HDPE liners in the Portsmouth CERCLA cell design may function for 600 to 1,400 years. A service life of about 500 years would ensure enough containment time to allow for decay of short-lived radionuclide contaminants (e.g., less than 100 year half-life) to innocuous levels, as noted by the NRC (NRC 1981).

The leachate collection and removal system above the primary liner and the leak detection and removal system below the primary liner would be effective for the period of active institutional controls. The period of active institutional controls is not known, but is assumed for design purposes to extend for at least 100 years. Subsequently, the final cover system, secondary liner, and geologic buffer would provide long-term control of leachate release since these engineered features would last minimally for 500 years. The final cover system would be designed to have a lower long-term vertical percolation rate than the basal liner system and geologic buffer. This would prevent leachate from mounding on top of the basal liner system after the period when the leachate removal system is no longer active and would control the long-term release of leachate by limiting the rate of infiltration into the waste and down through the basal liner system and geologic buffer.

Engineered subsurface and surface drainage systems are included in the conceptual designs of the EMDF at all sites. The extent of those drainage systems differs, depending on site-specific hydrologic characteristics and topography. The underdrain engineered features are relied on to maintain lowered ground water tables below the geobuffer systems. Surface drainage features (upgradient diversion ditch and French drain) between Pine Ridge and the installed facility (all sites) will provide diversion of upgradient flow, reduce potential erosion and subsidence of the cover and promote stability, all of which will support the isolation of the waste from contact with water. All drainage systems are designed with graded filtration, and non-weathering materials to provide long-lived performance.

Studies were conducted at the existing EMWMF of the potential for plugging of the underdrain by inorganic mineral precipitates. If this were to occur, mineral deposition in the core of the multizone filter might reduce the hydraulic conductivity, and thus, the overall effectiveness of the underdrain. To evaluate the potential for plugging, ground water geochemical data were evaluated to determine the solution saturation with respect to common minerals present in the ground water. Additionally, potential changes to the geochemical environment induced by the underdrain were considered to determine if a shift in the solution equilibrium might still result in undesirable formation of mineral precipitates. Four quarters of site ground water data from calendar year 2001 were used for the analysis. The data were analyzed using the public domain software application HYDROWIN. The output demonstrated that calcium-bicarbonate water was expected to be collected by the underdrain. Therefore, the major ions of concern would be calcium, magnesium, and iron, and the common minerals associated with these ions would be calcite, dolomite, and siderite. The saturation indexes for these minerals were calculated and a statistical evaluation conducted. It was determined that within the underdrain, all three indexes were undersaturated with respect to these three common carbonate minerals and plugging of the underdrain by inorganic mineral precipitates was unlikely (UCOR 2013).

To preclude the underdrain materials themselves affecting the concentration of soluble minerals (i.e., calcite, dolomite, and siderite), the drain materials would be comprised of siliceous materials, which under the low temperature and near neutral pH of the ground water system is essentially an inert/insoluble material. These materials would not be expected to adversely impact the saturation index. Even with some degree of diminished porosity and permeability, the underdrain is assumed to provide an effective avenue for long term drainage based on a much higher permeability of underdrain materials relative to that of in-situ materials. The measured hydraulic conductivity, K, of in-situ soils/saprolite and bedrock materials generally ranges between 10^{-4} cm/sec to 10^{-6} cm/sec or less. The design calculation sheets developed by Bechtel Jacobs in 2003 for the underdrain installed below Cell 3 at the EMWMF, indicate K values for various underdrain materials ranging from 2.0 x 10^{-2} cm/sec for sand, to 15 cm/sec for gravel (#57 size stone), to 35 cm/sec for rock (#3 ballast stone). Even with some degree of potential clogging, the minimum of five orders of magnitude difference between underdrain and in-situ K values will help to ensure the persistence of a lowered water table.

If a site is selected for an on-site disposal facility, drainage features will be configured to follow natural site drainage characteristics, and sized in final design considering site-specific hydrology, to optimally function over the long-term. A natural analog to achieving long-term successful site drainage is Machu Picchu, where rainfall exceeded 75 in./year, and drainage features were designed to withstand damage from potential landslides, settlement, and erosion. Machu Picchu has functioned as it was designed to for more than four centuries (Wright, et. al. 1997). Because of the long-time frames involved, the NRC recommends using these natural analogs to support longevity assumptions (e.g., thousands of years) (NRC 2015). Further information on the longevity of engineered features for on-site disposal facilities is given in Section 6.2.2.4.8.

Although it is extremely unlikely that DOE or a successor agency would lose complete control, scenarios in which a temporary loss of control allows some form of uncontrolled access and use of the site have been considered. Inadvertent intrusion occurs when a person without knowledge of the site comes into contact with the waste. One example might be construction of a house with basement on the landfill cap. Deliberate intrusion into the waste, as for example, to recover metals, is intentional intrusion and is not considered.

Inadvertent intrusion will be prevented by the design thickness and multiple layers of the final cover system (approximately 11 ft), including a 2 ft thick biointrusion layer (applicable for all sites). These structures are expected to warn people of, and discourage them from, inadvertent penetration of the landfill and exposures to waste. Excavation of basements for houses should not fully penetrate the cap, because basements in this area do not typically extend more than 10 ft deep. Excavating through the landfill cap would require heavy equipment or many laborers. Penetration of the cap by other means, such as drilling for a water well, would require heavy equipment and would produce artificial materials in the cuttings, which should signal the driller to stop work. In the event that the well does penetrate the waste, approximately 41 ft^3 of cuttings from the EMDF waste body (assumes 75 ft of waste penetrated by a 10 in. diameter borehole) would be brought to the surface. Given the estimated volume of clean soil that would be needed for void fill, only about 46% of the cuttings, or 19 ft^3, would be contaminated. This percentage would be further reduced by the amount of clean soils penetrated in the cap and liner and beneath the liner to the completion depth. The small volume of contaminated waste and short time of worker exposure would minimize the acute exposure risk. Risk due to chronic exposure, which would depend on how the cuttings are disposed after well completion, are also expected to be minimal. A more detailed and quantitative assessment of inadvertent intrusion scenarios and risks will be performed per DOE Order 435.1 requirements to be completed prior to landfill construction. That assessment will look in detail at exposure of an intruder under various scenarios. Conclusions from the assessment, in terms of exposure, will be evaluated and if deemed necessary, will be used to modify facility WAC in the Final WAC Attainment (Compliance) Plan, which is a primary document approved by the triparties.

The thick cap and biointrusion layer are also intended to prevent or minimize damage from burrowing animals and tree roots for hundreds of years or longer. The landfill, including the liner system, leachate collection/detection and removal systems, clean-fill dikes, waste, and final cover system would be designed to remain stable under a range of environmental conditions. Design calculations evaluate the potential for erosion, mass wasting, and earthquake accelerations, for the foreseeable future. Final design work for the cover will consider erosion. The ability of the planned grass cover and topsoil to resist the rill and interrill erosions would be evaluated using applicable models. This evaluation would consider the resistance of the system to formation of erosion gullies using, for example, a 2000 year design storm. The ability of the riprap in the biointrusion layer to resist gully advancement would also be considered under a 2000 year storm scenario using industry standard models and methods.

Survival of an engineered landfill structure for thousands of years is not unreasonable since, for example, many natural analogs can be identified. British earthen hill forts more than 2,000 years old remain essentially intact. Native American mounds in the Ohio and Tennessee River valleys, many of which are more than 1,000 years old, have also survived with little erosion, as have similar structures built by pre-Columbian civilizations in the much wetter climates of Central and South America. Detailed design calculations will be conducted, in part, to assess the capability of the landfill design to protect from long-term geomorphic and seismic stresses. If final design efforts identify areas needing improvement, these would be incorporated into the final design.

Because sinkhole development presents challenges to long-term landfill integrity, site-selection criteria preclude construction of EMDF over a rock unit susceptible to extensive karst development and collapse. The rock units underlying the EMDF footprint are not karstic, and there are no observable karst surface features on the south flank of Pine Ridge, as further discussed in Appendix E of this RI/FS. Aside from intentional human disturbance or major global climate changes, no other credible scenarios for exposing human or ecological receptors to the waste have been identified.

Institutional controls would prevent access to EMDF and use of local ground water. Active institutional controls would continue for an indefinite period and land use restrictions would be made permanent through the property deed or ROD. Further, state and federal regulations (e.g. 40 CFR 264.116 and 40 CFR 62.151) require that local authorities be provided with a survey plat showing the locations and dimensions of the landfill cells. S&M of the facilities and monitoring to determine the effectiveness of the primary controls would continue for the period of active institutional controls.

Long-term Environmental Effects

Long-term environmental effects are those impacts that may occur following closure of EMDF. Cleared land over EMDF would represent a long-term loss of forest habitat. The spoils area would be planted with native vegetation after closure and, if not needed for other purposes, would be allowed to revert to forest. The support facility areas could be re-vegetated or allowed to revert to natural cover. Wildlife species displaced by the construction and operation activities would, to some degree, begin to reoccupy these areas again following closure. The species mix may be different than originally present. Birds and small mammals in the surrounding area may re-colonize and forage in the disturbed area as the vegetative cover develops. Large mammals would continue to be excluded from the area by the access control fence. Because active institutional controls would continue indefinitely, trees would be prevented from growing on the EMDF cap, but may be allowed to grow between the fence line and the EMDF, providing a small area of relatively isolated forest habitat. Should institutional controls lapse, the landfill area would eventually progress toward an upland forest and animals would reoccupy this small area. The biointrusion layer would discourage or prevent growth of deep-rooted trees and disturbance by burrowing animals. However, even if the cap is colonized by forest succession, the cap integrity is likely to be preserved, because most eastern upland forest species are relatively shallow-rooted. Other long-term environmental effects for the On-site Disposal Alternative are addressed in the paragraphs that follow.

Transportation Impacts: The increased traffic from construction, operation, and closure of the EMDF would cease after closure. Long-term environmental effects associated with transportation required to maintain institutional controls and monitoring would be negligible.

Air Quality Impacts: Air emissions from construction, operation, and closure of the EMDF would cease upon completion of the final cap. No long-term impacts to air quality would be expected.

Wetland and Aquatic Resource Impacts: Impacts to aquatic resources in the vicinity of the disturbed area at the EBCV candidate site, primarily the upper reaches of the central and east branches of NT-3 and at least one draw that connects with NT-2, would be permanent and irreversible because the landfill would be constructed over them. Neither these streams nor the wetlands along them are known to harbor threatened or endangered species. Impacts to the lower reaches of NT-2 and NT-3 and Bear Creek from construction and operation of the landfill would significantly decrease following closure of EMDF, and long-term effects are not expected to be significant. Likewise, for the WBCV and Site 7a of the Dual Site Option will have permanent impacts to wetlands in those sites. Mitigation of those wetlands is expected. Should one of these sites be selected for an on-site disposal facility, detailed threatened or endangered species surveys would be completed as would wetland surveys.

For all sites, sediment detention basins would be removed and site restoration could include wetland or aquatic resource mitigation through restoration or replacement. Surface water would be routed around the waste cell and the impervious cap and vegetative cover would be maintained indefinitely, slightly increasing the volume of runoff water from the immediate area but preventing sediment loading of adjacent streams. Should institutional controls lapse, erosion of the landfill would likely be minimal because of the relatively gentle slopes (4:1 side slope and 5% top slope), the riprap erosion protection on the sides, and the vegetative cover on the top. Aquatic resources near the site could be impacted by future contaminant releases from EMDF to surface water, should such releases occur.

Surface Water Resource Impacts: The on-site EMDF would be designed, constructed, and maintained to prevent releases that could adversely affect surface water quality. PreWAC are determined that meet AWQC during the 1,000 year compliance period for the EBCV Site. Should another site be selected, PreWAC would be determined that would demonstrate this same protectiveness. The landfill is designed to resist erosion with minimal maintenance, and only extensive erosion would breach containment. The BCV area is geomorphically stable, and extensive erosion so severe that it would breach the containment systems is unlikely. Contaminant releases to ground water from leachate migrating from the EMDF in the long-term could also eventually impact surface water quality (see Appendix H for modeling results for the EBCV Site).

Ground Water Resource Impacts: Design, construction, and maintenance of the EMDF would prevent or minimize contaminant releases to ground water. These control elements include a multilayer cap to minimize infiltration and biointrusion; a liner that includes synthetic and clay barriers, a geologic buffer; and institutional controls that would include monitoring and ground water use restrictions. If releases were detected during the period of active institutional controls, mitigative measures would be implemented to protect human health and the environment. Results of modeling long-term impacts to ground water resulting from contaminants migrating from EMDF at the EBCV Site are provided in Appendix H. PreWAC analysis indicates that exposures would be acceptable at the hypothetical receptor location downgradient of the proposed EMDF site (see Appendix H). PreWAC modeling demonstrates protectiveness of the ground water resource, by meeting MCLs for the compliance period. Should another site be selected, PreWAC specific to that site would be determined that would in turn demonstrate this same protectiveness.

7.2.2.4 Short-term Effectiveness (On-site)

For the On-site Disposal Alternative (all sites), the short-term period is considered to include pre-construction investigations, construction, operation, and closure of EMDF. Operation of the on-site EMDF is expected to continue approximately 22 years through FY 2043 with closure activities completed in FY 2047 (waste generation and disposal is assumed to occur during those 22 years, beginning in FY 2022 ending in FY 2043). This evaluation does not address CERCLA remedial activities, waste or residuals that would be left in place at remediation sites, unacceptable waste streams, or any treatment residuals from on-ORR processing of waste to meet the EMDF WAC.

Potential risk to the public could result from transportation of hazardous and radioactive waste, operation of the on-site disposal facility, and wind-borne dispersion of contaminants. Risk to the public from waste handling and disposal activities at ORR would be low because of the robust and conservative protective systems supporting all phases of operation. Public access would be restricted at on- and off-site disposal facilities and at all waste generation, packaging, and handling sites. Selection of appropriate transport routes, compliance with DOT packaging and other requirements as necessary, and adherence to project-specific transportation safety and spill prevention, control, and countermeasures (SPCC) plans would minimize the likelihood of an accident and the severity of a release should an accident occur.

All waste handling and packaging activities would occur within controlled areas at remediation sites at Y-12, ORNL, ETTP, or at the on-site EMDF. SPCC plans would be prepared and implemented to address any accidental releases. Higher-hazard wastes would be managed with additional institutional and physical safeguards. All packaging and handling activities would be conducted by trained personnel following approved health and safety plans in accordance with DOE, DOT, state, and Occupational Safety and Health Administration (OSHA) requirements. A dedicated haul road would be used for transport of waste to EMDF. Risks to the public from waste handling and packaging activities would be extremely low.

Transportation risks to individuals and the public in direct or indirect contact with the waste during travel were evaluated based on guidance given in *A Resource Handbook on DOE Transportation Risk Assessment* (DOE 2002). Assessment of the risk was completed using the industry-recognized RADTRAN and RISKIND models. Additional risks, due to pre-operation (construction) activities and during operation (a catastrophic event) were analyzed for the On-site Disposal Alternative. A detailed discussion of the calculations and results is provided in Appendix F.

A single route transportation analysis was completed for the On-site Disposal Alternative, and as a conservative 11 mile one-way trip distance was used, it is applicable regardless of which on-site location is considered. Individual receptors, MEIs, and collective populations were considered as receptors. Modeling of radiation exposure during routine and accident scenarios for MEIs resulted in an estimated excess cancer risk (fatal and non-fatal) ranging from 3.06×10^{-9} to 6.65×10^{-8} for a single shipment (multiple shipments do not apply to an MEI); a collective population risk (analyzed for a driver, off-link [persons along or near the route], and handlers) resulted in an estimated excess cancer risk (fatal and non-fatal) ranging from 1.60×10^{-13} to 8.47×10^{-5}. Even though it is assumed that the majority of on-site travel will occur on a dedicated haul road, there would be people working within the zone of consideration for the risk model and thus off-link risk was considered in the on-site analysis. Vehicular risk (risk associated with travel/vehicles) due to emissions and accidents, resulted in an estimated 0.83 total incidents of illness, trauma, or fatality. While these results appear to be high, they account for cumulative risk, for transporting and handling hundreds of thousands of shipments of waste. On a per-shipment basis, cancer risks due to exposure range in order of magnitude from 10^{-13} to 10^{-7} and vehicular risk from 10^{-9} to 10^{-6}. The exact excess cancer risk value depends on the receptor being evaluated. Appendix F provides detailed analysis.

Pre-operational risks for an on-site facility result from fugitive dust emissions. EPA research has shown that particulate emissions from open sources such as unpaved roads, borrow areas, spoil areas, general grubbing, and landfill construction can contribute significantly to ambient air particulate matter (PM) concentrations and thus pose a risk to the local population. Regarding activities considered in the construction of an on-site disposal facility, the limit of interest is PM_{10} (particles with a mean aerodynamic diameter greater than 2.5 µm and less than or equal to 10 µm). A limit of 150 $\mu g/m^3$ for the 24-hour averaged PM_{10} has been established by EPA. Evaluations using an EPA model and applying control efficiencies to emission rates for some activities resulted in worst case PM_{10} values of between 106 and 150 $\mu g/m^3$ for all activities at the most conservative site location (Site 7a). See Appendix F for detailed information regarding this evaluation.

The catastrophic event analyzed for on-site operation of a disposal facility was a tornado. In the east Tennessee area, the probability of a tornado strike is estimated at 4.26×10^{-5} per year (FEMA 2009, NOAA 2011). Although a low probability is associated with this natural phenomenon, the consequences of such an event could be great. An estimate of the human health risk posed by a tornado striking the on-site disposal facility and releasing contamination was made using the RESRAD computer code (ANL 2001). An aggregate risk factor of 3.71×10^{-7} was determined, taking into account the facility operational lifecycle and the tornado probability. Appendix F provides detailed information for this assessment.

Risk related to seismic events will be evaluated in detail as part of the landfill design effort. However, the probability of occurrence of a damaging earthquake was qualitatively estimated for this RI/FS in Appendix F. The probabilistic seismic hazards for the Oak Ridge area are approximately Magnitude (M) 4.8 and radius (R) = 14.3 km for short-period spectral accelerations (S_a) (Peak Ground Acceleration and S_a at time = 0.2 sec) and M7.7 and R = 448 km for long-period spectral accelerations (S_a at time = 1.0 sec). These sources are consistent with the historical seismicity at ORR described previously, and are relevant for all sites considered.

The primary risks to workers for the On-site Disposal Alternative (no differentiation between sites) would result from construction and waste handling, transportation, and disposal activities. These activities would be conducted by trained personnel in accordance with ARARs, OSHA and DOT regulations, DOE requirements, approved health and safety plans, and ALARA principles. Risk from exposure during disposal activities would be generally limited because the waste would meet the EMDF WAC. Worker exposure would be further minimized by compliance with DOE waste packaging, transport, and handling requirements; the use of shielding and personal protective equipment; limits on driver work schedules; and other operational restrictions, such as spacing and distancing, to ensure that radiation doses to workers are kept ALARA. The overall risk to workers for this alternative is low.

It is assumed that waste would be disposed of in the same year it is generated. The potential for short-term environmental effects would be posed primarily by construction activities, spills during transportation and handling of wastes, operational releases, and closure activities. Short-term environmental impacts would be minimized by use of BMPs including engineered and administrative controls.

Land clearing, construction, and operations would cause the direct loss of small animals, and reduce the local habitat for larger mammals. Noise, fugitive dust, and forest clearing on and adjacent to the proposed EMDF would impact nearby habitats. Large mammals would be excluded from construction areas by access control fences. Small animals and birds feeding or living in the construction area would be driven out by construction activities. Other short-term environmental effects for the On-site Disposal Alternative are addressed in the following subsections.

Transportation Impacts: The short-term environmental risk from transportation would arise primarily from the potential for spills during waste shipment and impacts to air quality resulting from commuter, construction, and operations traffic. Adverse environmental effects in the event of a spill during waste transport would be minimal because:

- Wastes would not be in liquid form.
- Waste volumes per shipment would be small.
- Contaminant concentrations would be low for most waste streams.
- Waste would be properly packaged.
- The waste shipments would occur solely on non-public roads.
- SPCC plans would be quickly implemented if a spill occurred.

Air Quality Impacts: Potential short-term impacts to air quality would result from exhaust emissions and the generation of particulate matter during pre-construction investigations, construction, operation, and closure of the on-site disposal facility. Vehicular exhaust emissions would include volatile organic compounds from unburned hydrocarbons, carbon monoxide, sulfur dioxide, and nitrogen dioxide. A greater potential for short-term impacts to air quality would result from the increase in generation of fugitive dust by earth-moving activities and traffic on unpaved surfaces (see Appendix F).

Wetland and Aquatic Resource Impacts: Wetland areas along Bear Creek and all of the NTs at and adjacent to each of the four proposed EMDF sites were delineated in comprehensive surveys across BCV reported in 1993 by Rosensteel and Trettin. More detailed wetland delineation surveys were completed in 2015 along the tributaries of NT-3 within and adjacent to the EBCV (Site 5) footprint. The 2015 surveys did not include the NT-2 tributaries along the east and southeast margins of Site 5, but previous surveys did encompass those areas. Newly constructed wetlands along the southeast margin of Site 5 were completed in 2014 to compensate for wetland destruction associated with the UPF haul road. Newly constructed wetlands were also recently completed in 2014 along the southeast margin of Site 7a. These constructed wetlands would be directly impacted by construction at Sites 5 and 7a. Each of the proposed sites also include natural wetlands either within and/or adjacent to the footprints that would be impacted by construction. Future work will be required to assess the detailed wetland impacts associated with any of the candidate sites selected for landfill construction, including compensatory wetland mitigation required to offset destruction of wetland areas. Complete details of wetland and ecological surveys in BCV and for each of the proposed sites are provided in Appendix E.

Appropriate runoff and siltation controls would be implemented at the EMDF sites to minimize impacts to wetlands and streams outside the construction area during construction and operation.

Construction, operation, and closure of the on-site EMDF would be expected to have some short-term impacts on aquatic flora and fauna, potentially including the Tennessee dace, a Tennessee-listed in need of management species. Erosion and runoff controls and best management practices included in the EMDF design would largely protect aquatic resources from increased turbidity and siltation. Sediment, dust, oil, diesel fuel, gasoline, antifreeze, and other chemicals from construction activities and equipment could potentially be released to the aquatic environment but would be minimized by mitigative controls such as spill controls and clean-up. Construction or expansion of culverts across tributaries would also disturb the aquatic environment. While fish, including Tennessee dace, would tend to avoid disturbed areas, disruption and reduction of the aquatic environment may stress or possibly temporarily reduce fish populations in nearby segments of Bear Creek and its affected tributaries.

Surface Water Resource Impacts: Potential short-term impacts to tributaries bordering proposed sites would be substantial, and would include channel modifications, re-direction of flows, increased scour, possible increases in storm flow, and increases in sediment load downstream from the construction area, as well as potential for spills to release contaminants (e.g., fuel spills). Impacts to Bear Creek would be confined to increased sedimentation because no construction is expected to be required on the stream.

EMDF would be designed, constructed, and maintained to prevent releases that could adversely affect surface water quality. Land clearing and construction activities would expose varying areas depending on the site selected, the ultimate size of EMDF, phased construction implementation, and other detailed design considerations.

Surface water runoff from uncontaminated areas of the waste cell would be controlled by a run-on/run-off diversion and collection system that includes stormwater/sediment detention basins. These basins would prevent increased sediment discharge to the streams and control discharge during storms. A perimeter ditch and French drain system would be constructed around the landfill (for all proposed sites) to prevent surface run-on and re-direct water to the sediment basins before release to local streams. These basins would provide secondary containment for any fuel or oil spills that are not adequately contained at the spill site. Table 7-1 lists the conceptual footprint of these drainage features for the proposed sites.

Potentially contaminated runoff from EMDF, water used for decontamination, water from the leachate detection/collection system, and other wastewater generated during the operational period would be collected, characterized, and either discharged directly or appropriately treated at an on-site facility, as required. All releases would meet ARARs and discharge limits as summarized in the IWM FFS (UCOR 2016). The potential for impact to surface water resources from the migration of contaminants from EMDF in ground water would be exceedingly low because of engineered and active controls, as discussed previously in Section 7.2.2.3. Little or no overall short-term impacts to surface water resources would be expected from implementation of this alternative, with the exception of direct impacts to any water courses or wetlands displaced or eliminated by construction.

Ground Water Resource Impacts: Ground water resources could potentially be degraded in the short-term by contaminant releases from the surface or EMDF. Potential contaminant sources include construction materials (e.g., concrete and asphalt), spills of oil and diesel fuel, releases from transportation or waste handling accidents, and accidental releases of leachate from EMDF. Compliance with an approved erosion and sedimentation control plan and an SPCC plan would mitigate potential impacts from surface spills. Clean-up actions taken to mitigate spills or remove contaminated soils would reduce the source of contamination during the construction phase. Engineered controls and active controls, including the leachate collection system, would drastically reduce the potential for impact to ground water resources that could result from contaminant migration from EMDF.

Monitoring of ground water is planned to occur during pre-operational, operational, and post-closure periods per ARARs specified in Appendix G, Table 3-8. Should leakage from the landfill be detected and subsequently confirmed, corrective measures would be taken under CERCLA as administered by the FFA.

T&E Species Impacts: Tennessee Wildlife Resources Commission Proclamation 94-16 prohibits destruction of the habitat of a state-listed species. T&E vascular plant and fish surveys completed in 1998 for the EMWMF included the EBCV Site and Site 6b areas adjacent to the EMWMF. Acoustic bat surveys were completed by ORNL around the EBCV Site after the May 2013 downburst there to assess the potential for T&E bat species prior to timber recovery. The EBCV Site Option was also partially surveyed for T&E species prior to the downburst but final comprehensive surveys will be warranted at EBCV if selected for construction. Existing habitats in the areas surveyed were found to be either not suitable or marginally suitable for status species. The wind damage and timber recovery have further reduced habitat suitability. If status species are found at a later date, plans to mitigate adverse impacts would be developed and implemented in compliance with endangered, threatened, or rare species ARARs listed in Appendix G. Of the existing surveys that include Sites 6b and EBCV, the only T&E species currently identified is the Northern long-eared bat, which is listed as threatened. Other sites, should one be selected, would have to undergo a detailed T&E species survey, as well as a wetland delineation and hydrologic stream determination survey to determine impacts to these species and areas.

Construction of the EMDF at the EBCV Site would impact wetlands along the main channel and two western sub-tributaries of NT-3, as well as wetland areas recently constructed for compensatory mitigation along the southeast margin of the site that drain into NT-2. The NT-3 wetlands at the EBCV Site are not currently known to harbor any federal- or state-listed T&E species, or sensitive species listed as in need of management by the state. As noted, other sites will require detailed T&E surveys if selected. The Tennessee dace is a species of fish that has been listed as in need of management by the state that may be found in the lower reaches of the NTs and along Bear Creek. Impacts to the Tennessee dace from stream alterations would likely be minimal because engineering controls and best management practices would reduce potential impacts to streams below the proposed sites and the fish could migrate to unaffected areas in Bear Creek.

Cultural Resource Impacts: Archaeological surveys were completed in 1998 for the EMWMF that included the EBCV and 6b Site areas adjacent to the EMWMF. The EMWMF surveys indicate that there are no known significant historical or archaeological resources within, or in the vicinity of, the EMDF footprints or the support facility areas at those sites.

Detailed site-specific archaeological and cultural resource surveys have not been completed for the WBCV Site or Site 7a. However, several surveys have been completed to locate historic home sites and cemeteries across the ORR encompassing BCV and the proposed EMDF sites. The results of those surveys indicate two findings with potential significance to the WBCV Site and Site 7a: 1) the Douglas Chapel cemetery is located along the northeast margin of Site 7a; and 2) foundation materials of a historical structure designated as 833A are located along the southeast margin of the WBCV Site. Other historical structures and cemeteries previously identified within BCV do not appear to be in close enough proximity to the sites to warrant concern. Field investigations to verify current conditions of these cultural features and address potential mitigation will be needed if the sites are chosen for landfill construction. No detailed archaeological surveys appear to have been completed at Site 7a or WBCV but would be warranted if the sites are selected for EMDF construction. Appendix E should be referenced for detailed accounts of previous cultural resource surveys associated with the proposed sites.

Noise Impacts: There would be a short-term increase in noise levels during construction from sources such as earth-moving equipment, material handling equipment, waste transport vehicles, commuter traffic, and general human activity regardless of the location selected for an on-site facility. However, noise levels during operation and closure of EMDF would not differ from those currently existing due to the operations of EMWMF. Trucks used to transport wastes to EMDF from ORR would use a dedicated haul road and avoid publicly accessible routes. The increase in noise at EMDF may disturb wildlife in the immediate area and cause animals to avoid the area, especially during periods of high noise levels. While it is assumed for purposes of this RI/FS that construction and operation activities would be conducted only eight hours per day during the daytime, actual construction activities could follow a different pattern. The impact of increased noise levels from facility construction and operation would be local, with little or no impact expected at the ORR boundary.

Visual Impacts: Construction and operation activities at the proposed EMDF (any site) would be visible from Bear Creek Road, western parts of the Y-12 Plant, Chestnut Ridge, and Pine Ridge. Because Bear Creek Road is not a public thoroughfare and Chestnut Ridge and Pine Ridge are restricted within the ORR boundary and accessible only by dirt road or by foot, there should be no short-term visual impacts to the public.

Duration of the On-site Disposal Alternative: As shown in Figure 6-27 in Chapter 6, the total duration of the alternative (over which short-term effectiveness is evaluated) is approximately 30 years, consisting of early actions and design beginning in FY 2012 and FY 2017, respectively, followed by facility construction. Waste disposal operations are estimated to begin in FY 2022 and last for approximately 22 years until FY 2043 when facility closure activities would begin. This schedule is relevant for all proposed sites. Waste generation is assumed to occur during the 22 years of operation. Facility closure activities would end in FY 2047. A total lifecycle of 43 years is applicable. The post-closure period after FY 2047 is addressed in the long-term effectiveness evaluation in Section 7.2.2.3.

7.2.2.5 Reduction of Contaminant Toxicity, Mobility, or Volume by Treatment (On-site)

Except for treatment as necessary to meet the EMDF WAC, the On-site Disposal Alternative does not establish waste treatment requirements. Waste generators would be required to treat wastes as needed to meet the EMDF WAC before on-site disposal, which could reduce the toxicity, mobility, or volume of waste depending on the waste characteristics and treatment applied. For example, waste must be reduced in size according to physical WAC, to be accepted at the existing EMWMF. However, these waste generator actions are excluded from the scope of the On-site Disposal Alternative. For portions of waste disposed of off-site, treatment would similarly be applied as needed before shipment or at the receiving facilities. The On-site Disposal Alternative, for all sites, would reduce the mobility of contaminants through isolation of waste in the EMDF. This isolation is not a treatment, per se, and is addressed under long-term effectiveness and permanence.

7.2.2.6 Implementability (On-site)

Implementation of an On-site Disposal Alternative would involve meeting administrative and technical requirements for waste handling, packaging, and transport and construction, operation, closure, and post-closure monitoring of an on-site EMDF. For the volume of waste not meeting the EMDF WAC, handling, transport, and off-site transportation and disposal or interim storage would be required, and would be the responsibility of the generator/project generating the waste and not the On-site Disposal Alternative. All of the proposed actions would be performed using standard construction equipment and techniques. Similar construction and operation has been successful at the EMWMF. Construction and operation of the on-site EMDF, including other support facilities, would involve no unusual or unprecedented conditions or technologies.

Administrative Feasibility: DOE O 435.1 places requirements on DOE facilities concerning disposal of LLW. For CERCLA sites, it is DOE policy to use the CERCLA process to demonstrate that human health and environmental protection performance objectives are met. DOE’s Low-Level Waste Disposal Facility Federal Review Group (LFRG) is an independent group chartered (DOE 2011e) to ensure that DOE radioactive waste disposal facilities are protective of the public and environment. The LFRG assists EM senior managers in the review of operational envelope documentation that supports the approval of DOE O 435.1 requirements or appropriate CERCLA documents as described in Section II of the LFRG Charter. These LFRG reviews support the issuance of Disposal Authorization Statements for LLW disposal facilities and activities. In addition, the LFRG’s review process supports DOE implementation of its regulatory responsibility under the Atomic Energy Act of 1954 as amended and DOE O 435.1, *Radioactive Waste Management*, and maintains DOE's commitment to the Integrated Safety Management System process.

Construction of a disposal facility at the EBCV Site may require moving the 229 Security Boundary for Y-12. The proposed location at EBCV is just inside the 229 Security Boundary at the west end of the plant. In order to revise this boundary, DOE would publish a notice of revision in the Federal Register. The required steps to move the security boundary have been accomplished in the past and are implementable for the new disposal facility. No other locations would require moving the 229 Security Boundary for Y-12.

The southern part of the proposed EBCV footprint would potentially impact three planned wetland expansion areas identified in the ARAP issued in support of the UPF construction project. If the On-site Disposal Alternative, EBCV Site Option is selected, coordination of EMDF activities with planned UPF project activities, including a modification to the ARAP, would be required and are implementable. Wetland mitigation would be required at the WBCV and Dual Site Options as well.

All construction related activities would be conducted on-site and would not require permits to be issued by state or local governments; however, any substantive provisions of any permits (e.g., ARAP) that would otherwise be required would be considered ARARs. EMDF would be designed to meet all substantive requirements for a RCRA hazardous waste landfill and a TSCA chemical waste landfill. NRC licensing would not be required because DOE is exempt from NRC requirements. The small volume of waste not meeting the on-site disposal facility WAC would be shipped off-site to approved facilities or stored on-site at compliant facilities pending identification of treatment and disposal options, and would be the responsibility of the generator/project generating the waste and not the On-site Disposal Alternative. The administrative feasibility of off-site disposal, including the issue of state equity, is discussed in greater detail in Section 7.2.3.6.

Technical Feasibility: The technology currently available for disposal, treatment, transportation, storage, and supporting activities is proven and reliable for most waste projected to be generated at ORR and associated CERCLA sites, resulting in a low degree of uncertainty for the implementation of this alternative. This alternative could reasonably be implemented without schedule delays resulting from technical complications.

Hazardous waste landfill technology is the key component of the On-site Disposal Alternative. Many similar landfills, including EMWMF, have been constructed and are operating today, demonstrating their viability. Construction and operation of EMDF would involve no unusual or unprecedented conditions or technologies.

Underdrain systems are common practice in civil engineering projects to maintain separation and protection of structures, roadways, facilities, and utilities from both seepage and ground water. Examples of landfills utilizing underdrain systems can be found across the U.S. and in other countries. The Southeastern Public Service Authority (SPSA) Regional Landfill in Suffolk, Virginia began operating in 1983 and utilized underdrain systems, piping, and geocomposites to facilitate construction and lower the water table under the landfill cells. In 2011 an application submitted by the SPSA to expand the landfill was approved. The new expansion included additional underdrain systems to control ground water.

The Crossroads Landfill located in Norrisridgewock, Maine incorporated vertical wick drains and a blanket underdrain to manage water under new landfill construction. The site saw a catastrophic slope failure of the soft clays under the site in 1989 which impacted 50 acres of waste. To prevent future problems under new cells, over 75,000 vertical wick drains were installed at depths ranging from 20 ft to 75 ft to discharge into a 2 ft thick sand blanket layer. A new landfill liner system was then constructed over this blanket drain and over 1 M yd^3 of material was relocated from the failed area to the new cells. Intensive monitoring was performed for years to ensure that newly constructed landfill areas were stable and that there was no potential for shear failure of underlying soft clays.

Examples of landfills using underdrain systems in order to construct liner systems below the water table can be found in Texas at the Construction Recycling & Waste Corporation Landfill, in Arkansas at the Fort Smith Landfill (10 ft below in some areas), in Arizona at the Gray Wolf Regional Landfill (10 to 15 ft below in some areas), and at the Sonoma County Landfill in California. The Sonoma County Landfill is located in Petaluma, California and involved a 50 acre landfill expansion that excavated as much as 45 ft below the water table and then constructed along canyon walls as steep as 2H:1V. The already complex configuration was further complicated by the strict seismic requirements of California, surface water drainages towards the site, and limited downstream space available for sediment ponds. Both static and dynamic stability analysis was performed and a design was implemented that met state requirements for factors of safety for static slope stability and allowable acceleration and deformation for dynamic slope stability. Disposal of waste commenced in August of 2002 within Phases I and II the landfill expansion. These are only a short example of a long list of landfills utilizing underdrains to control ground water levels. Of the ground water collection systems found for the various landfills, all of them incorporated the ground water collected into the facility ground water monitoring plans because it was seen as an early warning indicator of contaminant transport from the waste unit.

Future Remediation Considerations: Future remedial actions at EMDF should not be required because waste treatment to meet ARARs is accomplished by generators as necessary to meet the disposal facility WAC, protectiveness is provided by compliance with the disposal facility WAC (see Appendix H), and a high level of isolation is provided by the engineered landfill. Only limited additional actions would be possible once the landfill is capped because of the relative permanence and massive nature of the disposal facility. Additional actions would be warranted only if major deviations from the expected performance of the landfill features occurred. For example, remedial actions would be triggered by releases of contaminants to ground water or erosion of the cap and exposure of the waste to the environment.

Monitoring: All release pathways at EMDF would be monitored through leachate collection, leachate detection monitoring, surface water and ground water monitoring, air monitoring, and physical inspection of external EMDF conditions as required in ARARs. The conceptual site model (Appendix E) and ground water modeling results (Appendix H) indicate that ground water and surface water under and near the EBCV Site can be adequately characterized, modeled, analyzed, and monitored. It is expected the same is true for other sites as well. Should releases to ground water go undetected, ground water in the immediate vicinity of EMDF could be contaminated and minor releases to Bear Creek could occur. The actual risk of exposure from such a release would be low.

Underdrains present at all proposed sites would be physically monitored as well. If detection monitoring of ground water wells (monitored per 40 CFR 264) or underdrain systems indicate a release has occurred and subsequent compliance monitoring confirms ground water protection standards may be exceeded, corrective actions would be implemented per the FFA. Those corrective actions might include pump and treat activities in combination with installation of diversion/interceptor trenches and/or wells for plume capture. Reactive barriers are another technology, though used less frequently, that can operate passively to capture and remediate ground water contaminant plumes. Underdrain outfall features could be modified to provide a collection point for impacted water, where that flow could be treated by available technologies to satisfy discharge limits protective of human health and the environment. Treatment would depend on the contaminants present, but could include the use of filtration, adsorption/ion exchange operations, including activated carbon, and/or precipitation. Water treatment technologies are advanced and readily implementable at all sites as a corrective action, if necessary. Should on-site disposal be the selected alternative, per requirements of TDEC 0400-12-02-.03(2)(e)(1)(i)(III), a description of how corrective actions would be implemented, will be appropriately addressed.

Services and Materials: Services and materials required for EMDF construction, off-site disposal, treatment, storage, and supporting operations would be available for implementation of this alternative for all proposed sites. EMDF would be designed and constructed to accommodate the projected waste volume. Construction would involve the use of standard equipment, trades, and materials. Many companies have successfully constructed disposal facilities and multiple bidders could be expected for procurements necessary to develop EMDF. Treatment services such as solidification and stabilization are available at both ORR and off-site disposal facilities. Permitted off-site disposal facilities are available with sufficient capacity to treat and dispose of the waste volume that exceeds on-site disposal facility WAC. Implementability of off-site disposal is further addressed in Section 7.2.3.6. Interim compliant storage for waste not meeting the WAC for the EMDF or off-site facilities can be reliably achieved.

This alternative is implementable at all proposed sites. The administrative structures required for implementation are largely in place; the required technology is proven, and services and materials required to implement the action, including an adequate body of vendors, are available.

7.2.2.7 Cost (On-site)

Estimated total project costs for the On-site Disposal Alternative at all proposed sites (EBCV Site, WBCV Site, and Dual Site Option [Site 7a/6b]) is given in Table 7-2. The cost estimate is based on facility conceptual designs that yield an approximate landfill waste disposal capacity (i.e., air space volume) as noted in the table, but does not include the cost for construction of excess capacity as the current waste generation forecast (with a 25% volume contingency) would only require 2.2 M yd^3. Cost contingency (22% for construction, 5% for operations) has been assumed, and is included in this estimate in Table 7-2 for each proposed site.

In terms of Present Worth, the estimated total project cost of the On-site Disposal Alternative Site Options correlates to an estimated cost of $279, $286, and $347 per unit volume of as-generated waste for the EMDF in 2016 dollars for the EBCV, WBCV, and Dual Site locations, respectively. This on-site cost may be directly compared to the cost per unit volume for off-site disposal (see Section 7.2.3.7).

These costs include a “Perpetual Care Trust Fund” intended to cover S&M and ground water monitoring needs for 1,000 years after closure of the landfill. It assumed that these post-closure activities will be funded in a similar fashion as was implemented for EMWMF, through a perpetual care fee. The cost was derived by estimating the needed annual S&M budget after closure of the landfill, assuming an annual compound interest rate, and using the operational life of the landfill to back calculate the needed annual deposit (Perpetual Care Fee) that would be required to meet the annual S&M budget. There are no assumptions regarding which entity will actually perform the post-closure care; the purpose of this Perpetual Care Fee in this document is to incorporate the expected cost in the estimate. The cost estimates were prepared using the methodology described in Section 7.1.7 and the technical scope and assumptions for the proposed EMDF site are described in Chapter 6. Appendix I provides further description of the project costs and assumptions for the candidate sites, including those for long-term S&M (Section 3.3 in Appendix I).

7.2.2.8 NEPA Considerations (On-site)

Socioeconomic Impacts: The short-term socioeconomic impact associated with the workforce required for construction, operation, and closure of EMDF would be small. The workforce would vary with project phases and would likely be drawn from the local labor market, resulting in minimal influx of workers to the area. If local waste disposal capacity provided by EMDF encourages more cleanup of individual sites, additional workers could be needed to support implementation of remedial actions at individual sites. The numbers of additional workers needed for remediation would be variable and most likely drawn from the local labor force.

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Table 7-2. Summary of the On-site Disposal Alternative Costs

Cost Element	Year(s) Implemented	EBCV Site Option [build to 2.2 M yd^3]		WBCV Site Option [build to 2.2 M yd^3]		Dual Site Option [build to 2.25 M yd^3]	
		Cost (FY 2012 Dollars)	Total Cost (FY 2012 Dollars)	Cost (FY 2012 Dollars)	Total Cost (FY 2012 Dollars)	Cost (FY 2012 Dollars)	Total Cost (FY 2012 Dollars)
CAPITAL COSTS							
Phase I includes Cells 1 and 2 (EBCV and WBCV); Phase I includes all of Site 6b (Dual Site)							
Engineering	varies by site	$22,598,980	$129.6	$22,598,980	$134.1M	$35,784,781	$143.9M
Site Development		$7,216,340		$9,270,613		$6,597,964	
Support Facilities		$18,202,168		$19,354,975		$20,084,991	
Construction of Cells		$81,578,843		$82,918,677		$81,387,512	
Phase II includes Cells 3 and 4 (EBCV and WBCV); Phase II includes Cells 1 and 2 (Dual Site 7a)							
Engineering	varies by site	$2,102,442	$44.3M	$2,102,442	$59.8M	$1,598,718	$88.2M
Construction of Cells		$42,225,549		$57,699,649		$86,569,044	
Phase III includes Cell 5 (EBCV and WBCV); Phase III includes Cells 3 and 4 (Dual Site 7a)							
Engineering	varies by site	$2,102,442	$31.0M	$2,102,442	$30.1M	$2,102,442	$66.3M
Construction of Cells		$28,848,064		$27,953,140		$64,211,941	
Final cap (for Dual Site includes both landfills)							
Engineering	varies by site	$2,046,565	$65.4M	$52,024,686	$60.2M	$78,100,640	$92.3M
Quality Assurance		$6,173,495		$2,102,442		$35,784,781	
Construction of Final Cap		$57,178,863		$57,699,649		$6,597,964	
Total Capital Cost (FY 2012 $)		**$265.9M**		**$284.2M**		**$390.6M**	
OPERATIONS COSTS							
Base Operations	FY 2022 - 2043	$266,399,602	$298.7M	$266,327,226	$298.6M	$280,855,255	$316.8M
Leachate System Operations		$28,640,275		$28,640,275		$32,271,862	
Security Operations		$3,657,045		$3,657,045		$3,657,046	
OTHER COSTS							
Pre-Construction Costs (e.g., Characterization)	FY 2012 - 2017	$11,294,256	$44.4M	$9,382,233	$42.5M	$16,372,211	$52.8M
Perpetual Care Fee & Post-closure Care	FY 2022 - 2054	$29,428,090		$29,428,090		$32,795,330	
Support Structure Demolition/Removal	FY 2054	$3,680,000		$3,680,000		$3,680,000	
Subtotal (Capital, Operations, Other)	**FY 2012- 2054** **43 Years Total**	**$613.4M**		**$625.4M**		**$760.2M**	
Contingency (22% Capital, 5% Operations)		**$72.5M**		**$75.7M**		**$100.8M**	
Total (FY 2012 $) Life Cycle Cost		**$685.8M**		**$701.1M**		**$861.0M**	
Total (FY 2016 $) Life Cycle Cost		**$716.5M**		**$732.6M**		**$899.6M**	
Present Worth (FY 2016 $)		**$542.9M**		**$557.7M**		**$676.2M**	

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There would be no long-term socioeconomic impacts associated with the On-site Disposal Alternative (regardless of site location) because the small workforce required to construct, operate, and close EMDF would no longer be required after closure activities cease. The post-closure care activities to be implemented would require a minimal workforce.

Land Use Impacts: The EBCV candidate site lies partially within the ORERP and other sites fully within the ORERP, which includes industrial areas, natural areas, aquatic natural areas, field research areas, and other areas designated for their unique natural attributes. Construction and operation of the EMDF at these sites would require clearing land within the ORERP that could result in short-term effects on these areas. Use of ORERP land for a disposal facility would represent a trade-off between the current use of the land for forest and use of the land for waste disposal. To minimize impacts during construction, roads and utility corridors would be located in existing rights-of-way wherever possible. Areas not immediately required for construction of EMDF would be seeded to minimize erosion. Potential impacts to ORERP environmental resources would be minimized by the buffer provided by the restricted area around the facility and by use of BMPs, including sediment and storm water controls during landfill operation.

The proposed EMDF site in EBCV and Site 6b of the Dual Site Option are adjacent to brownfield areas where the existing EMWMF and former waste disposal sites are located. Any future development in that area would be influenced by the presence of EMDF and other disposal facilities. In addition to their co-location with a brownfield area, other advantages for these proposed EMDF sites include the lack of public access and visibility and the presence of existing infrastructure. The proposed EMDF sites are co-located with other pre-existing waste disposal facilities in an area that is already subject to monitoring, oversight, and will be subject to future security surveillance.

BCV was divided into three zones in the BCV Phase I ROD (DOE 2000) for the purposes of establishing and evaluating performance standards in terms of resulting land and resource uses and residential risks following remediation (see Figure E-1 in Appendix E). The EBCV Site and Site 6b are located in Zone 3, with an agreed upon future land use goal of "DOE-controlled industrial use" stated in the BCV Phase I ROD. Construction of a disposal facility at either of these sites should not require a change to the BCV Phase I ROD to revise designated future land use for areas impacted by EMDF construction. The proposed EMDF sites would remain under DOE control within DOE ORR boundaries for the foreseeable future.

The WBCV Site and Site 7a are located in Zone 1 and Zone 2, respectively, with agreed upon future land use goals of residential use. Construction of a disposal facility at either of these sites would require a change to the BCV Phase I ROD to revise designated future land use for areas impacted by EMDF construction.

The approximate areas impacted by an on-site disposal facility built at the proposed sites and corresponding conceptual design capacities are summarized in Table 7-3. The area impacted during construction, operations, and final closure is the approximate area which may be cleared or otherwise impacted by construction and operations (e.g., landfill, perimeter roads, parking areas, temporary construction staging areas, sediment detention basins, spoils areas, etc.). As noted in a footnote, Sites EBCV and 6a will use existing infrastructure at EMWMF (21 acres) so that land is already impacted and in-use, so was not included in the area for development. Institutional controls would restrict access to impacted areas during construction, operations, and closure. Phased construction, reuse of construction spoil, implementation of BMPs, and other detailed design considerations would likely reduce the total area impacted at the proposed sites.

After the landfill is closed, the area requiring permanent commitment would be reduced to an area slightly greater than that of the landfill footprint with allowance for monitoring, maintenance, and security. The landfill footprint corresponds to the area of the landfill, including perimeter ditches and clean-fill dikes. The landfill footprint would be permanently maintained, representing long-term impact on the direct use of that land.

Table 7-3. EMDF Impacted Areas and Disposal Capacity at the Proposed Sites

EMDF Site Location	Acreage for Development [a]	Footprint of Disposal Facility [b]	Area of Permanent Commitment	Landfill Disposal Capacity (yd^3)
EBCV Site Option	71[c]	48	70	2.5 M
WBCV Site Option	94	52	71	2.8 M
Dual Site Option (Site 6b/7a)	127[c]	68	109	2.25 M
Hybrid Site (Site 6b)	53[c]	27	50	0.85 M

[a] Area for development, including temporary construction activities, existing and new support facilities, and spoils areas.
[b] Area of disposal facility footprint, computed to the outside edge of grading for perimeter clean-fill dike.
[c] EBCV Site and Site 6b use 21 acres of developed land that is currently being used by EMWMF. Therefore the 21 acres has not been included in the development acreage for these two sites.

Environmental Justice Impacts: No environmental justice impacts have been identified for any location for this alternative. The Scarboro community is the only formally identified environmental justice community near the ORR, and is not anticipated to be impacted by construction, operation, or closure of the On-site Disposal Alternative. Details are given in Appendix E, Section 2.4.2.

Irreversible/Irretrievable Commitment of Resources Impacts: Flora and fauna requiring forest habitat would be impacted by the permanent commitment of land to the EMDF (see Table 7-3). For the EBCV Site, one draw/ravine of NT-2 and the upper reaches of NT-3, including springs, seeps, and wetlands associated with each, would be permanently impacted. Likewise, seeps, springs, and wetlands will be impacted at the WBCV Site, Site 7a, and minimally at Site 6b. Transportation, construction, operation, closure, and long-term institutional controls for EMDF would require an irreversible and irretrievable commitment of fuel and other nonrenewable energy resources; geologic resources such as gravel, rock, and borrow soil; and manufactured landfill components (e. g., synthetic liner material). There are no known economic geologic materials in or near the candidate site that would be irreversibly affected.

Cumulative Impacts: Construction of EMDF would not result in any significant cumulative impacts to the surrounding environment if BMPs, including engineering and administrative controls, are used. Incremental impacts to air quality, traffic, and noise levels from construction and operation of an on-site disposal facility and from transportation of waste would not significantly alter existing or future conditions, although impacts would be noticeable to site workers. Ground water would not be used for construction or operation of EMDF. Only minor quantities of potable water would be used for dust control and other purposes and would not impact on- or off-site users.

Cumulative effects on ecological resources in the short-term depend largely on actual impacts to the area associated with the site. Construction of the EMDF would disturb forested areas in BCV and result in a net loss of forested area at all sites except Site 6b (already impacted as a borrow area). Forested area at the EBCV Site has been impacted significantly by a recent downburst; forested area at WBCV and Site 7a will be impacted to the greatest degree. The EMWMF as well as inactive waste disposal facilities are located in EBCV, adjacent to the proposed EBCV and 6b Sites. Environmental impacts from the inactive waste disposal areas that were not constructed and operated by today's environmental standards are already present, as shown by the decreased health of the upper portions of Bear Creek. Construction of the EMDF in BCV could contribute to the cumulative degradation of Bear Creek.

The evaluation of cumulative impacts for the On-site Disposal Alternative assumes that future activities at ORNL and Y-12 facilities continue at current levels throughout the construction, operation, and closure period of the EMDF. Existing non-DOE industrial facilities located adjacent to ORR are assumed to continue operations at their current levels.

The primary long-term cumulative impacts on ORR for this alternative, regardless of the location of that site within BCV, would result from the commitment of land and the potential benefit that local waste disposal capacity may impart to the overall cleanup of ORR and resulting land use. The loss of potential wildlife habitat or future land use at the EMDF may be at least partially offset by the cleanup and release of individual CERCLA sites elsewhere on the ORR. Removal of contamination and waste from these sites should result in positive long-term environmental effects by reducing the potential for exposure to and migration of contaminants, although some short-term impacts would be expected. The potential for contaminant releases from waste isolated in the EMDF would be less than the cumulative potential for releases from uncontained waste sources at multiple CERCLA sites. As a result of cleanup, habitat quality and biodiversity are expected to improve over time at these sites.

While cost, risk, and impacts are estimated in this RI/FS, the perpetual controls required for hosting an additional MLLW waste disposal facility on the ORR must be considered in the evaluation of cumulative impacts. The presence of a new disposal facility requires resources for monitoring and maintenance over the long-term. Co-location of the EMDF with the EMWMF and former waste management sites (i.e., BCBG, BY/BY, Oil Landfarm, etc.), as in the case of the EBCV Site and Site 6b of the Dual Site Option, aggregates the post-closure care and monitoring efforts. Proposed sites at WBCV and Site 7a of the Dual Site Option would require changes to ROD land use designation for those areas, and would extend the impact in BCV by as much as three miles.

7.2.3 Off-site Disposal Alternative Analysis

The Off-site Disposal Alternative involves transporting wastes generated at ORR to licensed or permitted off-site disposal facilities, and disposal of the waste in those facilities. Waste that does not meet the off-site disposal facility WAC would be placed in compliant storage pending the availability of treatment or disposal options. A detailed description of the Off-site Disposal Alternative is provided in Section 6.3.

7.2.3.1 Overall Protection of Human Health and the Environment (Off-site)

The Off-site Disposal Alternative would protect human health and the environment by removing wastes generated at ORR CERCLA sites, transporting them off-site, and isolating them from the environment by disposal in engineered facilities. Implementation of this alternative would prevent access to contaminated media and reduce the overall potential for releases from multiple sites on the ORR. Remediation of ORR and associated sites could result in human health or environmental benefits, depending on the eventual land use of these sites.

Human health and the environment would be protected in the vicinity of the receiving facilities by disposing of contaminated material appropriately. Operation of these facilities is not likely to result in exposure to waste or releases to the environment because the facilities are designed, licensed, monitored, and maintained to ensure reliable waste containment. The addition of CERCLA waste from ORR to these facilities would result in a negligible increase in risk above that resulting from disposal of other wastes at the facilities. The Energy*Solutions,* WCS*,* and NNSS facilities are located in isolated arid environments with few nearby human receptors.

Certain waste streams may not meet the WAC for existing off-site disposal facilities. This waste, projected to be a small volume, would be stored at ORR facilities with sufficient engineering controls and oversight to minimize the potential for exposure or release.

Worker risks from exposure during handling and preparation for transportation would be maintained to ALARA levels and comply with DOE orders through implementation of engineering controls and health and safety plans. The increased risk to transportation workers and the community from moving the waste within ORR and off-site would be minimized by compliance with DOT requirements; however, those risks in transporting the waste over thousands of miles, multiplied by thousands of shipments, become measurable. The considerable transportation distances required for off-site disposal result in an increased potential for accidents that result in higher risk of injuries, fatalities, or contaminant releases. Transportation risks from both vehicular accidents and exposure to contaminants are detailed in Section 7.2.3.4.

7.2.3.2 Compliance with ARARs (Off-site)

The actions included in the scope of the Off-site Disposal Alternative would comply with all ARARs and TBC guidance (identified in Appendix G). There are relatively few ARARs for this alternative because there are no chemical- or location-specific ARARs after waste is removed from the ORR and associated sites. Chemical- and location-specific ARARs, as well as action-specific ARARs associated with removal and treatment of wastes would be developed as part of individual site-specific remedial evaluations.

ARARs for this alternative are limited to requirements associated with transportation of waste and VR of waste, for Option 2. These requirements include shipping, packaging, labeling, record keeping, manifesting, and reporting requirements under DOT and RCRA regulations (49 CFR 171-174 and 177, 40 CFR 262 and 263) and Rules of the TDEC 0400-12-01-.03 and -.04. Because DOE O 435.1 specifies a preference for on-site disposal of LLW, shipment to a commercial disposal facility would require an exemption on a per project basis. Similar exemptions have been routinely approved since DOE began using commercial disposal capacity in 1992. ARARs guiding construction and operation of a VR facility are included as well.

The off-site facilities considered for this alternative are appropriately licensed and qualified in accordance with 40 CFR 300.440; the waste would be required to meet the receiving facilities' WAC. Once wastes were transferred from ORR, both administrative and substantive regulatory provisions would need to be met. Accordingly, requirements for permitting, recordkeeping, assessments, and/or other non-substantive elements would be triggered. Administrative and substantive regulatory requirements would be met through the facility's license or permit requirements and not as ARARs for this alternative after the waste is accepted by the facility. The owner/operator of the receiving facility would be responsible for all of its financial, operating, and closure requirements, including long-term S&M, for 100 years. S&M following the 100 year period (for commercial facilities) would be a state or federal responsibility (10 CFR 61). NNSS is a federally owned facility, and as such the federal government would be responsible for long-term S&M.

7.2.3.3 Long-term Effectiveness and Permanence (Off-site)

For the Off-site Disposal Alternative, the long-term period is considered to begin when all candidate waste has been disposed of off-site or placed in appropriate storage facilities. This evaluation does not address remedial activities, CERCLA waste or residuals that would be left in place at CERCLA remediation sites, non-candidate waste streams, or any treatment residuals from waste processing required to meet the WAC.

No residual risk would remain at ORR from candidate waste streams after the waste has been disposed off-site. The waste would be placed in off-site engineered disposal facilities designed to isolate waste from the environment, significantly reducing the possibility of intrusion or the migration of contaminants away from the facility. For the portion of waste requiring treatment to meet facility WAC prior to disposal, the potential for contaminant mobility would be further reduced. The receiving facilities would be responsible for monitoring and maintenance to ensure the effectiveness of waste isolation. In the case of LLW/RCRA waste shipped to Energy*Solutions* or WCS*,* the facilities have waste treatment capabilities and the respective WACs allow for receipt of untreated waste. It is assumed for the Off-site Disposal Alternative that the Energy*Solutions* or WCS facility would provide treatment of the waste prior to disposal to reduce the potential for contaminant mobility. Acceptable risk levels would be achieved by compliance with existing licenses or permits and regulatory requirements.

The Energy*Solutions* facility, WCS, and NNSS are located in arid environments with deep and/or saline ground water, and both are distant from population centers, factors that minimize long-term risk to human health. The off-site facilities use conventional, durable designs and materials to effectively isolate the waste. The arid climate at the facilities contributes to the long-term reliability of engineered features by minimizing infiltration. The engineered and natural features at these facilities are expected to provide adequate and reliable safeguards over the long term.

Under the Off-site Disposal Alternative, waste would be placed in licensed or permitted engineered disposal facilities that have been receiving wastes for a number of years and have operated in compliance with their permits and federal, state, and local regulations. Reliance on proven technologies minimizes uncertainty associated with this alternative.

For purposes of this evaluation, long-term environmental effects are those impacts that may be evident following receipt of the last shipment of waste off-site. Any potential environmental effects associated with transportation, including air emissions and accidental releases, would cease after this period. No long-term impacts to air quality, surface water, biota, wetlands, and aquatic or visual resources are anticipated at ORR or the vicinity from implementation of this alternative.

Potential long-term environmental effects at the off-site disposal facilities from the presence of ORR wastes are expected to be minimal; these wastes would represent a relatively small portion of the total waste inventory, and the receiving facilities are designed to minimize long-term environmental effects. No long-term impacts to air quality are expected at the receiving facilities from the inclusion of ORR waste because air emissions from vehicular use and construction activities for long-term monitoring and maintenance of the off-site facilities would not be increased.

7.2.3.4 Short-term Effectiveness (Off-site)

Short-term effectiveness for the Off-site Disposal Alternative is evaluated for the period beginning with the generation of CERCLA waste at ORR remedial sites and ending with disposal of all candidate waste streams at the receiving facilities. This evaluation does not address removal activities, CERCLA waste or residuals that would be left in place at individual units being remediated, or the risk associated with these elements.

As discussed in Section 7.2.2.4, risk to the public from waste handling activities at ORR would be extremely low. Public access would be restricted at waste generation, packaging, and handling sites, and activities would be governed by appropriate regulations and conducted by trained personnel. Risks at the receiving facilities would be controlled by compliance with permit requirements; access restrictions during disposal operations would minimize any impact to the community. For the Off-site Disposal Alternative, potential risk to the public would result from shipment of hazardous and radioactive waste.

The primary risks to workers for the Off-site Disposal Alternative would result from waste handling, waste transportation, and disposal activities. These activities would be conducted by trained personnel in accordance with ARARs, OSHA, and DOT regulations, DOE requirements, approved health and safety plans, and ALARA principles. Radiation exposure would be minimized by compliance with DOT regulations and DOE requirements for waste packaging, as well as the use of shielding and limits on driver work schedules. Risk from disposal activities at the receiving facilities would be minimized by compliance with their permit requirements. The overall risk to workers for this alternative is low.

Transportation risks to individuals and the public in direct or indirect contact with the waste during transport of the waste for off-site disposal were evaluated based on guidance given in *A Resource Handbook on DOE Transportation Risk Assessment* (DOE 2002). Assessment of the risk was completed using the industry-recognized RADTRAN and RISKIND models. A detailed discussion of the calculations and results is provided in Appendix F.

For the transportation risk analysis, several routes were evaluated: a route for classified waste that travels by truck to NNSS for disposal; a route for mixed (LLW/RCRA) waste that would be transported by truck from the generating site to the local ETTP rail system, then by rail from the ETTP rail yard to Energy*Solutions* in Clive, Utah, for disposal; and a third route (for Option 1 only) that LLW and LLW/TSCA waste would travel from the generating site to the ETTP rail system, from the ETTP rail system to a transfer facility in Kingman, Arizona, where it would be transferred to truck for the final leg to NNSS for disposal. Alternatively, in Option 2 the third route is a repeat of the route for Energy*Solutions* in Clive, Utah. Henceforth, in this risk discussion, Option 1 is considered as the bounding off-site case.

Individual receptors (MEIs) and collective populations were considered as receptors. Modeling of radiation exposure for routine and accident scenarios (all shipments), for MEIs, resulted in an estimated excess cancer risk (fatal and non-fatal) ranging from 1.58×10^{-5} to 7.21×10^{-3}; a collective population risk (analyzed for workers, on-link [persons sharing the road], and off-link [persons along the route]) resulted in an estimated excess cancer risk (fatal and non-fatal) ranging from 1.47×10^{-3} to 9.13×10^{-2}. Vehicular risk (risk associated with travel/vehicles) due to emissions and accidents, resulted in an estimate of 23.8 total incidents of illness, trauma, or death for the Off-site Disposal Alternative (majority of waste going to NNSS for disposal). If the majority of waste were transported to Energy*Solutions* for disposal, an estimated 6.65 incidents of illness, trauma, or death result. These results account for cumulative risk for transport and handling hundreds of thousands of waste shipments. On a per-shipment basis, both the estimated excess cancer risks due to exposure and estimated vehicular risk range in order of magnitude from 10^{-9} to 10^{-5}. The exact excess cancer risk value depends on the receptor being evaluated. Appendix F provides detailed analysis.

A comparative analysis was performed to assess risk of truck transport versus rail transport. The ORR to NNSS route was explored as an example. If all waste transported to NNSS via the ORR to Kingman, Arizona, to NNSS route were transported entirely by truck to NNSS, the overall (routine and accident) MEI and collective population risks due to radiation exposure would increase by a factor of about 10. Vehicle-related risk of fatalities (from emissions and accidents) increases approximately 5-fold going from rail to truck transport, and non-fatal accident risk increases by a factor of more than 10. Details of the analysis are provided in Appendix F.

Duration of the Off-site Disposal Alternative: For the Off-site Disposal Alternative, waste disposal operations are estimated to begin in FY 2022 and continue through FY 2043, a duration of approximately 22 years.

7.2.3.5 Reduction of Contaminant Toxicity, Mobility, or Volume by Treatment (Off-site)

Although the Off-site Disposal Alternative does not directly establish waste treatment requirements, some waste streams would be treated as needed to meet WAC before shipment and/or at the receiving facility. Waste treatment prior to shipment would remain the responsibility of the waste generator and would reduce the toxicity, mobility, and/or volume of waste, depending on the treatment applied. In the case of

LLW/RCRA waste shipped to Energy*Solutions* or WCS, the facilities have waste treatment capabilities and their WAC allow for receipt of untreated waste. It is assumed for the Off-site Disposal Alternative that the Energy*Solutions* or WCS receiving facilities would provide treatment of the waste prior to disposal to reduce the potential for contaminant mobility (although it is not included in the cost estimate). Transportation and disposal actions considered in this alternative would have no effect on toxicity or mobility through treatment.

Option 1 of the Off-site Disposal Alternative provides volume reduction of waste, which results in fewer transportation shipments to the off-site location in that Option (NNSS) resulting in transportation risk reduction. The volume reduction capacity achieved compared with the off-site capacity is inconsequential, that is, it would not likely have an effect on the size of that facility.

7.2.3.6 Implementability (Off-site)

This alternative is implementable. Off-site disposal would entail meeting administrative and technical requirements to coordinate the transportation and off-site disposal of waste and the continued availability of off-site disposal capacity. Implementation of this alternative would require compliance with state and federal regulations; compliance with licensing, permitting, and DOE administrative requirements.

Administrative Feasibility

The most uncertain administrative matter in the Off-site Disposal Alternative is the location of a transloading station where waste from generators would be transferred from trucks to rail. While an existing transloading station is currently available at the ETTP site and is currently located on DOE property with on-site travel (non-public road access), the future of ETTP is an industrial park, placing it in public commerce. Therefore, trucking waste from Y-12 or ORNL to ETTP would, in the future, require travel on public roads or could require building a rail spur and transloading facility within DOE property at some location convenient to ORNL and Y-12. This is a significant uncertainty that at this time is only accounted for in the Off-site Disposal Alternative contingency.

Review of state and federal regulations (addressed in Section 7.2.3.2 and Appendix G) indicates that there are no provisions that would prohibit shipment of waste derived from ORR sites to the receiving transloading and disposal facilities. These facilities are appropriately licensed or permitted and would be qualified prior to shipment per 40 CFR 300.440. Administrative and substantive regulatory requirements for handling and disposing of waste would be met through compliance with the facilities' permit requirements. Shipment of waste from ORR remedial sites would require an exemption from the DOE O 435.1 preference for on-site disposal. Similar exemptions have been routinely approved since DOE began using commercial disposal capacity in 1992. Shipment of waste from ORR would also have to take into consideration the prohibition of transporting radioactive waste through the Las Vegas Metropolitan Area, Callaghan-Tillman Bridge (Hoover Dam bypass), and North Las Vegas.

Agreements between and among states for the shipment and disposal of waste involve the issue of state equity, that is, the balance of benefits associated with activities that generate waste and the burden of resulting life-cycle waste management. The regulatory and administrative viability of off-site waste transportation and disposal is indicated by past and current operations. Previous ORR shipments to Energy*Solutions* and NNSS demonstrate that sustained waste shipment to these facilities is feasible. The states of Utah and Nevada have historically agreed to the transport and disposal of DOE wastes. Therefore, it is likely that these states would not object to continued operations. The administrative feasibility of this alternative could be challenged by future changes in the states' acceptance of waste transport and disposal. Additionally, those states that waste would be required to travel through to access the disposal facilities could challenge the pass-through of waste along public highways and roads.

Another consideration is the ability of off-site facilities to continue to receive waste in the event of an upset such as happened at WIPP in New Mexico. Operations and waste receiving has been halted at WIPP due to an accident occurrence. It is feasible that any disposal facility might undergo a similar incident resulting in the cessation of waste shipments for an undetermined length of time. It is currently projected that the WIPP shutdown could be longer than three to four years.

Wastes that exceed the off-site disposal facilities' WAC would require compliant storage pending the availability of treatment technologies or disposal options. For waste generated for which no treatment or disposal options could be identified, extended or indefinite waste storage could result in DOE being out of compliance with parameters for the treatment and storage of hazardous or radioactive materials established in Section 105 of the Federal Facility Compliance Act of 1992 and the ORR mixed waste Site Treatment Plan (EPA 1992, TDEC 2012).

Technical Feasibility

The technical feasibility of the Off-site Disposal Alternative depends directly on the implementability of waste transportation, disposal, and supporting activities. Technical feasibility indirectly depends on the implementability of treatment, storage, and other waste generator activities. The implementability of the technologies currently available for these components are proven and reliable for most waste projected to be generated at ORR, resulting in a low degree of uncertainty for the implementation of this alternative. It is expected that this alternative could be implemented without schedule delays resulting from technical complications. A technical uncertainty relative to this alternative is the availability of treatment and disposal options for waste exceeding the off-site facilities' WAC. However, as discussed in Chapter 2, the volume of waste generated with no currently defined path for disposal is anticipated to be small.

Future remedial actions at the receiving facilities should not be required because of waste treatment and the high level of isolation provided by the engineered facilities. Only limited additional actions would be possible, but difficult to implement, because of the relative permanence and massive nature of the disposal facilities. Additional actions would be warranted only if major deviations from expected performance of the disposal facilities occurred. Site conditions are well known at the receiving facilities and potential migration pathways are monitored to detect any contaminant releases and evaluate the effectiveness of waste confinement.

Services and materials required for waste transportation, treatment, storage, and disposal for implementation of the Off-site Disposal Alternative, would be readily available. Rail and truck transportation have been used to ship ORR waste in the past. Waste management facilities and services are available at ORR, including the administrative infrastructure to support comprehensive waste handling and storage operations.

The Energy*Solutions*, WCS, and NNSS facilities are permitted to treat and dispose of most waste types, forms, and quantities expected to be generated by the remediation of ORR, and both facilities currently accept comparable waste. Waste disposal services would be required for approximately 22 years at both Energy*Solutions* and NNSS facilities; WCS does not currently have capacity to receive a large portion of the projected waste volume so it is considered only for receipt of mixed waste. Although considered minimal, some uncertainty exists about whether the services currently provided by Energy*Solutions* (a commercial, non-DOE facility), and, to a lesser extent, by NNSS would be available for the duration of this alternative. Disposal capability would be assessed throughout the implementation of the alternative to determine the viability of continued cost-effective, reliable, and safe off-site waste disposal.

7.2.3.7 Cost (Off-site)

Estimated total project costs for the Off-site Disposal Alternative Options are given in Table 7-4. The cost estimates are based on the estimating methodology described in Section 7.1.7 and the technical scope and assumptions described in Chapter 6. A 27% contingency has been assumed, and is included in these estimates. Details are provided in Appendix I.

Table 7-4. Summary of Off-site Disposal Alternative (Options 1 and 2) Costs

Option 1 Cost Elements	Volume (yd^3)	Cost (FY 2012 dollars)	
		NNSS	Energy*Solutions* or WCS[1]
Classified Waste – Debris with 25% uncertainty	40,233	$58,902,061	NA
LLW or LLW/TSCA – Debris	1,300,858	$885,147,067	NA
LLW or LLW/TSCA – Soil	607,468	$455,696,406	
Project Management and Oversight	$36,043,638		
Subtotal (FY 2012 $)	$1,435,789,173		
Subtract the net cost avoided by implementing volume reduction for Option 1 only (see Appendix B)	– $80,501,000		
Revised Subtotal (FY 2012 $)	**$1,355,288,173**		
Contingency (12% Scope, 15% Bid) 27%	$365,927,807		
Total with Contingency (FY 2012 $)	**$1,721,215,979**		
Total with Contingency (FY 2016$)	**1,799,014,941**		
Escalated Cost with Contingency	**$2,650,519,526**		
Present Worth with Contingency (FY 2016 $)	**$1,494,358,468**		
Present Worth Average Annual Cost (22 year duration) (FY 2016 $)	**$67.9M**		
Option 2 Cost Elements			
Classified Waste – Debris with 25% uncertainty	40,233	$58,902,061	NA
LLW or LLW/TSCA – Debris	1,300,858	NA	$873,785,788
LLW or LLW/TSCA – Soil	607,468		$217,798,884
Project Management and Oversight	$29,812,168		
Subtotal (FY 2012 $)	**$1,180,298,901**		
Contingency (12% Scope, 15% Bid) 27%	$318,680,703		
Total with Contingency (FY 2012 $)	**$1,498,979,605**		
Total with Contingency (FY 2016 $)	**$1,566,733,483**		
Escalated Cost with Contingency	**$2,273,455,268**		
Present Worth with Contingency (FY 2016 $)	**$1,315,127,421**		
Present Worth Average Annual Cost (22 year duration) (FY 2016 $)	**$59.8M**		

[1] WCS destination only for mixed, mercury-contaminated debris. No costs for treatment are included.

For Option 2, the lowest priced option, the estimated total project cost of $1,315.1M in Present Worth 2016 dollars correlates to an estimated cost of $675 per unit volume of as-generated waste in 2016 dollars ($1,315.1M/1.95 M yd^3 as-generated waste[18] = $675 per yd^3 as-generated waste).

Oversize shipments (e.g., as in the case of equipment) are not part of the estimate, although there will be disposal of oversized equipment, which will not only incur surcharges for disposal but also cost more to load and transport. Rail transportation, which is approximately 11% less expensive than truck transport, is assumed for all shipments (with the exception of classified waste shipments to NNSS). Risks to off-site disposal, if realized, are significant and could be costly. A summary of risks is provided in Appendix I.

Appendix I provides a detailed description of the total Off-site Disposal Alternative costs for Options 1 and 2, and assumptions.

7.2.3.8 NEPA Considerations (Off-site)

Socioeconomic impacts: The short-term socioeconomic impacts associated with waste handling, transportation, and disposal activities for the Off-site Disposal Alternative would be minimal. This alternative would require minimal additional manpower resources at ORR. No new local facilities would be constructed. Because the receiving facilities are already operating, the manpower required to support the facilities' infrastructure is already in place. The incremental increase of waste from ORR could increase short-term manpower needs at these facilities.

Potential short and long-term socioeconomic benefits could be realized from the release or reuse of land resulting from the remediation of ORR and associated CERCLA sites. There would be no direct long-term socioeconomic impacts to ORR and the vicinity from activities associated with off-site transportation of waste under this alternative.

Land Use Impacts: Disposal of ORR waste at the receiving facilities would have no short or long-term land use impacts in the vicinity of those facilities. These facilities are already operating and are committed for the long-term to waste disposal and supporting operations. The incremental increase of waste to these facilities from ORR would not affect the existing long-term land use commitment and would have little or no effect on the workforce required for operation and maintenance. No changes in local population or nearby industrial or commercial operations would be expected.

Environmental Justice Impacts: No environmental justice impacts have been identified for this alternative. The vicinity of the Energy*Solutions* Clive, Utah, landfill is essentially uninhabited desert (no population within 5 miles) and is within a 100 square mile Hazardous Industrial Zone designated by the State of Utah. The NNSS disposal site is entirely contained within the DOE-controlled land, and there are no publically accessible areas within 15 miles.

Irreversible/Irretrievable Commitment of Resources Impacts: Implementation of the Off-site Disposal Alternative would require the irreversible and irretrievable commitment of land and geologic materials (e.g., gravel and borrow material) and non-renewable energy resources at any disposal site; however, land at the receiving facilities is already dedicated to waste disposal, and the addition of ORR waste would not alter that level of commitment. There would be no long-term commitment of land at ORR or the vicinity.

Waste packaging, handling, and transportation activities would require an irreversible and irretrievable commitment of fuel and other nonrenewable energy resources. Intermodal containers for classified waste

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[18] The as-generated waste volume includes 25% uncertainty (see Chapter 2 and Appendix A).

shipment to NNSS and LLW/RCRA waste shipment to Energy*Solutions* or WCS would be irretrievably committed; other containers would be reused.

Cumulative Impacts: Implementing the Off-site Disposal Alternative would not result in any significant cumulative impacts to the environment. Incremental impacts to air quality, traffic, and noise levels from waste transportation would not noticeably alter existing or future conditions. Any potential environmental effects from these factors, as well as the potential for accidental releases, would cease after the shipment and off-site disposal of all waste.

No direct long-term impacts to air quality, surface water, biota, wetlands, aquatic, or visual resources are anticipated at ORR or the vicinity from the implementation of this alternative. Residual risk would be reduced or eliminated at ORR and associated sites that are remediated. Removal of contamination and waste from these sites and disposal at an off-site facility could result in positive long-term environmental effects by reducing the potential for exposure to and migration of contaminants. Habitat quality and biodiversity may improve over time at these sites, depending on future land use decisions.

The potential for long-term cumulative impacts at the off-site disposal facilities from the presence of ORR wastes is expected to be minimal. These wastes would represent a relatively small portion of the total waste inventory, and the receiving facilities are designed, licensed or permitted, monitored, and maintained to ensure reliable waste containment and minimize long-term environmental effects.

7.2.4 Hybrid Disposal Alternative Analysis

The Hybrid Disposal Alternative involves building one small on-site disposal facility (proposed location Site 6b, which is the smaller of the two sites in the Dual Site Option of the On-site Disposal Alternative) and transporting and disposing of wastes that exceed the on-site capacity to licensed or permitted off-site disposal facilities. A detailed description of the Hybrid Disposal Alternative is provided in Section 6.4. This alternative is a combination of the previously discussed On-site and Off-site Disposal Alternatives, with one small distinction – the inclusion of mechanical VR in the on-site portion of the alternative. As a combination of the two alternatives just reviewed in Sections 7.2.2 (see all information in that section regarding Site 6b) and 7.2.3, this review will be rather brief.

7.2.4.1 Overall Protection of Human Health and the Environment (Hybrid)

The on-site portion of the alternative would meet risk-based RAOs and protect human health and the environment by consolidating a portion of future generated CERCLA waste exceeding the capacity of the existing EMWMF from the cleanup of ORR and associated sites into an engineered waste disposal facility, isolating the wastes from the environment. Additional protection would be provided indirectly by treatment of waste to meet the EMDF WAC. Prior to placement in the EMDF, wastes would be evaluated for compliance with the facility WAC; placement of that waste would result in an overall net reduction of risks associated with environmental contamination at the ORR and associated sites. In implementing mechanical VR at the on-site facility, more risk is presented to the workers through double-handling of waste and operation of equipment; however, reliable protective measures would be in place.

The off-site portion of the alternative would protect human health and the environment by removing a portion of wastes generated at ORR CERCLA sites, transporting them off-site, and isolating them from the environment by disposal in engineered facilities. Implementation of this portion of the alternative would prevent access to contaminated media and reduce the overall potential for releases from multiple sites on the ORR. Remediation of ORR and associated sites could result in human health or environmental benefits, depending on the eventual land use of these sites.

As described in previous On-site and Off-site Disposal Alternative sections, WAC at the facilities would control receipt of waste, to maintain the human health and environmental risks at acceptable levels, and ALARA procedures would be in place.

7.2.4.2 Compliance with ARARs (Hybrid)

Both the on-site and off-site portions of the alternative would comply with chemical-, location-, and action-specific ARARs and pertinent TBC guidance. Essentially all ARARs tables in Appendix G, for both on-site and off-site alternatives, would be used to implement the Hybrid Disposal Alternative. ARAR discussions for the on-site (Site 6b in Section 7.2.2.2) and off-site (Section 7.2.3.2) alternatives are applicable to the Hybrid Disposal Alternative.

7.2.4.3 Long-term Effectiveness and Permanence (Hybrid)

For the Hybrid Disposal Alternative, the long-term period is considered to begin when all candidate waste has been disposed of or stored on- or off-site, and the EMDF has been closed. Conclusion of this alternative is projected to occur in FY 2043. This alternative would result in residual risk at the ORR presented by the permanent disposal of waste in the closed landfill, which would have a lower total volume of waste and thus lower residual risk than other on-site alternative Site Options. Remaining discussions of long-term effectiveness and permanence for the on-site (Site 6b in Section 7.2.2.3) and off-site (Section 7.2.3.3) alternatives are applicable to the Hybrid Disposal Alternative.

7.2.4.4 Short-term Effectiveness (Hybrid)

For the Hybrid Disposal Alternative, the short-term period is considered to include pre-construction investigations, construction, operation, and closure of EMDF as well as the duration for which waste is shipped off-site following closure of the on-site facility. Operation of the on-site EMDF is expected to continue approximately 12 years through FY 2034 with closure activities completed in FY 2037 and post-closure activities completed by FY 2043 (waste generation and disposal is assumed to occur during those 12 years, beginning in FY 2022 ending in FY 2034). While the facility is being closed, waste will continue to be disposed off-site, through completion of the OREM program, projected to occur in FY 2043.

The primary risks in this alternative are the transportation risks to individuals and the public in direct or indirect contact with the waste during transport of the waste for off-site disposal, which was evaluated based on guidance given in *A Resource Handbook on DOE Transportation Risk Assessment* (DOE 2002). Assessment of the risk was completed using the industry-recognized RADTRAN and RISKIND models. A detailed discussion of the calculations and results is provided in Appendix F.

Individual receptors (MEIs) and collective populations were considered as receptors. Modeling of radiation exposure for routine and accident scenarios (all shipments), for MEIs on-site or off-site, resulted in an estimated excess cancer risk (fatal and non-fatal) ranging from 3.06×10^{-9} to 7.21×10^{-3}; a collective population risk (analyzed for workers, on-link [persons sharing the road], and off-link [persons along the route]) resulted in an estimated excess cancer risk (fatal and non-fatal) ranging from 1.60×10^{-13} to 9.13×10^{-2}. Vehicular risk (risk associated with travel/vehicles) due to emissions and accidents, resulted in an estimate of 2.8 total incidents of illness, trauma, or death for the Hybrid Disposal Alternative. These results account for cumulative risk for transport and handling hundreds of thousands of waste shipments. On a per-shipment basis, both the estimated excess cancer risks due to exposure and estimated vehicular risk range in order of magnitude from 10^{-13} to 10^{-5}. The exact excess cancer risk value depends on the receptor being evaluated. Appendix F provides detailed analysis.

Remaining discussions of short-term effectiveness apply for the on-site (Site 6b in Section 7.2.2.4) and off-site (Section 7.2.3.4) alternatives are applicable to the Hybrid Disposal Alternative.

7.2.4.5 Reduction of Contaminant Toxicity, Mobility, or Volume by Treatment (Hybrid)

Reductions of volume by treatment are associated with the Hybrid Alternative. The Hybrid Disposal Alternative provides an estimated 144,000 yd^3 of additional on-site capacity through mechanical VR (17% additional capacity) and provides a cost savings of approximately $32.3 M in avoided off-site transportation and disposal costs. However, there may be some measure of increased mobility of contaminants due to the concrete crushing involved in mechanical VR.

Although the off-site portion of the alternative does not directly establish waste treatment requirements, wastes would be treated as needed to meet WAC before shipment and/or at the receiving facility. Waste treatment prior to shipment would remain the responsibility of the waste generator and might reduce the toxicity, mobility, and/or volume of waste, depending on the treatment applied. In the case of LLW/RCRA waste shipped to Energy*Solutions* or WCS*,* the facilities have waste treatment capabilities and their WAC allow for receipt of untreated waste. It is assumed for the off-site portion of the alternative, that the Energy*Solutions* or WCS receiving facilities could provide treatment of the waste prior to disposal to reduce the potential for contaminant mobility (although it is not included in the cost estimate).

7.2.4.6 Implementability (Hybrid)

Refer to the implementability sections for both the On-site Disposal Alternative and Off-site Disposal Alternative for the Hybrid Disposal Alternative discussion, as it is fully a combination of both. In addition to those discussions, implementability of VR must be considered. VR is a technically known and frequently used processing step. Considerations for aerosolizing contamination must be made; high efficiency particulate air filtration is therefore included in the facility concept. Additional air monitoring would be required. Provisions for secondary waste generation must be made. All concepts are technically feasible. Administrative requirements are the same as those identified in the on- and off-site alternatives.

7.2.4.7 Cost (Hybrid)

Estimated total project costs for the Hybrid Disposal Alternative is given in Table 7-5. As a combination of costs estimated for on-site and off-site disposal, elements of both portions are given.

For this alternative, the estimated total project cost of $1,144M in Present Worth 2016 dollars correlates to an estimated cost of $587 per unit volume of as-generated waste Present Worth ($1,144M/1.95 M yd^3 as-generated waste[19] = $587 per yd^3 as-generated waste).

7.2.4.8 NEPA Considerations (Hybrid)

NEPA considerations are a combination of those discussed for on-site (specifically those addressing Site 6b) and off-site alternatives.

[19] The as-generated waste volume includes 25% uncertainty (see Chapter 2 and Appendix A).

Table 7-5. Hybrid Disposal Alternative Estimated Cost

	Cost Element	Year(s) Implemented	Site 6b [build to 0.85 M yd^3]	
			Cost (FY 2012 \$)	Total Cost (FY 2012 \$)
ON-SITE PORTION	**CAPITAL COSTS**			
	Cells 1 through 5 Construction:			
	Engineering	FY17 – FY22	\$18,643,504	\$124.3M
	Site Development		\$6,597,964	
	Support Facilities		\$17,671,328	
	Construction of Cells		\$81,387,512	
	Final cap:			
	Engineering	FY35 – FY37	\$2,046,565	\$41.1M
	Quality Assurance		\$4,616,887	
	Construction of Final Cap		\$34,470,890	
	Total Capital Cost (FY 2012 \$)		**\$ 165.4M**	
	OPERATIONS COSTS			
	Base Operations	FY22 – FY34	\$145,200,487	\$164.3M
	Leachate System Operations		\$17,184,165	
	Security Operations		\$1,928,808	
	OTHER COSTS			
	Pre-Construction Costs (e.g., Characterization)	FY12 – FY17	\$10,037,036	\$33.5M
	Post-Closure Care	FY35 – FY43	\$19,795,330	
	Support Structure Demolition/Removal	FY43	\$3,680,000	
	Subtotal (Capital, Operations, Other)	FY12- FY43 32 Years Total	**\$363.3M**	
	Contingency (22% Capital, 5% Operations)		**\$43.1M**	
	Total (FY 2012 \$) Life Cycle Cost		**\$406.4M**	
	PRESENT WORTH (FY16 \$)		**\$346.5M**	
OFF-SITE PORTION	**Off-site Portion**		**Off-site Destination**	
			NNSS	**Energy*Solutions***
	Classified Waste – Debris (all with 25% uncertainty)	FY22-FY43	\$28,063,712	
	LLW or LLW/TSCA/RCRA – Debris			\$471,969,144
	LLW or LLW/TSCA/RCRA – Soil			\$194,771,322
	Project Management and Oversight		\$17,277,785	
	SUBTOTAL (FY 2012 \$)		**\$712M**	
	CONTINGENCY (12% Scope, 15% Bid) 27%		**\$192M**	
	TOTAL with CONTINGENCY (FY 2012 \$)		**\$904M**	
	TOTAL with CONTINGENCY (FY 2016 \$)		**\$945M**	
	PRESENT WORTH (FY 2016 \$)		**\$798M**	
HYBRID DISPOSAL	**TOTAL with CONTINGENCY (FY 2012 \$)**	FY22-FY43	**\$1,310M**	
	TOTAL with CONTINGENCY (FY 2016 \$)		**\$1,370M**	
	PRESENT WORTH (FY 2016 \$)		**\$1,144M**	

7.3 COMPARATIVE ANALYSIS OF ALTERNATIVES

This comparative analysis evaluates the relative ability of the four alternatives to accommodate disposal of future generated CERCLA waste with respect to the evaluation criteria described in Section 7.1 and RAOs described in Chapter 4. The purpose of the comparative analysis is to identify the advantages and disadvantages of each alternative relative to the others and to identify the trade-offs to be made in selecting the preferred alternative.

Table 7-6 summarizes the differences among the alternatives. The No Action Alternative may not be supportive of timely remediation of ORR sites due to lack of a coordinated disposal strategy and could result in actions that are less protective and/or more costly (as a whole) than either of the action alternatives due to each project meeting disposal requirements individually. The On-site Disposal Alternatives (any site) would be less costly than the Hybrid or Off-site Disposal Alternatives, but additional land area on the ORR would have to be permanently dedicated to waste disposal, resulting in impacts on future land use and the environment. The Off-site Disposal Alternative could isolate the wastes more effectively long term than the On-site Disposal Alternative (any site) due to the arid climate, but long-distance waste transportation in the short-term could result in more accidents, resulting in injuries or fatalities. Figure 7-3 illustrates the significant difference in vehicular risk for the alternatives, a short-term effectiveness criterion. The Hybrid Disposal Alternative, as a combination of on-site and off-site disposal, falls as expected, in-between the two extremes.

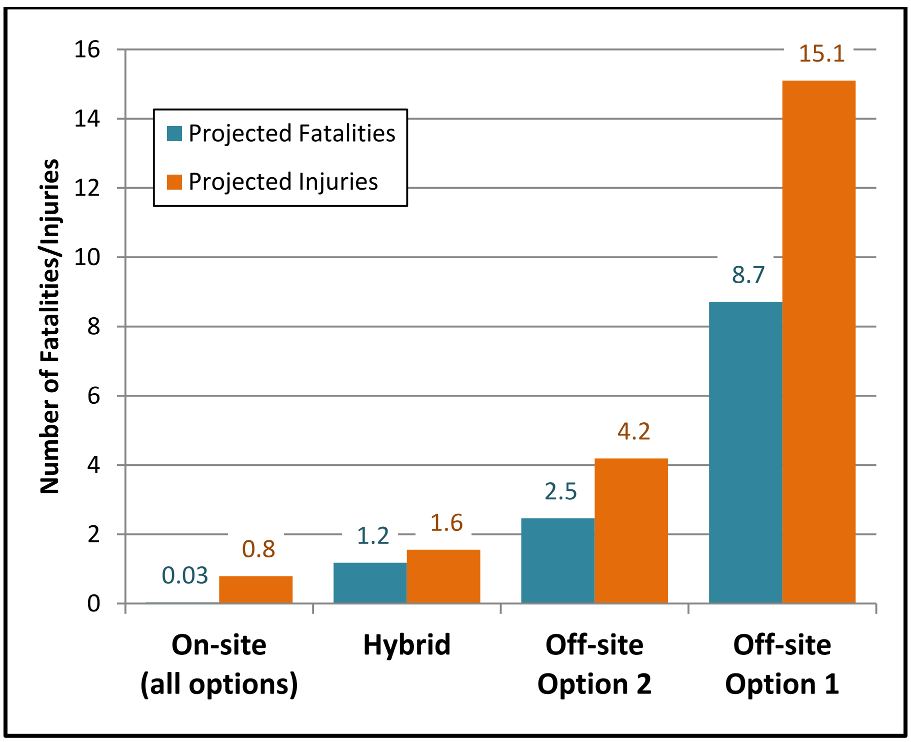

Figure 7-3. Comparison of Transportation Risk for On-site, Off-site, and Hybrid Disposal Alternatives

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Table 7-6. Comparative Analysis Summary for Disposal of ORR CERCLA Waste

<table>
<tr><th rowspan="2">Evaluation Criterion</th><th rowspan="2">No Action Alternative</th><th colspan="3">On-site Disposal Alternatives</th><th rowspan="2">Off-site Disposal Alternative (Options 1 and 2)</th><th rowspan="2">Hybrid Disposal Alternative</th></tr>
<tr><th>EBCV Site Alternative</th><th>WBCV Site Alternative</th><th>Dual Site (Sites 7a/6b) Alternative</th></tr>
<tr><td rowspan="2">Overall protection of human health and the environment</td><td rowspan="2">• Provides no action to collectively dispose of waste from multiple projects thus increasing chance of storage and/or management of waste in place and increasing short-term and long-term risk.
• Very likely that individual projects will ship waste individually using trucks, thus posing more risk to human health in the short-term.</td><td colspan="3">• Would meet all RAOs.
• Protective because waste would be disposed in a landfill designed for long-term containment in site-specific conditions. More protective in the short term because of decreased transportation risks but slightly less protective in long-term because wastes remain on the ORR.</td><td rowspan="2">• Would meet all RAOs.
• Protective because waste would be disposed in a landfill designed for long-term containment in site-specific conditions. More protective than the On-site or Hybrid Disposal Alternatives in preventing releases on the ORR because waste is permanently removed. Less protective in the short term because of increased transportation risks.</td><td rowspan="2">• Would meet all RAOs.
• Some of the waste (~36%) remains on the ORR, requiring permanent commitment of 50 acres of land.
• Protective because waste would be disposed in a landfill designed for long-term containment in site-specific conditions. There are increased short-term risks associated with transporting the waste to the off-site facility and there are slightly increased long-term risks associated with leaving some of the waste on the ORR.</td></tr>
<tr><td>• Much of the waste remains on the ORR, requiring permanent commitment of 70 acres of land. (If five cells only, 62 acres)</td><td>• Much of the waste remains on the ORR, requiring permanent commitment of 70 acres of land. (If five cells only, 58 acres)</td><td>• Much of the waste remains on the ORR, requiring permanent commitment of 109 acres of land.</td></tr>
<tr><td>Compliance with ARARs</td><td>• No action; therefore, no ARARs apply. ARARs for remedial actions at individual sites are specified in separate CERCLA documents.</td><td colspan="3">• Would comply with all chemical-, location-, and action-specific ARARs.</td><td>• Would comply with all chemical-, location-, and action-specific ARARs.</td><td>• Would comply with all chemical-, location-, and action-specific ARARs.</td></tr>
<tr><td rowspan="2">Long-term effectiveness and permanence</td><td rowspan="2">• If all waste from the projects is disposed appropriately, the long-term effectiveness may be comparable to other alternatives. However, with each project making a waste management decision, decisions to leave more contamination behind or to inappropriately dispose of the waste are possible, decreasing the long-term effectiveness of no action.</td><td colspan="3">• Provides long-term effective and permanent waste disposal because of landfill design and use of risk-based WAC. Potential non-acute residual hazards may be greater than for off-site disposal because of higher regional population, wetter climatic conditions, and shallower depth to ground water. However, determination of waste limits, land use controls, and monitoring should mitigate this risk.
• Operational and post-closure controls are expected to be equivalent at on- and off-site facilities.
• Environmental impacts may be partially offset by the more aggressive cleanup and release of individual ORR remediation-sites because there is a cost-effective waste management option.</td><td rowspan="2">• Provides long-term effective and permanent waste disposal for waste meeting the facility WAC. Land use at EnergySolutions and NNSS is already dedicated to waste disposal. ORR waste volume would represent a relatively small portion of the total permitted waste volume available at off-site facilities. The off-site facility locations in arid environments reduce the likelihood of contaminant migration, and fewer receptors exist in the vicinity of EnergySolutions and NNSS than near the ORR.
• Operational and post-closure controls are expected to be equivalent at on- and off-site facilities.
• A more expensive waste disposal option may result in less aggressive future cleanup decisions.</td><td rowspan="2">• Provides long-term effective and permanent waste disposal on-site because of landfill design and use of risk-based WAC. It also provides long-term effective and permanent waste disposal for waste meeting the off-site facility WAC.
• Potential non-acute residual hazards may be slightly greater for the waste disposed on-site than for that disposed off-site because of higher regional population, wetter climatic conditions, and shallower depth to ground water. However, land use controls and monitoring at the on-site disposal location should mitigate this risk.
• The off-site facility locations in arid environments reduce the likelihood of contaminant migration, and fewer receptors exist in the vicinity of EnergySolutions and NNSS than near the ORR.
• Operational and post-closure controls are expected to be equivalent at on- and off-site facilities.
• No notable environmental impacts are expected from using Site 6b for an on-site disposal facility.
• A more expensive waste disposal option may result in less aggressive future cleanup decision.</td></tr>
<tr><td>• Environmental impacts and permanent loss of wetlands (1.6 acres) would result from siting the EMDF at EBCV.</td><td>• Environmental impacts and permanent loss of forested habitat and wetlands (2.5 acres) would result from siting the EMDF at WBCV. The loss of ecological habitat is greatest at this site.</td><td>• Environmental impacts and permanent loss of forest habitat and wetlands (5.8 acres) [a] would result from siting the EMDF at two sites; however, there would be no notable loss of habitat at Site 6b as it has been used as a borrow area.</td></tr>
<tr><td rowspan="2">Short-term effectiveness</td><td rowspan="2">• Lack of a coordinated effort to dispose of CERCLA waste would likely result in much more waste being transported by trucks to off-site facilities. This greatly increases short-term transportation risk in the public sector.</td><td colspan="3">• Some adverse environmental effects would result from construction of the EMDF (wetland destruction) but would be controlled or mitigated per regulatory requirements and engineering practice. Mitigation measures are reliable.
• The On-site Disposal Alternatives are most protective of the public in the short term because of much lower transportation risks, regardless of the site location.</td><td rowspan="2">• No notable environmental effects would occur at the existing off-site facilities from increased ORR waste disposal.
• Transportation risks are significantly greater for the public than for the On-site Disposal Alternatives. Up to 6.7 injuries/fatalities from transportation accidents may occur under Option 2 and up to 23.8 under Option 1.</td><td rowspan="2">• Adverse environmental effects during construction are much lower than for other on-site facility options if Site 6b is used because it was used as a borrow area previously.
• Transportation risks to the public and workers are greater than on-site facility alternatives, but less than those encountered for the Off-site Disposal Alternative. Up to 2.8 injuries/fatalities from transportation accidents may occur.</td></tr>
<tr><td>• Wetland area to be mitigated is estimated as 1.6 acres.</td><td>• Wetland area to be mitigated is estimated as 2.5 acres.</td><td>• Wetland area to be mitigated is estimated as 5.8 acres.[a]</td></tr>
</table>

Table 7-6. Comparative Analysis Summary for Disposal of ORR CERCLA Waste (Continued)

<table>
<tr><th rowspan="2">Evaluation Criterion</th><th rowspan="2">No Action Alternative</th><th colspan="3">On-site Disposal Alternatives</th><th rowspan="2">Off-site Disposal Alternative</th><th rowspan="2">Hybrid Disposal Alternative</th></tr>
<tr><th>EBCV Site Alternative</th><th>WBCV Site Alternative</th><th>Dual Site (Sites 7a/6b) Alternative</th></tr>
<tr><td>Reduction of toxicity, mobility, or volume through treatment</td><td>• Reductions of toxicity, mobility, or volume would be determined in individual CERCLA actions. If more wastes were managed in place because no coordinated disposal option is available, less reduction in toxicity or mobility may result.</td><td colspan="3">• Any ex situ treatment to meet the facility WAC would reduce toxicity, mobility, or volume.</td><td>• Any ex situ treatment to meet the disposal facility WAC would reduce toxicity, mobility, or volume.</td><td>• Any ex situ treatment to meet the facility WAC would reduce toxicity, mobility, or volume.
• A reduction in volume is achieved with VR facility in the on-site portion of the Alternative. However, some measure of increased mobility may occur.</td></tr>
<tr><td rowspan="2">Implementability</td><td rowspan="2">• No technical actions requiring implementation included.
• No collective administrative actions required.
• Individual project-level management of wastes will be significant and repetitive.</td><td colspan="3">• Implementation is technically feasible; landfill design and construction of the type presented in this conceptual design is commonly carried out.
• Administrative requirements are considered achievable as demonstrated by the existing on-site facility (EMWMF).
• Services and materials required for design, construction, and operation of the landfill are readily available, as are qualified personnel, specialists, and vendors. Construction would involve the use of standard construction equipment, trades, and materials; no new technology development is required.
• There is little risk of having no disposal outlet. Should there be a significant problem during operations, off-site disposal would remain a viable option.</td><td rowspan="2">• Administrative and technical requirements are implementable as demonstrated by the current off-site shipment effort from ORR.
• However, disposal of waste at commercial and DOE facilities relies on continued availability of off-site disposal capacity. Future changes in the states' acceptance of waste transport and disposal could challenge implementation of the alternative. Travel through multiple states could raise challenges.
• There is risk of having no disposal outlet should there be a significant transportation or disposal incident. Inability to ship or dispose off-site would leave ORR with no waste disposal option.</td><td rowspan="2">• Implementation of the on-site disposal portion is technically feasible; landfill design and construction of the type presented in this conceptual design is commonly carried out. Less reliance on underdrain systems and less construction on steeper slopes.
• Less new construction is required. The landfill is smaller and much of the existing infrastructure at EMWMF may be usable.
• Administrative requirements of the on-site disposal portion are considered achievable as demonstrated by the existing on-site facility (EMWMF).
• Services and materials required for design, construction, and operation of the on-site landfill are readily available, as are qualified personnel, specialists, and vendors. Construction would involve the use of standard construction equipment, trades, and materials; no new technology development is required.
• Administrative and technical requirements of the off-site disposal portion are implementable as demonstrated by the current off-site shipment effort from ORR.
• However, disposal of waste at commercial and DOE facilities relies on continued availability of off-site disposal capacity. Future changes in the states' acceptance of waste transport and disposal could challenge implementation of the alternative. Travel through multiple states could raise challenges.
• Once the smaller on-site landfill is filled, there is a risk of having no disposal outlet should there be a significant transportation or disposal incident. Inability to ship or dispose off-site would leave ORR with no waste disposal option.</td></tr>
<tr><td>• Slightly greater use of underdrain system may be required at this site as well as construction on steeper slopes.
• Considerable new construction is required, but some existing infrastructure may be usable, reducing infrastructure construction efforts over other on-site alternatives.</td><td>• Potentially less reliance on underdrain systems and less construction on steeper slopes.
• Considerable new construction is required, including all new support facilities.</td><td>• Potentially less reliance on underdrain systems and less construction on steeper slopes.
• Most new construction is required, through construction of two landfills.</td></tr>
<tr><td>Cost</td><td>• No direct cost; however, efficiencies of consolidation and economies of scale would not be realized.
• Individual projects' cost (cumulative) for disposal of waste would greatly exceed costs when compared to completing disposal under a central effort.</td><td>• Cost per yd3 of as-generated waste disposed is $279 (Present Worth 2016 dollars).</td><td>• Cost per yd3 of as-generated waste disposed is $286 (Present Worth 2016 dollars).</td><td>• Cost per yd3 of as-generated waste disposed is $347 (Present Worth 2016 dollars).</td><td>• Cost per yd3 of as-generated waste disposed is $675 (Present Worth 2016 dollars).</td><td>• Cost per yd3 of as-generated waste disposed is $587 (Present Worth 2016 dollars).</td></tr>
</table>

[a] If Site 7b were used 1.7 acres of wetland would be impacted (as noted throughout, Sites 7a and 7b are quite comparable, and if selected, a detailed screening of both sites would be necessary to decide between them).

7.3.1 Overall Protection of Human Health and the Environment

The No Action Alternative could be least protective if the lack of a coordinated disposal program resulted in an increased reliance on management of waste in place at CERCLA remediation sites, or if the pace of clean-up were slowed.

Selection of any of the action alternatives could encourage more waste removal at remediation sites. If the presence of on-site disposal capacity encouraged removal of waste from individual CERCLA sites, environmental benefits could result at those sites depending on eventual land use. The Off-site and Hybrid Disposal Alternatives would be more effective in preventing potential future releases on the ORR because most of the CERCLA waste (majority in the case of the Hybrid Disposal Alternative) would be disposed of in off-site permitted facilities.

On-site, Hybrid, and Off-site Disposal Alternatives would be protective of human health and the environment. The On-site Disposal Alternatives and on-site portion of the Hybrid Disposal Alternative would be protective primarily through design and construction to required specifications and compliance with the WAC established for a new on-site CERCLA waste disposal facility. The Off-site Disposal Alternative and off-site portion of the Hybrid Disposal Alternative would be protective through compliance with the WAC for each of the off-site existing permitted facilities.

Permanent land commitment for the On-site and Hybrid Disposal Alternatives include:

- Hybrid (Site 6b – 50 acres)
- WBCV (Site 14 – 71 acres; ~ 58 acres for 5 cell buildout)
- EBCV (Site 5 – 70 acres; ~62 acres for 5 cell buildout)
- Dual Site (Sites 7a/6b – 109 acres)

Waste removal would require local and long-distance transport of waste, treatment of some waste streams, and waste handling and placement at the disposal facilities. These intensive actions would increase the probability of normal industrial or transportation accidents. Because of the greater volumes of waste shipped over long distances, transportation risks are significantly higher for the Off-site Disposal Alternative, and still significant for the Hybrid Disposal Alternative compared to on-site disposal, although less so. (Refer back to Figure 7-3).

7.3.2 Compliance with ARARs

No ARARs or TBC guidance are directly associated with the No Action Alternative; however, lack of a coordinated disposal program may make it more difficult for CERCLA actions at individual remediation sites to comply with some regulatory requirements. The potential for increased interim waste storage exists under the No Action Alternative. ARARs would be developed for each site-specific CERCLA action. Hybrid and On- and Off-site Disposal Alternatives would support individual CERCLA actions and meet all ARARs.

Certain waste streams may not meet the WAC for either the on-site EMDF or existing off-site disposal facilities. This waste, expected to be a relatively small volume, would be stored at compliant facilities with sufficient engineering controls and oversight to minimize the potential for exposure or release. It is not considered in this analysis, as it is not a differentiating factor.

The On-site Disposal Alternative (all Sites) and the on-site portion of the Hybrid Disposal Alternative would be designed to meet all ARARs and TBC guidance. These include chemical-, location-, and action-specific ARARs targeting public and environmental protectiveness, location and siting requirements, design and construction requirements, monitoring requirements, and closure/post-closure requirements as summarized in Appendix G.

The Off-site Disposal Alternative would comply with all ARARs and TBC guidance, which are limited to requirements associated with transportation of waste. Compliance of the disposal facilities with their licenses and permits would be determined prior to transport in accordance with the CERCLA Off-site Rule.

7.3.3 Long-term Effectiveness and Permanence

Both on-site and off-site disposal would be effective and permanent in the long-term. The No Action Alternative would likely be less protective if more wastes were managed in place at individual CERCLA sites rather than being consolidated in an engineered landfill. The Off-site Disposal Alternative and off-site portion of the Hybrid Disposal Alternative rely on engineering and institutional controls to prevent inadvertent intrusion, including engineered barriers to intrusion and waste migration. Off-site disposal of waste at Energy*Solutions*, WCS, and NNSS in the long-term may be more reliable at preventing exposure than on-site disposal on the ORR, as they are located in arid environments that reduce the likelihood of contaminant migration or exposure via ground water or surface water pathways. Fewer receptors exist in the vicinity of Energy*Solutions*, WCS, and NNSS than on the ORR.

Institutional controls for all alternatives should be effective to the same degree, provided no great disruptive societal occurrences take place. Uncertainties, of course, are associated with the future condition of society in the long term.

For the On-site Disposal Alternative and the on-site portion of the Hybrid Disposal Alternative, preventing exposure to contaminants placed in EMDF over the long term depends on success of the facility's waste engineered containment features, individual site characteristics, characteristics of waste placed in EMDF, and institutional controls.

Engineered Containment Features. For the On-site Disposal Alternative Site Options and the Hybrid Disposal Alternative (on-site portion), engineered structures and site features control mobility of contaminants. Engineered structures include the cover, waste (stability of waste loading), liner/buffer systems, and underdrain systems.

The cover and liner control mobility to the same degree for all sites (there is no differentiation between design and construction of these structures at each site). The multilayer cover system would be designed to decrease the contact of water with waste, minimize erosion, accommodate settling and subsidence, and prevent burrowing animals and plant root systems from penetrating the cover system and reduce the likelihood of inadvertent intrusion by humans by increasing the difficulty of digging or drilling into the landfill. With proper design and installation of the landfill systems (underdrain, liner, and final cover) there is no reasonable expectation of failure of the natural components of these systems. Institutional controls would restrict access to the site and prohibit actions that could penetrate the cover and expose the waste. Barring extraordinary efforts to penetrate the cover, it should remain effective for hundreds to thousands of years.

Experience at the EMWMF has demonstrated the need for some measure of underdrain networks to lower and maintain the water table below each of the proposed site footprints. While the underdrain networks are necessary and effective in isolating wastes from the underlying saturated zone, they do provide avenues for localized and relatively rapid transport of contaminants in ground water that could be released below the footprint and discharge at underdrain outfall locations. At the same time, however, contaminants leaching from the waste into the underdrain networks are likely to commingle with uncontaminated ground water passing naturally below the footprint that also enters the underdrain system. While contaminant mobility may be locally enhanced in areas at and adjacent to the underdrain paths, toxicity may also be inadvertently reduced by commingling with uncontaminated ground water. Even at the proposed sites where underdrain networks are minimal, ground water contamination migrating from footprint areas is likely to migrate along dominant strike-parallel fracture pathways to adjacent NT stream valleys where contaminants may similarly commingle with uncontaminated surface water along and adjacent to the NT stream channels. The relative width of the site footprints with respect to geologic strike and the generally north-south orientations of the adjacent NT stream valleys combine with the layout of the underdrain networks to influence contaminant mobility below and adjacent to each site.

The extent of the underdrain networks vary among the proposed sites. Assuming some degree of greater mobility is associated with the areal extent of the underdrain, the Hybrid Site 6b has the least underdrain network area (27,000 ft^2) and the EBCV Site has the most area (297,000 ft^2), with the Dual Site 7a/6b Option (132,000 ft^2) and the WBCV Site (259,000 ft^2) of intermediate area.

While the cover remains in place, migration of contaminants into ground water and surface water is the only credible pathway for exposure. PreWAC analysis indicates that exposures would be acceptable at the hypothetical receptor location downgradient of the proposed EMDF EBCV site (see Appendix H). For sites that were not modeled, PreWAC would be expected to be similar, and would be calculated based on site-specific modeling. Distinctions between sites would result in slightly different PreWAC limits, but the RAO goals for the compliance period and imposed limits beyond the compliance period would ensure that PreWAC are protective.

Individual Site Characteristics. Each Site Option could contribute to the mobility of contaminants that are released to varying degrees depending on certain site characteristics. A comparison of site characteristics can best be made by separating them into three categories: (1) features that contribute to mobility but there is no differentiation between sites, (2) features that contribute to mobility and distinctions between sites exist, and (3) features that contribute to mobility but differentiation between sites is uncertain or unable to be ascertained.

Site features that contribute to mobility of contaminants, but for which no clear and substantial differentiation between the Options can be made, include the predominantly clastic geologic formations present in the facility footprints, potential for flooding/drainage issues, and stability of the site in terms of seismic conditions. All sites are located in BCV where there is little variation in these features from site to site.

Some site features are identified that could contribute to contaminant mobility, and distinctions between Site Options exist. Those include properties of the site that allow for attenuation of contaminants and increased travel times to surface water and karst features, which in turn allow for increased contaminant decay with time. These site features include variations in vadose zone thickness below the footprint, distance from waste to karst features of the Maynardville Limestone south of each site, and variations in the distance between waste and surface water features. Another site feature that could contribute to increased mobility is the size of upgradient drainage areas, which affect long-term infiltration, ground water recharge, and ground water underflow at the sites.

Fate and transport modeling completed for EBCV (Site 5) indicates that the majority of travel time associated with contaminant transport occurs in the vadose zone. Therefore, the greater the vadose zone thickness, the greater the opportunity for contaminant attenuation and decay. The vadose zone thickness varies among each of the proposed sites depending on the base elevations of the conceptual design and local constraints on the water table dictated largely by the elevations along the NT valleys where the water table is at or near those of the stream channels bordering the sites. The vadose zone thickness is also influenced by site topography and the local topographic relief at each site. Site 6b where the ground surface has been lowered extensively by excavations for soil borrow is probably the most severely limited in terms of an originally thin vadose zone below the site upon which the landfill would be constructed. Estimates at this time of the conceptual designs do not indicate much difference in vadose zones for the remaining sites (EBCV, WBCV, and Site 7a of the Dual Site Option). Table 7-1 reports the depth from the bottom of the waste, to the top of the high (or estimated high) ground water table for the four sites.

Accounting for the depth of the vadose zone in modeling for different sites will compensate for differences in vadose zone thickness, with the result being that the PreWAC will be altered. That is, for a site with a thinner vadose zone modeling inputs will be adjusted to reflect that, and the result would be a more stringent PreWAC. All sites will be demonstrated to be protective in meeting RAOs, the constraint(s) placed by various features affect PreWAC and thus limit waste inputs to the facility.

Some portion of contaminants released to ground water below the proposed sites will travel southward along fracture pathways within the predominantly clastic formations of the Conasauga Group (i.e – those between the Pumpkin Valley and Nolichucky) toward Bear Creek and the outcrop belt of the Maynardville Limestone. Karst conditions and relatively rapid ground water flow rates in the Maynardville, and commingling between surface water and ground water along Bear Creek, are fairly well documented in BCV. Thus the greater the distance between each site footprint and Bear Creek and the Maynardville/Nolichucky contact, the greater the opportunity for reducing the potential for enhanced mobility offered in the Maynardville karst, and increasing the opportunity for contaminant attenuation within the clastic formations north of the Maynardville. However, as noted above for the underdrains, mixing of ground water and surface water along Bear Creek poses the likelihood of inadvertent commingling of ground water contaminants with uncontaminated surface water. Among the proposed sites, EBCV (Site 5) is located farthest north of Bear Creek and the Maynardville at a distance approximately twice as far as each of the other three proposed sites (~1200 ft vs ~600 ft).

Variations exist among the proposed waste footprints and the nearest surface water features where future ground water contaminants may slowly discharge and commingle with surface waters. Ground water flow associated with existing streams, springs, seeps, and wetland areas within and along the margins of the footprints will be captured by the proposed underdrain networks, but remaining stream channels and other springs, seeps, and wetlands in undisturbed areas adjacent to the sites provide areas where ground water (and dissolved contaminants) may continue to slowly discharge. The greater the distances between the footprint areas and these surface water features the greater the opportunity for reducing contaminant mobility and increasing contaminant attenuation. The relationships among each of the sites and adjacent NT stream channels, spring, seeps, and wetlands outside of the footprints varies considerably. The EBCV Site is approximately twice (~1200 ft) as far from Bear Creek as are the other sites (~600 ft). NT streams are all approximately the same distance from the perimeter of landfill conceptual designs.

The relationships of areas that would remain undisturbed and available for infiltration and ground water recharge upslope and upgradient of each site also have the potential to affect contaminant mobility and contaminant attenuation. Although infiltration across the footprint areas will be greatly diminished after capping and closure, some degree of ground water underflow will remain at the sites. The post-construction configuration of the water table, adjustments to the local hydraulic gradients, and ground water underflow will be influenced by the extent of upgradient recharge areas and topographical relationships between those areas, the footprints, and the final configuration of the caps and upgradient diversion and trench drains. The position of the water table along the east and west margins of the sites will be dictated primarily by the water table along the undisturbed elevations of the NT stream channels. Among the proposed sites, EBCV, which is located in closest proximity to Pine Ridge has the least area remaining to influence recharge and underflow; Site 7a has the greatest area remaining, while Sites 6b and WBCV have upgradient areas between the two (See Table 7-1 and Figure 7-2).

Site features that might contribute to mobility, but are very uncertain or unable to be ascertained would include waste loading of contaminants in three dimensional (3D) space at each site and hydrogeological features such as the accurate 3D determination of interconnected transmissive fracture networks below and downgradient of the sites..

Long-term Effects. Long-term effects at the proposed EMDF sites would consist of impacts to biota and habitat, primarily by the loss of forest cover and stream and wetland impacts. As indicated in Tables 7-1 and 7-4, the Dual Site Option will affect the greatest wetland area (5.8 acres) [however, as noted throughout the document, Site 7a may be replaced by Site 7b and would lower the effected wetland area to 1.7 acres] followed by the WBCV Site (2.5 acres), and lastly the EBCV Site (1.6 acres). Forested habitat is most affected at the WBCV Site.

7.3.4 Short-term Effectiveness

Short-term effectiveness includes protection of the community and workers during remedial action, short-term environmental effects, and the duration of remedial activities. For purposes of this RI/FS, the short-term period lasts through closure of the EMDF/completion of cleanup on the ORR, but does not include the subsequent period of institutional controls or long-term S&M at on- or off-site facilities.

On-site disposal presents the greatest challenges to the Oak Ridge area during remediation. Construction and operation of EMDF at any proposed site would present more local risk and impact to human health and the environment than off-site disposal, which does not involve new construction. Off-site disposal would generate few local impacts other than possibly encouraging cleanup of individual sites, and only incremental and minor impacts at the receiving disposal facility. Off-site disposal would result in additional risk from long-distance transportation. The Hybrid Disposal Alternative entails much of the same short-term risk that is encountered in the On-site Disposal Alternative in terms of new construction. The operational period is 12 years compared to 22 years for the On-site Disposal Alternative. Off-site disposal under the Hybrid Disposal Alternative carries additional risk in terms of long-distance transportation over on-site disposal, but not to the degree that the Off-site Disposal Alternative does (see Figure 7-3).

Under all the alternatives evaluated, risks to workers and the community from actions at the remediation sites and disposal facilities would be controlled to acceptable levels through compliance with regulatory requirements and health and safety plans. These risks would be similar and would be comparable to risk for industrial operations. The No Action Alternative would present no specific short-term risks or benefits to the community or workers other than those associated with individual actions at individual sites and off-site disposal. Less-intensive remedial actions may be implemented at some remediation sites under the No Action Alternative. If so, the replacement of excavation, treatment, transport, and disposal actions with in situ containment or treatment options would reduce the likelihood of adverse short-term effects on the community and workers. For sites undergoing removal, short-term effectiveness would be equivalent under all alternatives. The level of activity and resulting probability of exposure to contamination or industrial accidents at waste generation sites, treatment facilities, and disposal facilities would be similar.

For the Hybrid, On-site, and Off-site Disposal Alternatives, the most significant risks to the public would result from waste transportation. Potential risks result from exposure to gamma radiation during routine (accident free) transportation, from exposure to radionuclides during accidents, and from physical trauma or illness associated with vehicular accidents and emissions, regardless of the waste being carried. Table 7-7 contains a summary of the calculated risks for the alternatives, for all shipments. As seen in the table, off-site transportation carries a much higher risk than on-site transportation, due to the public roads and railroads travelled and the long distances involved. On-site transport carries a considerably lower risk due to the short travel distances and the non-public routes that would be followed. Hybrid disposal is a combination, and risk is bounded by the on- and off-site risks. Figure 7-3 illustrated this significant human health risk difference between the off-site, hybrid, and on-site alternatives. A breakdown of the risks for the individual routes travelled, accident versus routine travel, and fatal/non-fatal statistics is provided in Appendix F.

Table 7-7. Comparison of Risk Factors for On-site and Off-site Disposal Alternatives, All Shipments

Receptor	On-site Disposal Alternative (All Site Options)		Off-site Disposal Alternative (Option 2)		Hybrid Disposal Alternative	
	Radiological Risk Range	Vehicle-related Risk (death/injury)	Radiological Risk Range	Vehicle-related Risk (Death/Injury)	Radiological Risk Range	Vehicle-related Risk (Death/Injury)
Maximum Exposed Individuals	NA	0.8	8.29×10^{-4} to 1.11×10^{-3}	23.8 (NNSS) 6.7 (ES)	1.58×10^{-5} to 7.89×10^{-4}	2.8
Collective Population	6.35×10^{-5} to 8.47×10^{-5}		6.23×10^{-2} to 9.13×10^{-2}		2.31×10^{-5} to 5.93×10^{-2}	

Short-term environmental effects would be least for the No Action Alternative, minimal for the Off-site Disposal Alternative, and greatest for the On-site Disposal Alternative (all sites). For the No Action Alternative, no specific environmental impacts other than those associated with individual actions would be expected. Environmental effects could result from a spill during transport and handling for the Off-site Disposal Alternative, but there is a low risk of a spill and only minor adverse effects are likely to result. Vehicles along the transportation corridor would cause an inconsequential increase in pollution and noise levels. The additional environmental effects at the receiving off-site disposal facilities would be negligible over and above those caused by current and continuing operation of the facilities.

Construction and operation of EMDF would cause local short-term environmental effects typically associated with a large construction project at all locations. Sensitive human receptors (e.g., residence, church, school) would not be impacted because of the proposed EMDF site distance from these receptors. Disturbance to terrestrial resources would be expected, with land use resulting in temporary losses of habitat; destruction of small, limited-range animals; and displacement of wildlife adjacent to the construction areas. Potentially sensitive forest and wetland areas at the proposed sites would be impacted. The most impact would be at the Dual Site Option (Sites 7a/6b) where 5.8 acres of wetland would be impacted and 82 acres of forested area (Site 6b is not considered to be impacted in the short-term as forested area there was cleared due to its use as a borrow area). If Site 7b were used as opposed to 7a (Site 7b is similar to Site 7a in most respects) only 1.7 acres of wetland would be impacted. Impacts at the WBCV Site would include 2.5 acres of wetland and 94 acres for development of the site. Impacts at the EBCV Site would include 1.6 acres of wetland and 71 acres for development (21 acres to be used for development are already impacted by existing EMWMF infrastructure). For the Hybrid Disposal Alternative, no significant impacts would be seen in the short term, as that site has already been cleared as a borrow area for EMWMF. No wetlands are present at Site 6b.

Other potential short-term effects from EMDF construction and operation include the probable slight degradation of surface waters by increased sediment and runoff to surrounding NTs. Aquatic resources, including the Tennessee dace, may be somewhat impacted in Bear Creek. Additional assessments of effects on protected and sensitive resources, if present, would be performed as necessary and mitigative measures would be identified and implemented in consultation with the appropriate state or federal agencies.

The duration of remedial activities for the No Action Alternative would depend on CERCLA actions selected for the individual remediation sites, but at much higher costs expected to be incurred by disposing of/storing wastes individually at the project level, it is very likely that No Action would greatly extend cleanup of the ORR. The duration of disposal activities for the Hybrid and On- and Off-site Disposal Alternatives would be similar based on generation schedules at the remediation sites described in Chapter 2 and Appendix A. There is a significant risk to the Off-site Disposal Alternative schedule, in that if annual programmatic funding is not increased to account for higher annual costs to dispose of waste (versus on-site disposal that has a significant capital cost, but very low annual cost compared to off-site), the ORR cleanup program would be extended by a significant number of years.

7.3.5 Reduction of Toxicity, Mobility, or Volume through Treatment

Although the disposal alternatives evaluated do not directly establish waste treatment requirements, wastes would be treated as needed to meet WAC either before shipment to an on-site or off-site facility, or at the off-site receiving facility (the Energy*Solutions* and WCS facilities have treatment capabilities). Waste treatment prior to shipment would remain the responsibility of the waste generator. Waste treatment by the generator or at the receiving facility could reduce the toxicity, mobility, and/or volume of waste, depending on the treatment applied. For the No Action Alternative, if more wastes are managed in place because of the lack of a coordinated disposal option, containment or in situ treatment technologies could be less effective in reducing toxicity or mobility than the ex situ treatment technologies that would be used for removal and disposal options.

There is no distinction between On-site Disposal Alternative Site Options in terms of reduction of volume. Hybrid and Off-site Disposal Alternatives (Option 1 only) include mechanical VR, which offers some measure of volume reduction compared to the On-site Disposal Alternative Site Options; however in so doing some increased mobility may result due to increased debris surface areas and reduction of soil used as fill within the landfill (which provides some attenuation of contaminants). There is no distinction between alternatives in terms of the degree to which mobility is irreversible.

The mechanical VR provided in the Off-site Disposal Alternative (Option 1) has a distinct advantage in terms of short-term effectiveness (transportation risk) and cost. In terms of reducing the volume permanently disposed at off-site facilities, it likely would not ultimately affect the size of the off-site facility itself to any great degree, as a percentage of the capacity of the facility. The Hybrid Disposal Alternative provides an estimated 144,000 yd^3 of additional on-site capacity through mechanical VR (17% additional capacity) and provides a cost savings of approximately $32.3 M in avoided off-site transportation and disposal costs.

7.3.6 Implementability

All alternatives considered are implementable. All are administratively feasible, although not without substantial effort. Both on-and off-site disposal are technically feasible, although the on-site component presents greater technical challenges. Services and materials for all alternatives considered are readily available.

Development of an on-site EMDF in either the On-site Disposal Alternative or Hybrid Disposal Alternative would require cooperation with and support from federal and state regulatory agencies and must include public involvement. Administrative feasibility of disposal activities for the No Action Alternative would be considered under CERCLA decisions for individual sites. For the Off-site Disposal Alternative and off-site portion of the Hybrid Disposal Alternative, existing agreements with state agencies for interstate shipment of waste, and with the states of Utah and Nevada for disposal of wastes are likely to continue. A DOE exemption from the requirement to dispose of LLW at the generation site or at another DOE site could be readily obtained.

For all action Alternatives, wastes that do not meet the WAC for any disposal facility would be stored in compliant facilities that would meet the administrative requirements for storage.

Technical implementability of waste disposal for the No Action Alternative would be considered under CERCLA decisions for individual sites. The technical components of the Hybrid, On-, and Off-site Disposal Alternatives would be straightforward to implement using existing and readily available technologies. Once the wastes are disposed of on- or off-site, the need for additional actions in the future would be extremely unlikely. The main difference between on- and off-site disposal is the requirement for construction of the EMDF (on-site and hybrid) versus the long-distance transport requirements for off-site disposal. Both are readily implementable, but construction of the EMDF is more complex. The Hybrid Disposal Alternative would introduce some complexity in terms of when to implement off-site disposal versus use on-site disposal, and how that would be coordinated with generators (e.g., what should go off-site, versus stay on-site). Sequencing of waste soils to be used as fill could be an issue (for example, most soil waste is projected to be generated in out years. But if an on-site facility is no longer available, soil will have to be disposed of off-site.)

Services and materials needed for construction and operation of the EMDF or for shipment and disposal of waste are readily available. Disposal capacity is available for waste that would not meet on-site facility WAC under the Hybrid and On-site Disposal Alternatives and would require off-site disposal, and storage capacity would be available for waste not meeting any facility's WAC. Disposal capacity is currently available at the representative off-site disposal facilities and is anticipated to continue to be available. The availability of services and materials does not apply to the No Action Alternative. Services and materials needed for waste disposal would be determined in CERCLA actions at individual sites without the benefit of a comprehensive strategy.

Because of state equity issues, it is possible that public concerns regarding shipments outside of Tennessee could affect the availability of off-site disposal facilities. Uncertainty about continued availability of the off-site disposal capacity at representative facilities, NNSS (a DOE facility) and Energy*Solutions* (a non-DOE, commercial facility) presents a risk to the program, especially when the current shut-down situation of the WIPP disposal facility is considered. Given the 30 years of anticipated CERCLA waste generation, the On-site Disposal Alternative provides a much greater level of certainty than the Hybrid or Off-site Disposal Alternatives that long-term disposal capacity would be available at the time wastes are generated.

7.3.7 Cost

Specific disposal costs cannot be estimated for the No Action Alternative. Disposal costs would depend on the individual actions taken at the CERCLA remediation sites. If lack of a coordinated disposal program under the No Action Alternative encourages management of wastes in place at individual CERCLA sites, rather than removal and disposal, disposal costs would be avoided. If on- or off-site disposal is selected, the removal, ex situ treatment, and local transport portion of alternatives requiring disposal may be more costly than in situ remedial actions at a remediation site. For those CERCLA sites that select removal and disposal without the benefit of a coordinated ORR-wide disposal program, transport costs and disposal fees could be much higher due to procuring disposal services on a project basis and lack of economies of scale.

The projected cost for the Off-site Disposal Alternative is approximately two times that of the cost of the three On-site Disposal Alternatives. Estimated total project costs are divided by the waste volume to be disposed (the same for each alternative). Cost per unit of volume of as-generated waste disposed for each on-site alternative are (in Present Worth 2016 dollars): \$279 per yd^3 for the EBCV Site; \$286 for the WBCV Site; and \$347 for the Dual Site. The Hybrid Disposal Alternative is \$587 per yd^3, and the Off-site Disposal Alternative, Option 2 (lowest priced off-site option) is an estimated \$675 per yd^3 with the same assumed uncertainty of 25% in waste volumes for each alternative, and appropriate cost contingency applied to all estimates (details are given in Appendix I).

Rail transportation, which is approximately 11% less expensive than truck transport, is assumed for the majority of shipments. Risk figures identified in Table 7-7 associated with the off-site alternative far exceed risks identified for the on-site alternative. Risk, if realized, translates to increased costs.

7.3.8 NEPA Considerations

Land use within the permanent institutional control boundary of all alternatives would be restricted. Other areas used during construction and operations of on-site facilities could be released for other uses after facility closure.

If the Hybrid, On- or Off-site Disposal Alternatives encourage more thorough remediation of CERCLA environmental restoration sites than under the No Action Alternative, reduction or elimination of restrictions at those sites could have a positive effect on socioeconomics and land use. The effects of implementing the No Action Alternative would depend on decisions at individual sites, but could result in less release and less beneficial reuse of the individual sites if more waste is managed in place because of the lack of coordinated disposal capacity. Multiple sites could be more difficult to manage and less reliable than institutional and engineered controls at disposal facilities where large volumes of wastes are consolidated.

Implementation of the Off-site Disposal Alternative would have only a minor socioeconomic impact. The Off-site Disposal Alternative could encourage remediation at generator sites, but socioeconomic impacts associated with waste handling, packaging, and transport would be minimal. Only a slight incremental increase in the workforce at the off-site disposal facilities would be needed to accommodate ORR-generated wastes.

On-site disposal would likely have the greatest effect on socioeconomics and land use. The construction and disposal actions for the On-site Disposal Alternatives would increase the number of jobs locally, but the maximum increase would not be significant relative to the total current workforce. Loss of land use at the disposal site could be partially offset by reductions in restrictions at the remediation sites, but it is possible that the same improvements in land use opportunities at generator sites could occur under the No Action and Off-site Disposal Alternatives without the commitment of additional land on ORR. The proposed site locations for EBCV and Site 6b of the Dual Site are adjacent to existing waste disposal sites and therefore minimize the potential impact of the presence of a new facility on future use of the area. This is not the case for the Sites at WBCV and Site 7a of the Dual Site that are sites in undeveloped areas and currently proposed for future Unrestricted use. To some extent, differences in cost between on- and off-site disposal could impact decisions and remediation progress at individual sites.

The primary adverse environmental effect of the Hybrid (on-site portion) and On-site Disposal Alternatives at the EMDF site would result from the permanent commitment of the EMDF area for waste management, replacement of woodland habitat with grass and shrub habitat, and loss of sensitive stream and wetland habitat. The commitment of land area may be offset in part by cleanup and release of some of the ORR remediation sites. Any cumulative impact in the forested areas near the proposed EMDF site or on future land use is anticipated to be minimal. The Dual Site commits just over 50% more land than either of the other two On-site Disposal Alternative Locations.

The immediate areas surrounding the proposed on-site locations are currently unpopulated. The nearest residents to the sites range from 0.79 mi to 1.14 miapproximately to the north of the sites.

Cumulative effects of the Off-site Disposal Alternative would be caused by increased traffic along the transportation corridor. The short-and long-term effects at the disposal facilities would be minor as described for the On-site Disposal Alternative. If the cleanup and release of remediation sites is encouraged by this action, environmental benefits at ORR could result.

Cleanup actions at remediation sites could be similar for all alternatives. Off-site disposal would provide a greater cumulative benefit because the Hybrid and On-site Disposal Alternatives would permanently alter the proposed EMDF location. The cost differential between the Hybrid, On-site, and Off-site Disposal Alternatives is substantially in favor of on-site disposal and could encourage greater cleanup of individual ORR remedial sites.

7.3.9 Summary of Differentiating Criteria

The No Action Alternative does not allow for consolidated disposal of waste to be generated by future CERCLA actions. The lack of a central effort to dispose of the large volumes of waste predicted by the ORR cleanup would extend the time of cleanup by decades at significant increased cost, likely result in more stored waste for extended periods, and likely result in trucking significant quantities of waste, which carries a high transportation risk. The success of the No Action Alternative in meeting the RAOs would depend on the individual decisions made for each CERCLA remediation site. By virtue of compliance with the CERCLA process, cleanup actions would be protective, but if increased management of waste in place and long-term restrictions on land use resulted from no action, long-term effectiveness could be reduced. The need to coordinate and implement disposal services on a project-by-project basis could increase the time and cost required to complete remedial actions at individual sites.

For most of the NEPA evaluation criteria, the differences between alternatives are minor. Two significant differences exist between Site Options under the On-site Disposal Alternative – projected land use and permanent commitment of acreage. The EBCV Site and Site 6b (of the Dual Site Option and Hybrid Disposal Alternative) are located in Zone 3, with an agreed upon future land use goal of "DOE-controlled industrial use" stated in the BCV Phase I ROD. The WBCV Site and Site 7a (Dual Site Option) are located in Zone 1 and Zone 2, respectively, with agreed upon future land use goals of "residential use". Construction of a disposal facility at either of these sites would require a change to the BCV Phase I ROD to revise designated future land use for areas impacted by EMDF construction. In terms of permanent land commitment, the Dual Site requires a commitment of 109 acres, significantly more than for the other two On-site Disposal Alternative locations at WBCV or EBCV (each about 70 acres).

There is also a notable socioeconomic difference between the On-site Disposal Alternative and the Off-site Disposal Alternative. The On-site Disposal Alternative would result in more local jobs, because the dollars spent on cleanup and disposal would fund efforts on the ORR, allowing more funds to be directed toward cleanup activities as opposed to funds being directed toward more costly waste disposal. Additionally, those funds spent on waste disposal would be spent in East Tennessee.

The alternatives are differentiated by four key CERCLA criteria or subcriteria, (1) long-term effectiveness, (2) short-term transportation risk, (3) availability of services and materials, and (4) cost.

Long-term Effectiveness: On-site, Hybrid, and Off-site Disposal Alternatives would be considered protective long term of human health and the environment by disposal of waste in a landfill designed for site-specific conditions. Landfill designs at all On-site and Hybrid Disposal Alternative Sites are the same in terms of covers and liners, and are likely very similar to those engineered features at off-site disposal facilities. With regard to site-specific characteristics, no observations (e.g., size of underdrain systems, distance to Bear Creek/Maynardville Limestone, vadose zone thickness[20]) are seen as significantly different between sites, in terms of long-term effectiveness, to warrant emphasis. Off-site disposal at Energy*Solutions* and NNSS may be more effective long term in preventing exposure to or migration of contamination because of the climatic and geologic conditions. Fewer receptors exist in the vicinity of

[20] Vadose zone thickness differences between sites would be accommodated by changing the PreWAC. That is, if a site has a thinner vadose zone, it would have correspondingly more restrictive PreWAC limits.

Energy*Solutions* and NNSS than near the ORR. The Off-site Disposal Alternative would be more effective in preventing future releases on the ORR because CERCLA waste would be disposed in off-site facilities.

Short-term Effectiveness: Risk associated with local transport of waste to either the on-site disposal facility or the truck-to-rail transfer facility at ETTP for subsequent off-site shipment would be the same for all action alternatives. For the Hybrid and Off-site Disposal Alternatives, there would be additional significant vehicle-related risk due to transportation of the waste to off-site locations, although less for the Hybrid Disposal Alternative. Waste may be transported off-site by rail, truck, or a combination. Comparative analysis of risk incurred by these various transportation mechanisms demonstrates that rail transport results in a significantly lower transportation risk than does truck transportation of the waste. Off-site Disposal Alternatives pose the highest transportation risk (for Option 2, 2.5 fatalities). Risk in the Hybrid Disposal Alternative is about half the Off-site Disposal Alternative (Option 2) risk at 1.2 fatalities, but still presents over 40 times the risk of the On-site Disposal Alternative (all sites) in terms of fatalities.

Availability of Services and Materials: Currently services and materials needed for pre-construction investigations, construction and operation of the Hybrid and On-site Disposal Alternatives and transportation and disposal capacity for the Hybrid and Off-site Disposal Alternative are available. No impediments to continued operation for the Hybrid or On-site Disposal Alternatives are likely to arise. State equity issues and reliance on off-site facilities introduce a significant element of uncertainty into the continuing viability of off-site disposal during the anticipated operational period. Because CERCLA waste generation on the ORR is likely to continue for 30 years, on-site disposal would provide much greater certainty that sufficient disposal capacity is actually available at the time the wastes are generated. If an issue arose associated with transportation or with off-site disposal making either unavailable, waste generation at the ORR, and therefore cleanup, would have to stop if the Off-site Disposal Alternative were selected.

Cost: The estimated project cost for Option 2 of the Off-site Disposal Alternative is almost 2.5 times the estimated project cost of the lowest priced On-site Disposal Alternative. Additionally, cost and schedule risks identified with the Off-site Disposal Alternative have the capacity to greatly increase the cost associated with this alternative, compared with cost and schedule risks associated with all Sites of the On-site Disposal Alternative. The Hybrid Disposal Alternative also is significantly higher cost than the On-site Disposal Alternatives, slightly more than twice that of the lowest priced On-site Disposal Alternative Site.

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APPENDIX A:
WASTE VOLUME ESTIMATES AND WASTE CHARACTERIZATION DATA

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CONTENTS

FIGURES

TABLES

ACRONYMS

AD	As-disposed (waste volume)
AG	As-generated (waste volume)
CARAR	Capacity Assurance Remedial Action Report
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
COPC	contaminant of potential concern
EMDF	Environmental Management Disposal Facility
EMWMF	Environmental Management Waste Management Facility
FY	Fiscal Year
M	Million
ORNL	Oak Ridge National Laboratory
RI/FS	Remedial Investigation/Feasibility Study
WAC	Waste Acceptance Criteria
WACFACS	Waste Acceptance Criteria Forecast Analysis Capability System
WGF	waste generation forecast
WL	waste lot
WTMS	Waste Transportation Management System

1. INTRODUCTION

This Appendix presents further detail about the waste volume estimates, estimated waste generation schedules, and waste characterization data that are used as the basis for the Remedial Investigation/ Feasibility Study (RI/FS) alternative development and evaluation.

1.1 "AS-GENERATED" WASTE VOLUME ESTIMATE

As described in Chapter 2, the as-generated (AG) waste volume estimate from the waste generation forecast (WGF) was used to predict as-disposed (AD) waste volumes for the On-site Disposal Alternative and to provide the basis for waste shipment analysis in the Off-site Disposal Alternative.

Figure A-1 and Figure A-2 present the annual base as-generated waste volume estimates for Fiscal Year (FY) 2014 to FY 2043 by material type and by waste type, respectively. The base as-generated waste volume estimates do not include uncertainty.

Table A-1 shows the annual base as-generated waste volume estimate for FY 2014 to FY 2043 by material type, waste type, and year. Table A-2 provides the total base as-generated waste volume estimate for FY 2014 to FY 2043 by project, material type, and waste type, per the WGF, with subtotals for the following timeframes:

- FY 2014 to FY 2024: FY 2024 is the estimated year when the Environmental Management Waste Management Facility [EMWMF] reaches maximum capacity based on a 25% uncertainty allowance added to the as-disposed volume estimate as described below and in Section 2.2.2 of the RI/FS.
- FY 2022 to FY 2043: Estimated timeframe for operation of the new Environmental Management Disposal Facility [EMDF] under the On-site Disposal Alternative and for waste shipments under the Off-site Disposal Alternative.

Table A-3 provides the annual as-generated volume estimate (FY 2022 to FY 2043) with 25% uncertainty that is the basis for the Off-site Disposal Alternative waste shipments. The calculation, by year, is given by:

$$AG * 1.25 = AG25$$

Where AG is the as-generated waste volume in cubic yards (yd^3) for the year, and AG25 is the as-generated waste volume for the year including 25% uncertainty. Annual AG25 are summed for all years (FY 2014 to FY 2043) to obtain the total, 1.95 Million (M) total yd^3 of waste ($AG25_{total}$).

$$\sum AG25 = AG25_{total}$$

1.2 "AS-DISPOSED" WASTE VOLUME ESTIMATE

Prediction of as-disposed waste volumes for the RI/FS uses a methodology that starts with the as-generated waste volume estimates. Figure A-3 is a schematic showing the calculations used to obtain the final as-disposed volume from the as-generated waste volume estimates; these calculations are performed for each year and summed to obtain final totals. The following steps also outline the calculations that are used to obtain as-disposed volumes by year (as given in Figure A-3):

1.	$AG = AG_{soil} + AG_{debris}$	AG waste volume for the year is the sum of soil and debris AG waste volumes.
2.	$AG_{soil} / 1.2984 = AD_{soil}$	The factor 1.2984 is the density ratio of as-disposed to as-generated soil (1.61/1.24) used to calculate the AD soil volume. AD_{soil} is defined in Appendix A of the 2004 CARAR[1] and revised per the 2009 CARAR, Section 3.1.
3.	$AG_{debris} / 2.01235 = AD_{debris}$	The factor 2.01235 is the density ratio of as-disposed to as-generated debris (1.63/0.81) used to calculate the AD debris volume. AD_{debris} is defined in the 2004 CARAR, Appendix A for general construction debris.
4.	AD_{debris} * 2.26 = Total Fill Required	The factor 2.26 provides the Total Fill volume required when disposing of debris, and is based on operational experience as described in the 2012 CARAR, Section 3.2.
5.	Total Fill Required – AD_{soil} = Clean Fill	Clean Fill is additional material that is required over and above the available waste soil (AD_{soil}). It is possible for AD_{soil} to exceed the Total Fill Required, in which case there will be excess volume of waste soil fill, and no Clean Fill required that year.
6.	$AD = AD_{debris} + AD_{soil}$ + Clean Fill	AD waste volume total for the year is the sum of AD_{debris}, AD_{soil}, and Clean Fill.
7.	AD * 0.25 = U25	AD is multiplied by 0.25 to determine the 25% uncertainty allowance, U25.
8.	AD + U25 = AD25	The uncertainty allowance is added to AD to obtain the AD plus uncertainty (AD25) for the year.
9.	$\sum AD25 = AD25_{total}$	$AD25_{total}$ is the sum of AD25 for all years.

Table A-4 shows the as-disposed waste volume estimate per year through FY 2043 and delineates the volume estimate by debris (AD_{debris}), waste used as fill (AD_{soil}), clean fill, excess soil waste, and the 25% uncertainty allowance added for the total AD25 yearly as-disposed waste volume with uncertainty. Based on the as-disposed waste volume estimate, the On-site Disposal Alternative assumes maximum capacity of EMWMF (2.18 M yd^3) is reached in FY 2024 and a new Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) waste disposal facility becomes operational in FY 2022, allowing overlap of approximately two years for operational flexibility. Table A-4 also shows the estimated dates when new disposal facility cells begin operation and reach capacity (capacity is 2.5 M yd^3), when CERCLA waste disposal is complete and disposal facility closure begins.

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[1] CARAR is the Capacity Assurance Remedial Action Report.

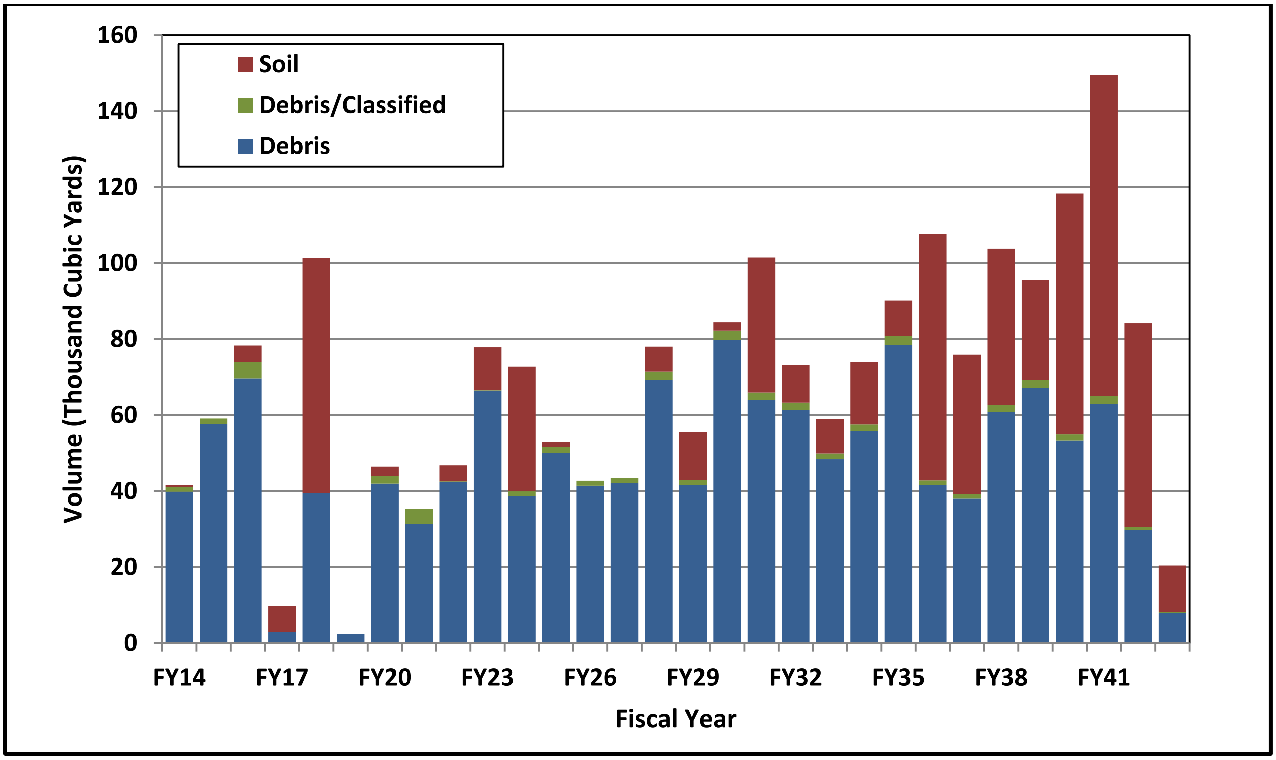

Figure A-1. Base As-generated Waste Volume Estimate by Material Type (FY 2014 to FY 2043)

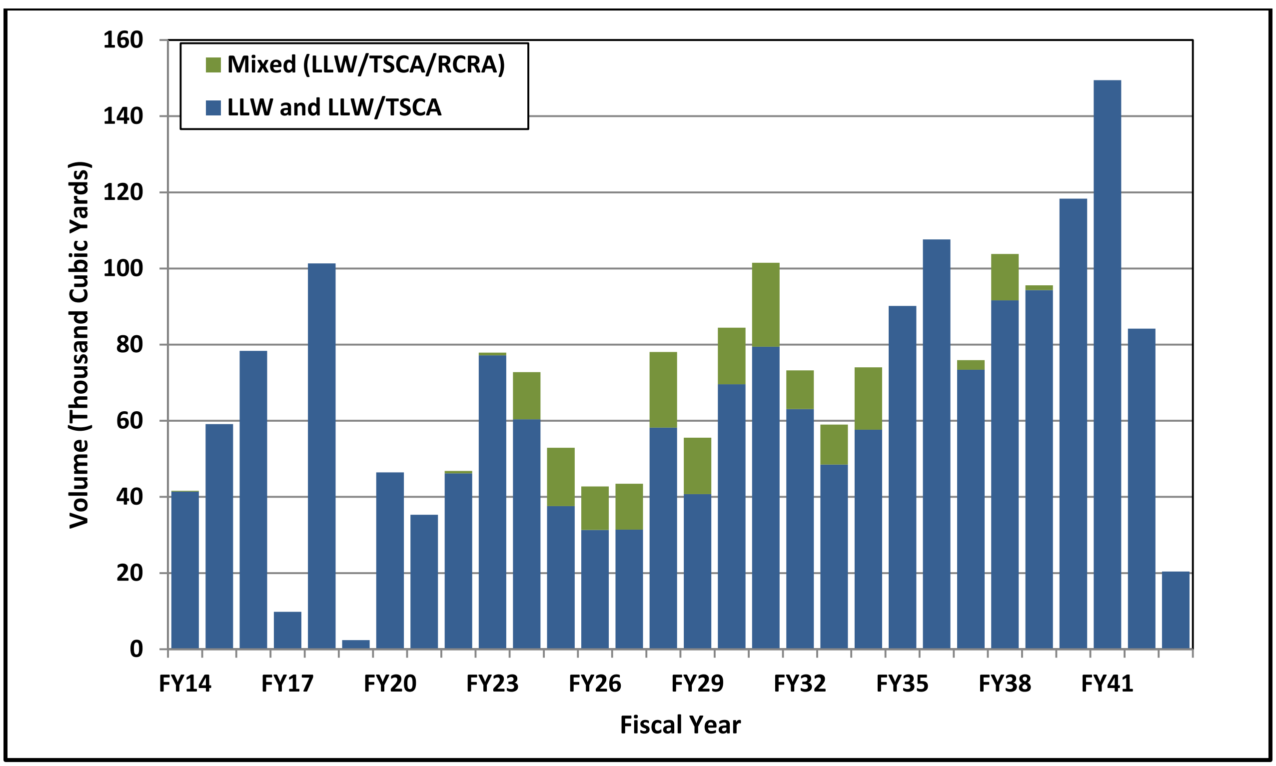

Figure A-2. Base As-generated Waste Volume Estimate by Waste Type (FY 2014 to FY 2043)

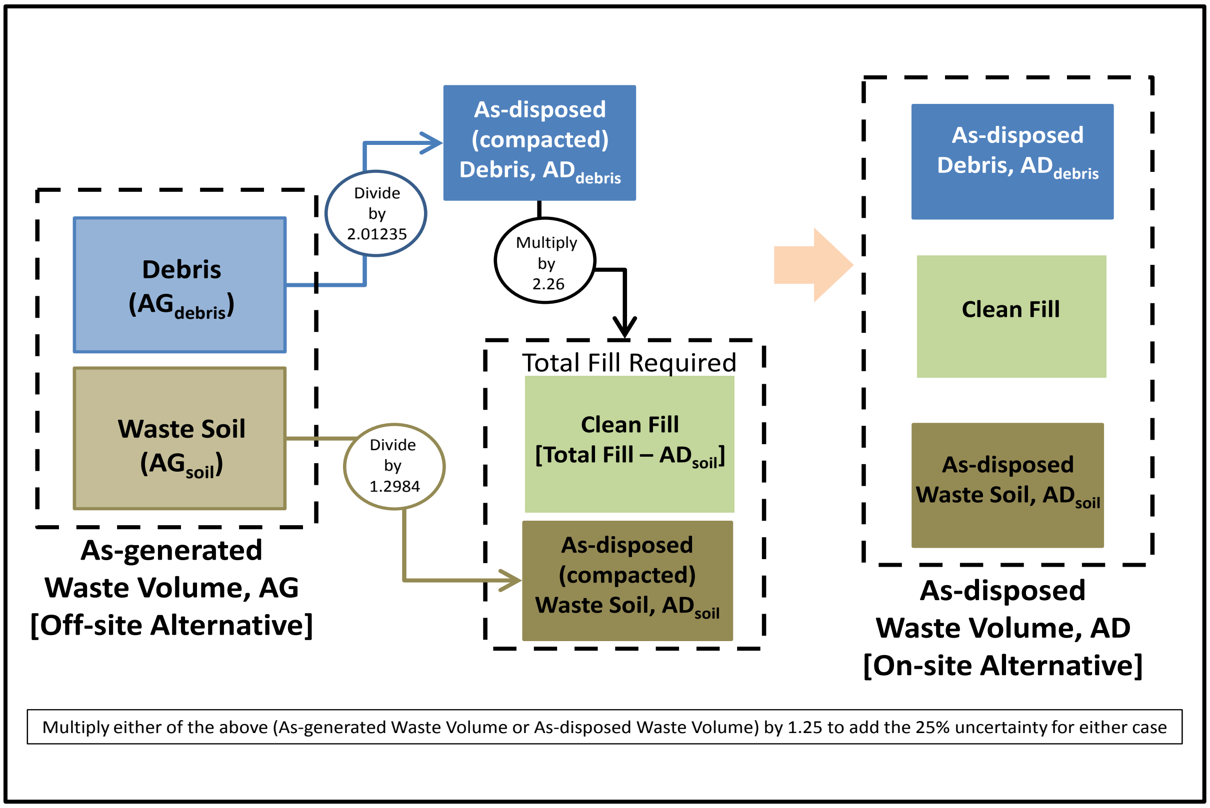

Figure A-3. Schematic of Calculations to Determine As-disposed Waste Volumes

1.3 WASTE CHARACTERIZATION DATA

The waste characterization results are in the form of a derived data set for radionuclide contaminants. The data set forms the basis for calculating transportation risk for the On- and Off-site Disposal Alternatives, and risk associated with natural phenomena (wind-borne [tornadic] contamination risk) for the On-site Disposal Alternative.

1.3.1 Radionuclide Characterization

A contaminant data set of mass-weighted average radionuclide concentrations was developed for use in evaluation of natural phenomena risk and transportation risk. The process used to develop the data set consisted of the following steps described in Section 1.3.1.1 through Section 1.3.1.3:

- Data collection
- Data set development exceptions
- Development of data set to be used for risk evaluation

A description of the process steps and calculations is provided below.

1.3.1.1 Data Collection

The data collection process is described below.

1. Identified waste lots (WLs) for waste disposed at EMWMF: Using a Waste Transportation Management System[2] (WTMS) EMWMF Disposition Summary Report, a list of 134 WLs were identified.
2. Collected radionuclide contaminants of potential concern (COPCs) and expected value[3] concentration data for identified WLs:[4] The expected concentration value used for each radionuclide COPC is listed in Table A-5. Data were obtained from the following sources:
   a) The Waste Acceptance Criteria Forecast Analysis Capability Systems (WACFACS)[5] output report for the identified WL. WACFACS output reports contain values for COPCs that have a numerical limit in the EMWMF analytic Waste Acceptance Criteria (WAC). These reports do not contain values for COPCs that have an unlimited EMWMF analytic WAC (e.g., Cs-137). In order to obtain concentration data for Cs-137 and other COPCs that are predominantly present in the Oak Ridge National Laboratory (ORNL) waste streams but have an unlimited EMWMF analytic WAC, data sources described in (b) and (c) below were used to obtain ORNL expected value concentration data.

   b) The auditable safety analysis-derived WAC section of the waste profile for the identified WL.

   c) Summary statistics from WL profiles.
3. Collected net weight data for identified WLs: As-disposed net weight data were obtained from the WTMS EMWMF Disposition Summary Report. Net weight data for each identified WL are shown in Table A-5.

1.3.1.2 Data Set Development Exceptions

Exceptions to the process were made for the following WLs that were merged or split out from the original approved WL profile and therefore shipped under a different WL number. These WLs are:

- WL #6.998 is a commingled WL that includes wastes from WL # 6.49, 6.50, 6.51, 6.52, 6.53, 6.54, 6.55, 6.56, and 6.57.
- WL #6.999 is a commingled WL that includes wastes from WL # 6.32, 6.33, 6.34, 6.35, 6.38, 6.39, 6.45, 6.46, 6.47, and 6.48.
- WL #149.11 was shipped as WL #149.4.
- WL #200.999 is a commingled WL that includes wastes from WL # 200.01, 200.02, and 200.04.

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[2] WTMS is a web-based tool that provides a central source for manually compiling and printing shipping documents required for the transport of waste and materials generated by the EM contractor.

[3] Symbolized by E(x) in waste lot summary statistics.

[4] Some radionuclide data values were reported as radionuclide concentration values for radionuclide pairs (e.g., Cm-243/244, Cm-245/246, Pu-239/240, Ru-106/Rh-106, U-233/234, and U-235/236). The radionuclide concentration values for Cm-243/244 were assigned to Cm-243, Cm-245/246 were assigned to Cm-245, Pu-239/240 were assigned to Pu-239, Ru-106/Rh-106 were assigned to Ru-106, U-233/234 were assigned to U-234, and U-235/236 were assigned to U-235.

[5] WACFACS is the primary tool used to ensure analytic WAC compliance at the EMWMF.

For these WLs:

- In Step 3 of Data Collection (see Section 1.3.1.1 above), the as-disposed volumes from the 2012 Capacity Assurance Remedial Action Report (DOE 2012) and reported radionuclide COPC concentrations for each individual WL were used to calculate a volume-weighted average concentration for each radionuclide COPC. The value was substituted as the concentration value C_{ij} in Step 1 in Section 1.3.1.3 below for the commingled/shipped WL j, where C_{ij} = concentration of radionuclide contaminant i in pCi/g, for WL j.

1.3.1.3 Development of Data Set for Natural Phenomena and Transportation Risk Evaluation

The steps and assumptions to develop the data set for natural phenomenon and transportation risk evaluation (provided in Appendix F) are summarized below:

1. Calculate the activity in pCi of each radionuclide with a reported value in each individual WL data set.

$$\text{Activity}_{ij} = C_{ij} * \text{Weight}_j * 453.6 \text{ g/lb}$$

where:

Activity_{ij} = Activity of radionuclide i in pCi, for WL j

Weight_j = Net weight in lb for WL j (all shipments)

2. Calculate the total activity in the data set for each radionuclide i.

$$\text{Activity}_i = \sum \text{Activity}_{ij}$$

where:

Activity_i = Total activity in pCi, for radionuclide i, summed for all WLs $j = 1 \text{ to } m$ with a reported value for radionuclide i

3. Calculate the average concentration in pCi/g for each radionuclide present in the WL data set.

$$C_i = \text{Activity}_i / [(\text{Weight}_{tot}*(453.6 \text{ g/lb})] \quad \text{and} \quad \text{Weight}_{tot} = \sum \text{Weight}_j$$

where:

Weight_{tot} = Total net weight in lb, summed for all WLs $j = 1 \text{ to } m$ in the data set with a reported value for radionuclide i

C_i = Average concentration of radionuclide i in the data set (all WLs with a reported value for radionuclide i)

The calculation spreadsheet of mass-weighted average concentrations for radionuclide COPCs is provided in Table A-6.

Table A-1. Base As-generated Waste Volume Estimate (FY 2014 to FY 2043)[a]

As-generated Waste Volume Estimate (yd³)												
Waste Type	**Material Type**	**FY 2014**	**FY 2015**	**FY 2016**	**FY 2017**	**FY 2018**	**FY 2019**	**FY 2020**	**FY 2021**	**FY 2022**	**FY 2023**	**FY 2024**
LLW (includes LLW/TSCA)	Debris	39,699	57,678	69,642	2,986	39,549	2,383	41,984	31,398	41,929	65,846	27,803
	Debris/Classified	1,263	1,451	4,331	0	0	0	2,006	3,892	0	0	0
	Soil	450	0	4,375	6,820	61,803	0	2,467	0	4,242	11,348	32,563
	TOTAL	**41,411**	**59,129**	**78,348**	**9,806**	**101,352**	**2,383**	**46,457**	**35,290**	**46,171**	**77,194**	**60,366**
Mixed (LLW/RCRA, LLW/RCRA/TSCA)	Debris	200	0	0	0	0	0	0	0	631	686	12,183
	Debris/Classified	0	0	0	0	0	0	0	0	0	0	0
	Soil	0	0	0	0	0	0	0	0	0	0	224
	TOTAL	**200**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**631**	**686**	**12,407**
TOTAL		**41,611**	**59,129**	**78,348**	**9,806**	**101,352**	**2,383**	**46,457**	**35,290**	**46,802**	**77,880**	**72,773**

Waste Type	**Material Type**	**FY 2025**	**FY 2026**	**FY 2027**	**FY 2028**	**FY 2029**	**FY 2030**	**FY 2031**	**FY 2032**	**FY 2033**	**FY 2034**	**FY 2035**
LLW (includes LLW/TSCA)	Debris	36,265	31,322	31,391	51,612	35,640	67,369	57,442	57,205	45,780	54,920	80,901
	Debris/Classified	0	0	0	0	0	0	0	0	0	0	0
	Soil	1,313	0	20	6,582	5,107	2,197	21,998	5,855	2,727	2,743	9,271
	TOTAL	**37,579**	**31,322**	**31,411**	**58,194**	**40,747**	**69,567**	**79,439**	**63,060**	**48,507**	**57,663**	**90,172**
Mixed (LLW/RCRA, LLW/RCRA/TSCA)	Debris	15,340	11,416	12,034	19,859	7,259	14,866	8,515	6,103	4,124	2,635	0
	Debris/Classified	0	0	0	0	0	0	0	0	0	0	0
	Soil	0	0	0	0	7,562	0	13,537	4,073	6,372	13,739	0
	TOTAL	**15,340**	**11,416**	**12,034**	**19,859**	**14,821**	**14,866**	**22,052**	**10,176**	**10,497**	**16,375**	**0**
TOTAL		**52,918**	**42,738**	**43,445**	**78,052**	**55,568**	**84,433**	**101,491**	**73,236**	**59,003**	**74,038**	**90,172**

Waste Type	**Material Type**	**FY 2036**	**FY 2037**	**FY 2038**	**FY 2039**	**FY 2040**	**FY 2041**	**FY 2042**	**FY 2043**	**Total FY 2014 to FY 2043**
LLW (includes LLW/TSCA)	Debris	42,840	36,708	58,925	67,914	54,946	64,960	30,638	8,200	1,335,875
	Debris/Classified	0	0	0	0	0	0	0	0	12,943
	Soil	64,787	36,694	32,722	26,410	63,394	84,517	53,539	12,217	556,160
	TOTAL	**107,627**	**73,402**	**91,648**	**94,324**	**118,340**	**149,477**	**84,177**	**20,417**	**1,904,978**
Mixed (LLW/RCRA, LLW/RCRA/TSCA)	Debris	0	2,527	3,790	1,263	0	0	0	0	123,431
	Debris/Classified	0	0	0	0	0	0	0	0	0
	Soil	0	0	8,375	0	0	0	0	0	53,882
	TOTAL	**0**	**2,527**	**12,165**	**1,263**	**0**	**0**	**0**	**0**	**177,313**
TOTAL		**107,627**	**75,929**	**103,812**	**95,588**	**118,340**	**149,477**	**84,177**	**20,417**	**2,082,291**

LLW low-level waste
RCRA Resource Conservation and Recovery Act of 1976
TSCA Toxic Substance Control Act of 1976

[a] The waste generation forecast does not forecast the volume of classified waste other than for East Tennessee Technology Parl (ETTP). Three percent of debris (post-ETTP cleanup) is assumed to be classified (volumes not shown here).

Table A-2. Base As-generated Waste Volume Estimate by Project (FY 2014 to FY 2043)[a]

Work Breakdown Structure Project	Material Type	LLW and LLW/TSCA (yd^3)			Mixed- LLW/RCRA and LLW/RCRA/TSCA (yd^3)			Total EMWMF	Total EMDF	Total All (FY14-43) (yd^3)
		FY14-24 (EMWMF)	FY22-43 (EMDF)	Total LLW	FY14-24 (EMWMF)	FY22-43 (EMDF)	Total Mixed			
2026 Complex	Debris		10,012	10,012					10,012	**10,012**
2528 Complex	Debris		484	484					484	**484**
3019A & Ancillary Facilities	Debris		62,263	62,263					62,263	**62,263**
3525 Complex	Debris		7,659	7,659					7,659	**7,659**
3544 Complex	Debris		295	295					295	**295**
3608 Complex	Debris		4,466	4,466					4,466	**4,466**
4501/4505 Comlex	Debris		22,814	22,814					22,814	**22,814**
5505 Building	Debris		3,689	3,689					3,689	**3,689**
6010 and East BV Complex	Debris		44,916	44,916					44,916	**44,916**
9206 Complex	Debris		15,490	15,490					15,490	**15,490**
9212 Complex	Debris		113,571	113,571					113,571	**113,571**
9213 and 9401-2 Demolition	Debris		8,000	8,000					8,000	**8,000**
Alpha-2 Complex	Debris		62,800	62,800		10,190	10,190		72,990	**72,990**
Alpha-3 Complex	Debris		37,108	37,108					37,108	**37,108**
Alpha-4 Complex	Debris		41,314	41,314		13,771	13,771		55,085	**55,085**
Alpha-5 Complex	Debris	169	85,836	86,005		36,787	36,787	169	122,623	**122,792**
Balance of Site Facilities	Debris	25,115		25,115				25,115		**25,115**
BCV S-3 Ponds	Soil		1,094	1,094					1,094	**1,094**
BCV White Wing Scrap Yard Remedial Action	Debris		10,017	10,017					10,017	**10,017**
	Soil		62,506	62,506					62,506	**62,506**
Beta-1 Complex	Debris		46,920	46,920					46,920	**46,920**
Beta-3 Deactivation Only	Debris		19,502	19,502					19,502	**19,502**
Beta-4 Complex	Debris		54,189	54,189		21,598	21,598		75,787	**75,787**
Beta-4 LMD	Debris	387		387				387		**387**
Biology Complex	Debris		29,088	29,088				-	29,088	**29,088**
	Soil		5,069	5,069				-	5,069	**5,069**
BV Chem Dev Lab Facilities	Debris		1,189	1,189				-	1,189	**1,189**
BV Inactive Tanks & Pipelines	Debris		405	405				-	405	**405**
	Soil		158	158				-	158	**158**

Table A-2. Base As-generated Waste Volume Estimate by Project (FY 2014 to FY 2043) (Continued)

Work Breakdown Structure Project	Material Type	LLW and LLW/TSCA (yd^3)			Mixed- LLW/RCRA and LLW/RCRA/TSCA (yd^3)			Total EMWMF	Total EMDF	Total All (FY14-43) (yd^3)
		FY14-24 (EMWMF)	FY22-43 (EMDF)	Total LLW	FY14-24 (EMWMF)	FY22-43 (EMDF)	Total Mixed			
BV Isotope Area Facilities (3038)	Debris		1,825	1,825				-	1,825	**1,825**
BV Reactor Area Facilities	Debris		7,076	7,076		144	144	-	7,220	**7,220**
	Soil		552	552				-	552	**552**
BV Remaining Inactive Tanks and Pipeline	Debris		23,446	23,446				-	23,446	**23,446**
BV Remaining Slabs and Soils	Debris		30,024	30,024				-	30,024	**30,024**
	Soil		46,660	46,660				-	46,660	**46,660**
BV Tank Area Facilities	Debris		3,433	3,433				-	3,433	**3,433**
	Soil		182	182				-	182	**182**
Central Neutralization Facility Closure	Debris	5,743		5,743				5,743		**5,743**
Central Stack East Hot Cell Complex	Debris		5,647	5,647				-	5,647	**5,647**
Central Stack West Hot Cell Complex	Debris		4,356	4,356				-	4,356	**4,356**
Centrifuge Facilities	Debris	27,229		27,229				27,229		**27,229**
	Debris/ Classified	5,398		5,398				5,398		**5,398**
EGCR Complex	Debris		45,811	45,811					45,811	**45,811**
Fire Station Complex	Debris		815	815					815	**815**
Hot Storage Garden	Debris		190	190					190	**190**
HPRR Complex	Debris		2,553	2,553					2,553	**2,553**
K-1037 and K-1037-C	Debris	35,960		35,960				35,960		**35,960**
	Debris/ Classified	500		500				500		**500**
K-25 Facility D&D (ETTP)	Debris	38,228		38,228				38,228		**38,228**
	Debris/ Classified	1,263		1,263				1,263		**1,263**
K-27 Deactivation Waste	Debris	1,106		1,106				1,106		**1,106**

Table A-2. Base As-generated Waste Volume Estimate by Project (FY 2014 to FY 2043) (Continued)

Work Breakdown Structure Project	Material Type	LLW and LLW/TSCA (yd^3)			Mixed- LLW/RCRA and LLW/RCRA/TSCA (yd^3)			Total EMWMF	Total EMDF	Total All (FY14-43) (yd^3)
		FY14-24 (EMWMF)	FY22-43 (EMDF)	Total LLW	FY14-24 (EMWMF)	FY22-43 (EMDF)	Total Mixed			
K-27 Demolition Waste	Debris	65,911		65,911				65,911		**65,911**
	Debris/ Classified	5,782		5,782				5,782		**5,782**
K-27 Tie Lines	Debris	540		540				540		**540**
K-31 Facility	Debris	55,049		55,049				55,049		**55,049**
LLLW Complex	Debris		1,773	1,773					1,773	**1,773**
Material Difference 114–PBS40	Debris	5,010		5,010				5,010		**5,010**
MV HRE Facility	Debris		725	725					725	**725**
MV LGWO Complex	Debris		7,859	7,859					7,859	**7,859**
MV Waste Storage Facilities	Debris		1,129	1,129					1,129	**1,129**
Newly Generated LLW/MLLW and Additional Waste PBS-42	Debris	6		6				6		**6**
ORNL Non-HF Well P&A	Debris		20	20					20	**20**
ORNL Remaining Non-HF Well P&A	Debris		14	14					14	**14**
ORNL Soils and Sediments	Debris		2,053	2,053					2,053	**2,053**
	Soil		76,563	76,563					76,563	**76,563**
ORNL Surveillance & Maintenance / Environmental Monitoring	Debris	528		528				528		**528**
ORNL Water Quality Program	Debris	15		15				15		**15**
Poplar Creek Facilities	Debris	14,687		14,687				14,687		**14,687**
	Soil	10,934		10,934				10,934		**10,934**
SE Services Group Complex	Debris		112	112					112	**112**
Sewage Treatment Plant Complex	Debris		73	73					73	**73**
Southeast Lab Support Complex	Debris		39	39					39	**39**
Steam Plant Complex Legacy Material Disposition	Debris		80	80					80	**80**
Tank Facilities Demolition	Debris		3,000	3,000					3,000	**3,000**
TRU Treatment Contract	Debris	50		50				50		**50**
	Soil	450		450				450		**450**
TSCA Incinerator Facilities	Debris	5,385		5,385				5,385		**5,385**

Table A-2. Base As-generated Waste Volume Estimate by Project (FY 2014 to FY 2043) (Continued)

Work Breakdown Structure Project	Material Type	LLW and LLW/TSCA (yd^3)			Mixed- LLW/RCRA and LLW/RCRA/TSCA (yd^3)			Total EMWMF	Total EMDF	Total All (FY14-43) (yd^3)
		FY14-24 (EMWMF)	FY22-43 (EMDF)	Total LLW	FY14-24 (EMWMF)	FY22-43 (EMDF)	Total Mixed			
TWPC Complex	Debris		3,106	3,106					3,106	**3,106**
UEFPC Remaining Slabs and Soils	Debris		116,354	116,354		40,460	40,460		156,814	**156,814**
	Soil		234,840	234,840		41,692	41,692		276,532	**276,532**
UEFPC Sediments - Streambed and Lake Reality	Soil					11,966	11,966		11,966	**11,966**
UEFPC Soils	Soil		3,154	3,154					3,154	**3,154**
UEFPC Soils 81-10 Area	Debris			-		280	280		280	**280**
	Soil	31,813	1,313	33,126		224	224	31,813	1,537	**33,350**
Y-12 Surveillance & Maintenance/ Environmental Monitoring	Debris			-	200		200	200		**200**
Y-12 Salvage Yard	Debris	20		20				20		**20**
Zone 2 Remedial Action	Debris	105,096		105,096				105,096		**105,096**
	Soil	80,871		80,871				80,871		**80,871**
TOTAL VOLUME		**523,245**	**1,381,733**	**1,904,978**	**200**	**177,112**	**177,312**	**523,445**	**1,558,845**	**2,082,291**

LLW = low-level waste; RCRA = Resource Conservation and Recovery Act of 1976; TSCA = Toxic Substance Control Act of 1976

[a] The waste generation forecast does not forecast the volume of classified waste other than for ETTP. Three percent of debris (post-ETTP cleanup) is assumed to be classified (volumes not separated here).

Table A-3. As-generated Waste Volume Estimate (FY 2022 to FY 2043)[a] with Uncertainty

As-generated Waste Volume Estimate (yd^3) with Uncertainty									
Waste Type	**Material Type**	**FY 2022**	**FY 2023**	**FY 2024**	**FY 2025**	**FY 2026**	**FY 2027**	**FY 2028**	**FY 2029**
LLW (includes LLW/TSCA)	Debris + 25%	6,384	1,940	33,705	43,972	37,978	38,062	62,580	43,214
	Debris/Classified + 25%	197	60	1,042	1,360	1,175	1,177	1,935	1,337
	Soil + 25%	0	0	0	1,642	0	24	8,227	6,383
	TOTAL	**6,581**	**2,000**	**34,748**	**46,973**	**39,152**	**39,263**	**72,742**	**50,934**
Mixed (LLW/RCRA, LLW/RCRA/TSCA)	Debris +25%	765	832	14,771	18,599	13,842	14,591	24,079	8,802
	Debris/Classified +25%	24	26	457	575	428	451	745	272
	Soil +25%	0	0	280	0	0	0	0	9,453
	TOTAL	**788**	**857**	**15,508**	**19,175**	**14,270**	**15,043**	**24,823**	**18,527**
TOTAL with Uncertainty at 25%		**7,370**	**2,857**	**50,256**	**66,148**	**53,422**	**54,306**	**97,566**	**69,460**

Waste Type	**Material Type**	**FY 2030**	**FY 2031**	**FY 2032**	**FY 2033**	**FY 2034**	**FY 2035**	**FY 2036**	**FY 2037**
LLW (includes LLW/TSCA)	Debris +25%	81,685	69,648	69,361	55,508	66,590	98,092	51,944	44,508
	Debris/Classified +25%	2,526	2,154	2,145	1,717	2,059	3,034	1,607	1,377
	Soil +25%	2,747	27,497	7,318	3,408	3,429	11,589	80,984	45,868
	TOTAL	**86,958**	**99,299**	**78,825**	**60,633**	**72,079**	**112,715**	**134,534**	**91,752**
Mixed (LLW/RCRA, LLW/RCRA/TSCA)	Debris +25%	18,025	10,325	7,400	5,001	3,195	0	0	3,064
	Debris/Classified +25%	557	319	229	155	99	0	0	95
	Soil +25%	0	16,921	5,091	7,965	17,174	0	0	0
	TOTAL	**18,583**	**27,565**	**12,720**	**13,121**	**20,469**	**0**	**0**	**3,158**
TOTAL with Uncertainty at 25%		**105,541**	**126,864**	**91,545**	**73,754**	**92,547**	**112,715**	**134,534**	**94,911**

Waste Type	**Material Type**	**FY 2038**	**FY 2039**	**FY 2040**	**FY 2041**	**FY 2042**	**FY 2043**	**Total (FY 2022 to FY 2043)**
LLW (includes LLW/TSCA)	Debris +25%	71,447	82,346	66,622	78,764	37,148	9,943	1,151,440
	Debris/Classified +25%	2,210	2,547	2,060	2,436	1,149	308	35,612
	Soil +25%	40,903	33,013	79,242	105,646	66,924	15,271	540,115
	TOTAL	**114,559**	**117,905**	**147,925**	**186,846**	**105,221**	**25,521**	**1,727,167**
Mixed (LLW/RCRA, LLW/RCRA/TSCA)	Debris +25%	4,595	1,532	0	0	0	0	149,418
	Debris/Classified +25%	142	47	0	0	0	0	4,621
	Soil +25%	10,468	0	0	0	0	0	67,353
	TOTAL	**15,206**	**1,579**	**0**	**0**	**0**	**0**	**221,391**
TOTAL with Uncertainty at 25%		**129,765**	**119,485**	**147,925**	**186,846**	**105,221**	**25,521**	**1,948,558**

LLW = low-level waste; RCRA = Resource Conservation and Recovery Act of 1976; TSCA = Toxic Substance Control Act of 1976

[a] The waste generation forecast does not forecast the volume of classified waste other than for ETTP. Three percent of debris (post-ETTP cleanup) is assumed to be classified (given in Table).

Table A-4. As-disposed Waste Volume Estimate

	Thru FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022	FY 2023	FY 2024	FY 2025	FY 2026	FY 2027	FY 2028	FY 2029
EMWMF	**(ACTUAL)**																
Clean Fill=	456,786	45,880	66,406	79,707			2,676	47,504	39,633	37,909	63,413						
Excess Waste=					1,899	3,184											
Waste Fill=	369,070	347		3,370	3,353	44,416		1,900		3,267	8,740	24,946					
Debris=	496,075	20,454	29,383	36,760	1,484	19,653	1,184	21,860	17,537	18,220	31,926	136	**NA**	**NA**	**NA**	**NA**	**NA**
Total waste plus fill	1,321,931	66,681	95,789	119,836	6,737	67,253	3,860	71,264	57,170	59,396	104,079	25,082					
25% Uncertainty	NA	16,670	23,947	29,959	1,684	16,813	965	17,816	14,292	14,849	26,020	6,271					
Total Waste with Uncertainty	1,321,931	83,352	119,736	149,796	8,421	84,066	4,826	89,080	71,462	74,245	130,098	31,353					
Cumulative Waste (EMWMF) w/ 25%	**1,321,931**	**1,405,283**	**1,525,019**	**1,674,814**	**1,683,235**	**1,767,301**	**1,772,127**	**1,861,207**	**1,932,669**	**2,006,913**	**2,137,012**	**2,168,364**					
EMDF																	
Clean Fill=										6,621	2,567	44,293	56,945	47,997	48,754	75,198	38,422
Excess Waste=																	
Waste Fill=												306	1,011		15	5,069	9,757
Debris=	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	2,930	1,136	19,734	25,644	21,238	21,579	35,516	21,318
Total waste plus fill										9,551	3,703	64,333	83,600	69,235	70,349	115,783	69,497
25% Uncertainty										2,388	926	16,083	20,900	17,309	17,587	28,946	17,374
Total Waste with Uncertainty										11,939	4,629	80,416	104,501	86,544	87,936	144,729	86,872
Cumulative Waste (EMDF) w/ 25%										**11,939**	**16,567**	**96,983**	**201,484**	**288,028**	**375,964**	**520,693**	**607,564**
Cumulative Waste (All) w/ 25%	**1,321,931**	**1,405,283**	**1,525,019**	**1,674,814**	**1,683,235**	**1,767,301**	**1,772,127**	**1,861,207**	**1,932,669**	**2,018,852**	**2,153,579**	**2,265,347**	**2,369,848**	**2,456,392**	**2,544,328**	**2,689,057**	**2,775,928**
										(A)		**(B)**					

	FY 2030	FY 2031	FY 2032	FY 2033	FY 2034	FY 2035	FY 2036	FY 2037	FY 2038	FY 2039	FY 2040	FY 2041	FY 2042	FY 2043	Total (All Time)
EMDF															
Clean Fill=	90,664	46,705	63,453	49,038	51,944	83,717		15,801	38,781	57,350	12,883	7,860			1,678,908
Excess Waste=							1,786						6,827	200	13,895
Waste Fill=	1,692	27,368	7,646	7,008	12,695	7,140	48,112	28,261	31,652	20,341	48,825	65,094	34,408	9,209	825,021
Debris=	40,866	32,776	31,460	24,799	28,601	40,202	21,289	19,497	31,165	34,377	27,305	32,281	15,225	4,075	1,227,683
Total waste plus fill	133,222	106,850	102,559	80,845	93,239	131,059	71,187	63,559	101,598	112,068	89,013	105,235	56,460	13,484	3,745,507
25% Uncertainty	33,305	26,712	25,640	20,211	23,310	32,765	17,797	15,890	25,400	28,017	22,253	26,309	14,115	3,371	605,894
Total Waste with Uncertainty	166,527	133,562	128,199	101,056	116,549	163,824	88,983	79,449	126,998	140,085	111,266	131,544	70,575	16,855	4,351,401 (All Waste+Uncert.)
Cumulative Waste (EMDF) w/ 25%	**774,091**	**907,654**	**1,035,853**	**1,136,909**	**1,253,458**	**1,417,282**	**1,506,265**	**1,585,715**	**1,712,713**	**1,852,797**	**1,964,063**	**2,095,607**	**2,166,182**	**2,183,037**	**2,183,037 (EMDF)**
Cumulative Waste (All) w/ 25%	**2,942,456**	**3,076,018**	**3,204,217**	**3,305,273**	**3,421,822**	**3,585,646**	**3,674,630**	**3,754,079**	**3,881,077**	**4,021,161**	**4,132,427**	**4,263,971**	**4,334,546**	**4,351,401**	**4,351,401 (All Waste+Uncert.)**
		(C)							**(D)**					**(E)**	

Time Line

(A)	FY 2022:	EMDF Cells 1 and 2 start operations	**(D)**	FY 2038:	EMDF Cells 3 and 4 reach capacity (951,180 yd^3); Cells 5 and 6 start operations
(B)	FY 2024:	EMWMF reaches capacity (~ 2.18 M yd^3)	**(E)**	FY 2043:	ORR Cleanup complete; EMDF closure begins
(C)	FY 2031:	EMDF Cells 1 and 2 reach capacity (822,900 yd^3); Cells 3 and 4 start operations			

Table A-5. Radionuclide Concentration Data Set

**Units in pCi/g*

Site	Waste Lot	WL Name	Net Weight (g)	Ag-110m	Am-241	Am-243	Bi-214	C-14	Cm-242	Cm-243	Cm-244	Cm-245	Cm-246	Cm-247
Y-12	1.0	BYBY RA	8.66E+10		1.80E-01									
ORNL	2.01	SWSA 4 Remedial Action IHP-1 RA	2.22E+10		2.18E+01			2.10E+00						
ETTP	3.00	K-1070-A RA	2.59E+10		2.00E-01									
ETTP	4.02	PWR K-1085-401 RA	5.93E+07											
ETTP	4.03	Blair Quarry Soils	1.35E+10											
ETTP	4.05	K-710	2.80E+08											
ETTP	4.06	K-1085 Old Firehouse Burn Area Drum Burial Site, Area 6 Soils	1.51E+07		3.08E-01									
ETTP	4.08	Duct Island Soil Mounds	1.47E+08		3.20E-01									
ETTP	4.11	K-711/K-766 Debris and Soils	5.37E+08											
ETTP	4.12	K-770 Scrap Yard Soils	8.81E+10											
ETTP	4.14	K-1093 Scrap Yard Debris	6.63E+08		4.42E-01			2.31E+00						
ETTP	6.01	K25 HMA-1 DD R2	3.41E+09		7.75E-02									
ETTP	6.02	K27 Units 1-7 ACM R2 (ARRA)	3.87E+08		8.45E-02									
ETTP	6.03	K25 HMA-2 DD Rev 2	1.91E+08		4.23E-01									
ETTP	6.04	K-27 Units 402-8 & 402-9 Hazardous Materials Abatement	5.90E+07		5.28E-02									
ETTP	6.06	K-25 Bldg Area 6 PER R1	2.13E+08											
ETTP	6.12	K-25 Bldg Non-Purge Ext. Transite	6.80E+08		2.35E-02									
ETTP	6.13	K-25 Bldg Area 5.1 PER R0	1.36E+08											
ETTP	6.14	K-1232 Tank Farm Miscellaneous Debris R0	7.86E+07											
ETTP	6.16	K-601 Misc Debris	1.07E+09											
ETTP	6.17	Building K-1030 Debris	9.11E+08		1.79E-01									
ETTP	6.18	Building K-1024 Debris	8.51E+08		1.20E-01			7.98E+00						
ETTP	6.19	K-25/K-27 Bldg Struc Debris	1.92E+09		3.17E-01									
ETTP	6.27	K-25/K-27 EMR Debris Material (K-27 ARRA)	2.74E+09		6.60E-01									
ETTP	6.28	K-25 Lead Based Pain Debris	5.54E+08											
ETTP	6.31	K-25 Building Northwest Bridge	5.25E+08											
ETTP	6.41	K-25 West Side Compressors Group 1 R1	6.11E+09											
ETTP	6.42	K-25 West Side Converters Group 1 R1	1.02E+09											
ETTP	6.43	K-25 West Side Converters Group 1 R1	3.49E+09											
ETTP	6.58	K25 East and North Low-Risk Converters	3.03E+09											
ETTP	6.59	Building K-25 East Wing and North End Low-Risk Compressors	2.08E+09											
ETTP	6.60	K-25 West Wing Post Mined Low-Risk Compressors	8.48E+07											
ETTP	6.998	Comingled waste lot that inlcudes WL's 6.49-6.57	4.63E+10		4.33E-03									
ETTP	6.999	Comingled waste lot that includes WL's 6.32, 6.33, 6.34, 6.35, 6.38, 6.39, 6.45, 6.46, 6.47, 6.48	1.66E+11											
ETTP	8.02	Building K-33 Concrete Pedestal	1.14E+10											
ETTP	8.05	BNFL Compressor Blades	5.89E+08		2.01E-02									
ETTP	8.07	BNFL K-31 Concrete Pedestal Waste Lot	4.61E+09		1.61E-01									
ETTP	8.08	K-33 Concrete Floor Scabble	2.27E+09		4.93E+00									
ETTP	8.11	Non-PG/Non-Fissile Components	2.66E+08		1.67E-01									
ORNL	10.01	Old Hydrofracture Facility Remediation Wastes (Containers)	7.04E+08		3.52E+02			8.95E+01						
ETTP	14.01	K-1303 Building Debris	1.92E+09											
ETTP	14.02	K-1302 Building Debris	3.06E+08		5.00E-02									
ETTP	14.03	K-1413 Building Debris	1.10E+09		1.50E-01									
ETTP	14.04	K-1303 Metal Debris	1.61E+08											
ETTP	14.05	K-1300 Stack Debris	1.97E+08		2.00E-02									

Table A-5. Radionuclide Concentration Data Set (Continued)

*Units in pCi/g

Site	Waste Lot	WL Name	Net Weight (g)	Ag-110m	Am-241	Am-243	Bi-214	C-14	Cm-242	Cm-243	Cm-244	Cm-245	Cm-246	Cm-247
ETTP	14.06	K-1413 Process Piping and Equipment	7.78E+07		1.00E-02									
ETTP	14.07	Overhead Fluorine Pipelines and K-1301/K-1407 Metal Debris	2.60E+07		1.00E-02									
ETTP	14.08	K-1301, K-1405, and K-1407 Asbestos	9.08E+06		1.75E+00									
ETTP	14.11	K-1420 Equipment and Building Debris	5.28E+09											
ETTP	14.14	K-1401/K-723 R4	2.43E+10		8.67E-02									
ETTP	14.15	K-1420 Calciner	5.32E+07		6.74E-01									
ETTP	14.16	Main Plant D&D Housekeeping R0	1.53E+07											
ETTP	14.17	UF6 Cylinders Wooden Saddles	2.88E+08											
ETTP	14.21	K-1066-G Scrap, Debris and Abandoned Equipment	5.12E+08											
Offsite	24.0	ACAP RA	3.87E+10											
Offsite	24.01	ACAP Debris	2.46E+06											
Offsite	24.02	ACAP Soil	1.30E+09											
ETTP	30.01	ETTP OD RSM1 R1	2.07E+09											
ETTP	30.02	ETTP OD CD	8.38E+08											
ETTP	30.03	ETTP OD RSM 5	6.00E+07											
ETTP	30.06	ETTP OD DAW R1	1.18E+09											
ETTP	30.07	OD VRR-1	1.60E+09					8.60E-02						
ETTP	30.08	OD VRR-2	4.81E+08		4.82E+01			6.02E+00						
ETTP	30.09	ETTP OD DAW-2 R1	2.19E+08											
ETTP	30.10	ETTP OD DAW-3	1.78E+08		4.79E+02									
Offsite	30.12	DWI 901 Stored Soils	1.83E+08		5.13E-01									
ETTP	30.13	ETTP Outdoor Solids	3.53E+08		1.35E-01									
ETTP	62.01	Poplar Creek Process Facilities Building Debris and Miscellaneous Materials	6.46E+07		4.02E-01									
ETTP	62.04	K-413 Building Debris and Process Equipment	7.17E+08											
ETTP	62.05	K-1231 and K-1233 Demolition Debris	1.68E+09											
ETTP	65.01	K-770 Scrap Yard	4.16E+10											
ETTP	65.02	K-770 14 Series Piles	9.56E+08											
ETTP	65.03	K-770 B-25 Boxes	8.81E+08					1.32E+00						
ETTP	66.01	KAFaD Group 1 Buildings K-724 and K-725 Excess Material Project	2.86E+06											
ETTP	66.04	K-1064 Peninsula Area	1.31E+08		5.35E-01									
ETTP	66.06	K-1025 Buildings Structural Wood	3.40E+07											
ETTP	66.07	DBOS Building Debris and Misc Materials R2	9.78E+09		2.45E+00									
ETTP	73.01	Centrifuge Equipment U	8.57E+07											
ETTP	73.02	Centrifuge Equipment C	9.73E+07											
ORNL	80.01	HFIR Impoundments	8.49E+09		1.32E+01			6.77E+00						
ORNL	80.02	HRE Pond Sediments	6.88E+09											
ORNL	81.01	T1/T2 R4 HFIR Tanks Debris R5	1.01E+09		5.33E+01			8.19E-01						
ORNL	81.02	22-Trench Debris & Secondary Waste	8.24E+06		1.82E+00									
ORNL	84.01	GAAT RA Waste R3	1.22E+09		6.91E+01			1.21E+01						
ORNL	84.02	ITRA Waste R1	3.15E+08		2.39E+02	8.56E+00		8.97E-02		1.28E+02	1.83E+04	2.57E+00	5.43E+00	2.68E-05
ORNL	84.03	W1-A B12 Box Soil	3.18E+08		9.98E+02			9.75E+00						
ORNL	84.04	W1-A B12 Box Soil-1	1.79E+08		3.94E+03			1.23E+01						
ORNL	84.05	RASW Inactive Tanks Secondary Equipment	1.81E+06		3.41E+01			5.44E-03						
ORNL	84.06	HIC-1 FFA Inactive Tanks	4.56E+06		8.47E+02	6.46E+00		7.28E-02		9.74E+01	4.58E+04	1.93E+00	4.23E+00	2.09E-05
ORNL	87.01	SIOU Bricks	6.26E+09		2.84E+02			3.23E+02						

Table A-5. Radionuclide Concentration Data Set (Continued)

**Units in pCi/g*

Site	Waste Lot	WL Name	Net Weight (g)	Ag-110m	Am-241	Am-243	Bi-214	C-14	Cm-242	Cm-243	Cm-244	Cm-245	Cm-246	Cm-247
ORNL	87.02	SIOU Debris R2	1.00E+09		2.89E+01			3.27E+01						
ORNL	89.01	MSRE Remedial Action	4.69E+07		4.12E+01									
ORNL	102.01	Building 3026 Debris and Misc Material	8.53E+08					2.00E+00						
ORNL	111.01	Melton Valley Weir Cleanout and Bank Stabilization Project	6.63E+08		8.57E+00			7.79E+00						
Y-12	114.01	Jack Case Center Contaminated Force Main	1.96E+07											
Offsite	145.01	David Witherspoon, Inc. 901 Site- Candora Soil	1.34E+10		2.63E-01			7.57E+00						
Offsite	145.02	DWI 901 Scrap Metal and Debris R2	1.81E+09											
Offsite	145.03	DWI 901 Site Building and Miscellaneous Debris	4.90E+08		1.78E-01			7.40E+00						
Offsite	145.04	David Witherspoon, Inc. 901 Site Soil	7.29E+10		3.89E-01									
Offsite	146.01	DWI 1630 Soil and Incidental Debris R6	1.35E+11		2.80E+00									
Offsite	146.02	DWI 1630 Site: Drums and Drum Soils	4.96E+08		2.80E+00									
ORNL	149.01	NHF D&D	4.64E+09		6.67E+01			3.29E+00						
ORNL	149.02	NHF Well P&A Debris R2	5.98E+07		1.00E+03			1.12E+01						
ORNL	149.03	HRE Ancillary Facilities	1.16E+08											
ORNL	149.04	HRE Waste Evaporator System and Sampling Station Waste R2	2.12E+08					5.30E-02						
ORNL	149.06	NHF Well P&A Primary Waste	5.94E+07		6.18E+00			2.77E-01						
ORNL	149.07	NHF Process	2.90E+07		1.69E+03			1.39E+02						
ORNL	149.09	7841 Scrap Yard Debris and Equipment	1.20E+09		7.40E+02	6.12E-01		4.50E+00	1.63E-01		9.44E+03			
ORNL	149.10	MV Tanks 454 and 455	9.91E+06		2.41E+03			1.78E-03						
ORNL	155.01	K-1070-B Burial Ground Remediation	1.12E+11		1.08E+00									
ETTP	155.02	BOS Lab Facilities Miscellaneous Wastes	1.83E+09		2.47E+00									
ETTP	155.03	BOS Lab Area Soil	1.56E+08		1.31E+00									
ETTP	155.04	BOS Lab Area Acid Pits and Piping	1.52E+08		1.18E-01									
ETTP	155.05	K-1015-A Laundry Pit	1.33E+08											
ETTP	157.01	K-29 Building D&D	3.63E+10		6.51E-02									
ORNL	164.01	Hot Storage Garden R1	3.12E+07		3.76E+00									
ORNL	167.01	Epicor II Lysimeters, MV Soils & Sediments	7.73E+08		6.59E+00			1.90E-01						
ORNL	200.03	Facilities 3504, 3508, 3541, 3550 and 3592 Building Debris and Misc Material	5.09E+07											
ORNL	200.999	Comingled Waste Lot that includes Waste Lots 200.1, 2001.2 and 200.4	2.76E+09		1.27E+01			6.19E+00						
ORNL	201.01	Miscellaneous Materials from Buildings 2001, 2019 and 2024	9.07E+06		3.17E-01	3.95E-01		3.73E+00						
ORNL	201.02	Building 2000 Structure and Contents	1.19E+09		3.47E-01	4.35E-01		2.27E+00						
ORNL	201.03	Slabs - Drains, Pipes and Slabs	5.58E+09		1.32E-01	1.45E-01	3.89E-01	1.60E+00		7.00E-02		4.00E-03		4.00E-03
ORNL	203.01	Buildings 2011, 2017 and 3044	6.34E+08											
ORNL	207.01	3026 Hot Cells	2.47E+08	4.76E-01	1.83E-01			1.10E+00		1.40E-01		7.00E-02		1.47E-01
Y-12	301.01	Capability Unit 29 Legacy Material Bldg 9201-5	1.05E+08											
Y-12	301.02	Legacy Material from Building 9201-5	4.98E+07											
Y-12	301.04	Legacy Material from Building 9201-5 First and Third Floor Beryllium Areas	1.10E+09											
Y-12	303.01	Old Salvage Yard Piles SY-HI (Areas 1 and 2)	7.39E+09											
Y-12	303.02	Old Salvage Yard SY-H1 Area 1 Pile, Rev 1	1.41E+09											
Y-12	304.01	Building 9211 D&D	9.04E+09					1.34E+01						
Y-12	304.02	Building 9769 D&D	1.86E+09		1.63E-01									
ETTP	401.01	K-33 Building Debris and Misc Material	2.00E+11											
ETTP	997.01	Main Plant LR/LC Buildings	2.52E+09		8.77E-02									
ETTP	997.02	K-1035 Demolition Debris	5.90E+09											

Table A-5. Radionuclide Concentration Data Set (Continued)

**Units in pCi/g*

Site	Waste Lot	WL Name	Net Weight (g)	Co-57	Co-60	Cs-134	Cs-137	Eu-152	Eu-154	Eu-155	F-59	H-3	I-129	K-40
Y-12	1.0	BYBY RA	8.66E+10											
ORNL	2.01	SWSA 4 Remedial Action IHP-1 RA	2.22E+10									5.31E+01	2.10E+00	
ETTP	3.00	K-1070-A RA	2.59E+10											
ETTP	4.02	PWR K-1085-401 RA	5.93E+07											
ETTP	4.03	Blair Quarry Soils	1.35E+10											
ETTP	4.05	K-710	2.80E+08											
ETTP	4.06	K-1085 Old Firehouse Burn Area Drum Burial Site, Area 6 Soils	1.51E+07											
ETTP	4.08	Duct Island Soil Mounds	1.47E+08											
ETTP	4.11	K-711/K-766 Debris and Soils	5.37E+08											
ETTP	4.12	K-770 Scrap Yard Soils	8.81E+10											
ETTP	4.14	K-1093 Scrap Yard Debris	6.63E+08									2.95E+01		
ETTP	6.01	K25 HMA-1 DD R2	3.41E+09											
ETTP	6.02	K27 Units 1-7 ACM R2 (ARRA)	3.87E+08											
ETTP	6.03	K25 HMA-2 DD Rev 2	1.91E+08											
ETTP	6.04	K-27 Units 402-8 & 402-9 Hazardous Materials Abatement	5.90E+07											
ETTP	6.06	K-25 Bldg Area 6 PER R1	2.13E+08											
ETTP	6.12	K-25 Bldg Non-Purge Ext. Transite	6.80E+08											
ETTP	6.13	K-25 Bldg Area 5.1 PER R0	1.36E+08											
ETTP	6.14	K-1232 Tank Farm Miscellaneous Debris R0	7.86E+07											
ETTP	6.16	K-601 Misc Debris	1.07E+09											
ETTP	6.17	Building K-1030 Debris	9.11E+08											
ETTP	6.18	Building K-1024 Debris	8.51E+08											
ETTP	6.19	K-25/K-27 Bldg Struc Debris	1.92E+09											
ETTP	6.27	K-25/K-27 EMR Debris Material (K-27 ARRA)	2.74E+09											
ETTP	6.28	K-25 Lead Based Pain Debris	5.54E+08											
ETTP	6.31	K-25 Building Northwest Bridge	5.25E+08											
ETTP	6.41	K-25 West Side Compressors Group 1 R1	6.11E+09											
ETTP	6.42	K-25 West Side Converters Group 1 R1	1.02E+09											
ETTP	6.43	K-25 West Side Converters Group 1 R1	3.49E+09											
ETTP	6.58	K25 East and North Low-Risk Converters	3.03E+09											
ETTP	6.59	Building K-25 East Wing and North End Low-Risk Compressors	2.08E+09											
ETTP	6.60	K-25 West Wing Post Mined Low-Risk Compressors	8.48E+07											
ETTP	6.998	Comingled waste lot that inlcudes WL's 6.49-6.57	4.63E+10											
ETTP	6.999	Comingled waste lot that includes WL's 6.32, 6.33, 6.34, 6.35, 6.38, 6.39, 6.45, 6.46, 6.47, 6.48	1.66E+11											
ETTP	8.02	Building K-33 Concrete Pedestal	1.14E+10											
ETTP	8.05	BNFL Compressor Blades	5.89E+08											
ETTP	8.07	BNFL K-31 Concrete Pedestal Waste Lot	4.61E+09											
ETTP	8.08	K-33 Concrete Floor Scabble	2.27E+09											
ETTP	8.11	Non-PG/Non-Fissile Components	2.66E+08											
ORNL	10.01	Old Hydrofracture Facility Remediation Wastes (Containers)	7.04E+08									7.45E+00	1.53E-02	
ETTP	14.01	K-1303 Building Debris	1.92E+09											
ETTP	14.02	K-1302 Building Debris	3.06E+08											
ETTP	14.03	K-1413 Building Debris	1.10E+09											
ETTP	14.04	K-1303 Metal Debris	1.61E+08											
ETTP	14.05	K-1300 Stack Debris	1.97E+08											

Table A-5. Radionuclide Concentration Data Set (Continued)

**Units in pCi/g*

Site	Waste Lot	WL Name	Net Weight (g)	Co-57	Co-60	Cs-134	Cs-137	Eu-152	Eu-154	Eu-155	F-59	H-3	I-129	K-40
ETTP	14.06	K-1413 Process Piping and Equipment	7.78E+07											
ETTP	14.07	Overhead Fluorine Pipelines and K-1301/K-1407 Metal Debris	2.60E+07											
ETTP	14.08	K-1301, K-1405, and K-1407 Asbestos	9.08E+06											
ETTP	14.11	K-1420 Equipment and Building Debris	5.28E+09											
ETTP	14.14	K-1401/K-723 R4	2.43E+10											
ETTP	14.15	K-1420 Calciner	5.32E+07											
ETTP	14.16	Main Plant D&D Housekeeping R0	1.53E+07											
ETTP	14.17	UF6 Cylinders Wooden Saddles	2.88E+08											
ETTP	14.21	K-1066-G Scrap, Debris and Abandoned Equipment	5.12E+08											
Offsite	24.0	ACAP RA	3.87E+10											
Offsite	24.01	ACAP Debris	2.46E+06											
Offsite	24.02	ACAP Soil	1.30E+09											
ETTP	30.01	ETTP OD RSM1 R1	2.07E+09											
ETTP	30.02	ETTP OD CD	8.38E+08											
ETTP	30.03	ETTP OD RSM 5	6.00E+07											
ETTP	30.06	ETTP OD DAW R1	1.18E+09											
ETTP	30.07	OD VRR-1	1.60E+09									4.58E+00		
ETTP	30.08	OD VRR-2	4.81E+08									2.23E+02		
ETTP	30.09	ETTP OD DAW-2 R1	2.19E+08											
ETTP	30.10	ETTP OD DAW-3	1.78E+08										4.50E-03	
Offsite	30.12	DWI 901 Stored Soils	1.83E+08											
ETTP	30.13	ETTP Outdoor Solids	3.53E+08											
ETTP	62.01	Poplar Creek Process Facilities Building Debris and Miscellaneous Materials	6.46E+07											
ETTP	62.04	K-413 Building Debris and Process Equipment	7.17E+08											
ETTP	62.05	K-1231 and K-1233 Demolition Debris	1.68E+09											
ETTP	65.01	K-770 Scrap Yard	4.16E+10											
ETTP	65.02	K-770 14 Series Piles	9.56E+08											
ETTP	65.03	K-770 B-25 Boxes	8.81E+08										6.33E-01	
ETTP	66.01	KAFaD Group 1 Buildings K-724 and K-725 Excess Material Project	2.86E+06											
ETTP	66.04	K-1064 Peninsula Area	1.31E+08											
ETTP	66.06	K-1025 Buildings Structural Wood	3.40E+07											
ETTP	66.07	DBOS Building Debris and Misc Materials R2	9.78E+09											
ETTP	73.01	Centrifuge Equipment U	8.57E+07											
ETTP	73.02	Centrifuge Equipment C	9.73E+07											
ORNL	80.01	HFIR Impoundments	8.49E+09									6.98E+02		
ORNL	80.02	HRE Pond Sediments	6.88E+09											
ORNL	81.01	T1/T2 R4 HFIR Tanks Debris R5	1.01E+09									1.22E-02	5.26E-05	
ORNL	81.02	22-Trench Debris & Secondary Waste	8.24E+06											
ORNL	84.01	GAAT RA Waste R3	1.22E+09									1.80E-01	7.71E-04	
ORNL	84.02	ITRA Waste R1	3.15E+08		1.82E+02		1.98E+03	7.08E+02	5.51E+02	1.35E+03		1.02E-02	1.49E-05	
ORNL	84.03	W1-A B12 Box Soil	3.18E+08											
ORNL	84.04	W1-A B12 Box Soil-1	1.79E+08											
ORNL	84.05	RASW Inactive Tanks Secondary Equipment	1.81E+06									5.94E-04	7.89E-07	
ORNL	84.06	HIC-1 FFA Inactive Tanks	4.56E+06		1.88E+00		8.93E+03	2.98E+01	6.64E+00	8.93E+00		7.95E-03	1.05E-05	
ORNL	87.01	SIOU Bricks	6.26E+09											

Table A-5. Radionuclide Concentration Data Set (Continued)

*Units in pCi/g

Site	Waste Lot	WL Name	Net Weight (g)	Co-57	Co-60	Cs-134	Cs-137	Eu-152	Eu-154	Eu-155	F-59	H-3	I-129	K-40
ORNL	87.02	SIOU Debris R2	1.00E+09											
ORNL	89.01	MSRE Remedial Action	4.69E+07									3.78E+03	9.46E-02	
ORNL	102.01	Building 3026 Debris and Misc Material	8.53E+08									2.67E+00		
ORNL	111.01	Melton Valley Weir Cleanout and Bank Stabilization Project	6.63E+08		6.57E+03		3.83E+03					6.06E+02		
Y-12	114.01	Jack Case Center Contaminated Force Main	1.96E+07											
Offsite	145.01	David Witherspoon, Inc. 901 Site- Candora Soil	1.34E+10											
Offsite	145.02	DWI 901 Scrap Metal and Debris R2	1.81E+09											
Offsite	145.03	DWI 901 Site Building and Miscellaneous Debris	4.90E+08											
Offsite	145.04	David Witherspoon, Inc. 901 Site Soil	7.29E+10											
Offsite	146.01	DWI 1630 Soil and Incidental Debris R6	1.35E+11											
Offsite	146.02	DWI 1630 Site: Drums and Drum Soils	4.96E+08											
ORNL	149.01	NHF D&D	4.64E+09											
ORNL	149.02	NHF Well P&A Debris R2	5.98E+07									5.14E+00	4.36E-02	
ORNL	149.03	HRE Ancillary Facilities	1.16E+08				4.36E-01							
ORNL	149.04	HRE Waste Evaporator System and Sampling Station Waste R2	2.12E+08		6.16E+00		1.69E+04					1.68E+00	5.73E-03	
ORNL	149.06	NHF Well P&A Primary Waste	5.94E+07									1.95E-04	1.69E-05	
ORNL	149.07	NHF Process	2.90E+07									2.07E-01	8.85E-03	
ORNL	149.09	7841 Scrap Yard Debris and Equipment	1.20E+09		2.94E+02	2.48E+04	4.03E+04	4.57E+04	3.46E+04	9.44E+03		6.47E+00	1.04E-02	
ORNL	149.10	MV Tanks 454 and 455	9.91E+06									3.42E-02	4.06E+01	
ORNL	155.01	K-1070-B Burial Ground Remediation	1.12E+11											
ETTP	155.02	BOS Lab Facilities Miscellaneous Wastes	1.83E+09											
ETTP	155.03	BOS Lab Area Soil	1.56E+08											
ETTP	155.04	BOS Lab Area Acid Pits and Piping	1.52E+08											
ETTP	155.05	K-1015-A Laundry Pit	1.33E+08											
ETTP	157.01	K-29 Building D&D	3.63E+10											
ORNL	164.01	Hot Storage Garden R1	3.12E+07		4.93E+00		2.39E+04		1.46E+00					9.70E+00
ORNL	167.01	Epicor II Lysimeters, MV Soils & Sediments	7.73E+08									3.90E+03		
ORNL	200.03	Facilities 3504, 3508, 3541, 3550 and 3592 Building Debris and Misc Material	5.09E+07											
ORNL	200.999	Comingled Waste Lot that includes Waste Lots 200.1, 2001.2 and 200.4	2.76E+09											
ORNL	201.01	Miscellaneous Materials from Buildings 2001, 2019 and 2024	9.07E+06		1.26E-01		4.81E-01	6.16E-01	6.44E-01	2.70E-01		9.23E-01		1.60E+00
ORNL	201.02	Building 2000 Structure and Contents	1.19E+09		1.11E-01		1.23E+00	5.10E-01	5.27E-01	2.28E-01		5.16E-01		1.40E+00
ORNL	201.03	Slabs - Drains, Pipes and Slabs	5.58E+09		7.30E-02		7.30E-02	2.13E-01	2.42E-01	1.18E-01		3.42E+00	2.28E+00	4.78E+00
ORNL	203.01	Buildings 2011, 2017 and 3044	6.34E+08									6.28E+01		
ORNL	207.01	3026 Hot Cells	2.47E+08	1.48E-01	1.92E+01		6.04E+00	1.08E+00	1.33E+00		1.49E+00	3.32E+02	1.51E+00	
Y-12	301.01	Capability Unit 29 Legacy Material Bldg 9201-5	1.05E+08											
Y-12	301.02	Legacy Material from Building 9201-5	4.98E+07											
Y-12	301.04	Legacy Material from Building 9201-5 First and Third Floor Beryllium Areas	1.10E+09											
Y-12	303.01	Old Salvage Yard Piles SY-HI (Areas 1 and 2)	7.39E+09											
Y-12	303.02	Old Salvage Yard SY-H1 Area 1 Pile, Rev 1	1.41E+09											
Y-12	304.01	Building 9211 D&D	9.04E+09									3.37E+01		
Y-12	304.02	Building 9769 D&D	1.86E+09									1.81E+00		
ETTP	401.01	K-33 Building Debris and Misc Material	2.00E+11											
ETTP	997.01	Main Plant LR/LC Buildings	2.52E+09											
ETTP	997.02	K-1035 Demolition Debris	5.90E+09											

Table A-5. Radionuclide Concentration Data Set (Continued)

**Units in pCi/g*

Site	Waste Lot	WL Name	Net Weight (g)	Kr-85	Mn-54	Nb-94	Ni-59	Ni-63	Np-237	Pb-210	Pb-214	Pm-147	Pu-238	Pu-239
Y-12	1.0	BYBY RA	8.66E+10						3.55E-01					1.00E-01
ORNL	2.01	SWSA 4 Remedial Action IHP-1 RA	2.22E+10						7.60E-01					5.61E+01
ETTP	3.00	K-1070-A RA	2.59E+10						1.95E-01					1.00E-01
ETTP	4.02	PWR K-1085-401 RA	5.93E+07											
ETTP	4.03	Blair Quarry Soils	1.35E+10						6.23E-01					4.35E-02
ETTP	4.05	K-710	2.80E+08						6.26E-02					6.00E-02
ETTP	4.06	K-1085 Old Firehouse Burn Area Drum Burial Site, Area 6 Soils	1.51E+07											1.06E-01
ETTP	4.08	Duct Island Soil Mounds	1.47E+08						4.50E-01					1.37E+00
ETTP	4.11	K-711/K-766 Debris and Soils	5.37E+08											
ETTP	4.12	K-770 Scrap Yard Soils	8.81E+10											
ETTP	4.14	K-1093 Scrap Yard Debris	6.63E+08											
ETTP	6.01	K25 HMA-1 DD R2	3.41E+09						1.32E-01					2.79E-02
ETTP	6.02	K27 Units 1-7 ACM R2 (ARRA)	3.87E+08						1.62E-01					5.67E-02
ETTP	6.03	K25 HMA-2 DD Rev 2	1.91E+08						5.38E-01					4.22E-01
ETTP	6.04	K-27 Units 402-8 & 402-9 Hazardous Materials Abatement	5.90E+07						4.80E-02					5.87E-02
ETTP	6.06	K-25 Bldg Area 6 PER R1	2.13E+08						3.63E-01					
ETTP	6.12	K-25 Bldg Non-Purge Ext. Transite	6.80E+08						1.60E-02					1.00E-02
ETTP	6.13	K-25 Bldg Area 5.1 PER R0	1.36E+08						8.90E-01					5.62E-02
ETTP	6.14	K-1232 Tank Farm Miscellaneous Debris R0	7.86E+07											
ETTP	6.16	K-601 Misc Debris	1.07E+09											
ETTP	6.17	Building K-1030 Debris	9.11E+08											1.71E-01
ETTP	6.18	Building K-1024 Debris	8.51E+08						1.40E-01					
ETTP	6.19	K-25/K-27 Bldg Struc Debris	1.92E+09						2.96E-01					2.92E-01
ETTP	6.27	K-25/K-27 EMR Debris Material (K-27 ARRA)	2.74E+09						1.71E-01					2.74E+00
ETTP	6.28	K-25 Lead Based Pain Debris	5.54E+08											
ETTP	6.31	K-25 Building Northwest Bridge	5.25E+08											
ETTP	6.41	K-25 West Side Compressors Group 1 R1	6.11E+09											
ETTP	6.42	K-25 West Side Converters Group 1 R1	1.02E+09											
ETTP	6.43	K-25 West Side Converters Group 1 R1	3.49E+09											
ETTP	6.58	K25 East and North Low-Risk Converters	3.03E+09											
ETTP	6.59	Building K-25 East Wing and North End Low-Risk Compressors	2.08E+09						2.58E-01					
ETTP	6.60	K-25 West Wing Post Mined Low-Risk Compressors	8.48E+07											
ETTP	6.998	Comingled waste lot that inlcudes WL's 6.49-6.57	4.63E+10						1.28E-01					7.21E-03
ETTP	6.999	Comingled waste lot that includes WL's 6.32, 6.33, 6.34, 6.35, 6.38, 6.39, 6.45, 6.46, 6.47, 6.48	1.66E+11											
ETTP	8.02	Building K-33 Concrete Pedestal	1.14E+10											2.33E-01
ETTP	8.05	BNFL Compressor Blades	5.89E+08						3.91E-01					8.43E-02
ETTP	8.07	BNFL K-31 Concrete Pedestal Waste Lot	4.61E+09						1.32E-02					3.20E-02
ETTP	8.08	K-33 Concrete Floor Scabble	2.27E+09						6.83E-02					2.52E+00
ETTP	8.11	Non-PG/Non-Fissile Components	2.66E+08						3.83E-01					8.33E-02
ORNL	10.01	Old Hydrofracture Facility Remediation Wastes (Containers)	7.04E+08						1.49E+00					1.05E+01
ETTP	14.01	K-1303 Building Debris	1.92E+09											6.00E-02
ETTP	14.02	K-1302 Building Debris	3.06E+08						4.00E-02					4.00E-02
ETTP	14.03	K-1413 Building Debris	1.10E+09						3.00E-02					8.00E-02
ETTP	14.04	K-1303 Metal Debris	1.61E+08											6.00E-02
ETTP	14.05	K-1300 Stack Debris	1.97E+08						1.60E-01					5.00E-02

Table A-5. Radionuclide Concentration Data Set (Continued)

**Units in pCi/g*

Site	Waste Lot	WL Name	Net Weight (g)	Kr-85	Mn-54	Nb-94	Ni-59	Ni-63	Np-237	Pb-210	Pb-214	Pm-147	Pu-238	Pu-239
ETTP	14.06	K-1413 Process Piping and Equipment	7.78E+07						9.00E-02					4.30E-01
ETTP	14.07	Overhead Fluorine Pipelines and K-1301/K-1407 Metal Debris	2.60E+07											
ETTP	14.08	K-1301, K-1405, and K-1407 Asbestos	9.08E+06						1.62E+00					4.40E-01
ETTP	14.11	K-1420 Equipment and Building Debris	5.28E+09											
ETTP	14.14	K-1401/K-723 R4	2.43E+10						2.26E-01					3.93E-02
ETTP	14.15	K-1420 Calciner	5.32E+07						9.67E+00					6.71E+00
ETTP	14.16	Main Plant D&D Housekeeping R0	1.53E+07											
ETTP	14.17	UF6 Cylinders Wooden Saddles	2.88E+08											
ETTP	14.21	K-1066-G Scrap, Debris and Abandoned Equipment	5.12E+08											1.63E-01
Offsite	24.0	ACAP RA	3.87E+10											
Offsite	24.01	ACAP Debris	2.46E+06											
Offsite	24.02	ACAP Soil	1.30E+09											
ETTP	30.01	ETTP OD RSM1 R1	2.07E+09						1.96E+00					8.01E-01
ETTP	30.02	ETTP OD CD	8.38E+08						6.41E+00					
ETTP	30.03	ETTP OD RSM 5	6.00E+07						2.80E-02					3.00E-03
ETTP	30.06	ETTP OD DAW R1	1.18E+09						2.75E-01					
ETTP	30.07	OD VRR-1	1.60E+09											6.80E-01
ETTP	30.08	OD VRR-2	4.81E+08						1.13E+01					2.29E+00
ETTP	30.09	ETTP OD DAW-2 R1	2.19E+08						1.35E-01					
ETTP	30.10	ETTP OD DAW-3	1.78E+08						1.68E-02					4.94E+01
Offsite	30.12	DWI 901 Stored Soils	1.83E+08						1.17E+02					
ETTP	30.13	ETTP Outdoor Solids	3.53E+08						2.20E-02					1.22E-02
ETTP	62.01	Poplar Creek Process Facilities Building Debris and Miscellaneous Materials	6.46E+07						6.80E-02					
ETTP	62.04	K-413 Building Debris and Process Equipment	7.17E+08											2.43E-02
ETTP	62.05	K-1231 and K-1233 Demolition Debris	1.68E+09											6.29E-02
ETTP	65.01	K-770 Scrap Yard	4.16E+10											
ETTP	65.02	K-770 14 Series Piles	9.56E+08											
ETTP	65.03	K-770 B-25 Boxes	8.81E+08						3.74E-01					
ETTP	66.01	KAFaD Group 1 Buildings K-724 and K-725 Excess Material Project	2.86E+06											
ETTP	66.04	K-1064 Peninsula Area	1.31E+08						7.44E+00					2.71E-01
ETTP	66.06	K-1025 Buildings Structural Wood	3.40E+07											
ETTP	66.07	DBOS Building Debris and Misc Materials R2	9.78E+09						1.45E-01					1.17E+00
ETTP	73.01	Centrifuge Equipment U	8.57E+07											
ETTP	73.02	Centrifuge Equipment C	9.73E+07											
ORNL	80.01	HFIR Impoundments	8.49E+09											4.19E+00
ORNL	80.02	HRE Pond Sediments	6.88E+09											
ORNL	81.01	T1/T2 R4 HFIR Tanks Debris R5	1.01E+09						1.43E-02					3.28E+01
ORNL	81.02	22-Trench Debris & Secondary Waste	8.24E+06											2.00E-01
ORNL	84.01	GAAT RA Waste R3	1.22E+09						2.12E-01					4.54E+01
ORNL	84.02	ITRA Waste R1	3.15E+08						2.33E-02				6.62E+02	1.18E+02
ORNL	84.03	W1-A B12 Box Soil	3.18E+08						6.16E+00					1.03E+03
ORNL	84.04	W1-A B12 Box Soil-1	1.79E+08						1.31E+01					4.05E+03
ORNL	84.05	RASW Inactive Tanks Secondary Equipment	1.81E+06						1.54E-03					3.99E+01
ORNL	84.06	HIC-1 FFA Inactive Tanks	4.56E+06						2.06E-02				1.24E+04	1.05E+03
ORNL	87.01	SIOU Bricks	6.26E+09						1.42E+00					6.93E+02

Table A-5. Radionuclide Concentration Data Set (Continued)

**Units in pCi/g*

Site	Waste Lot	WL Name	Net Weight (g)	Kr-85	Mn-54	Nb-94	Ni-59	Ni-63	Np-237	Pb-210	Pb-214	Pm-147	Pu-238	Pu-239
ORNL	87.02	SIOU Debris R2	1.00E+09						1.45E-01					8.95E+01
ORNL	89.01	MSRE Remedial Action	4.69E+07						5.52E-01					1.17E+02
ORNL	102.01	Building 3026 Debris and Misc Material	8.53E+08											
ORNL	111.01	Melton Valley Weir Cleanout and Bank Stabilization Project	6.63E+08										9.50E-01	4.24E+00
Y-12	114.01	Jack Case Center Contaminated Force Main	1.96E+07						2.51E-01					1.14E-01
Offsite	145.01	David Witherspoon, Inc. 901 Site- Candora Soil	1.34E+10											1.32E+00
Offsite	145.02	DWI 901 Scrap Metal and Debris R2	1.81E+09											9.82E-02
Offsite	145.03	DWI 901 Site Building and Miscellaneous Debris	4.90E+08						9.00E-02					3.21E-01
Offsite	145.04	David Witherspoon, Inc. 901 Site Soil	7.29E+10						8.48E-02					1.74E+00
Offsite	146.01	DWI 1630 Soil and Incidental Debris R6	1.35E+11						8.48E-02					1.91E-01
Offsite	146.02	DWI 1630 Site: Drums and Drum Soils	4.96E+08						8.48E-02					1.91E-01
ORNL	149.01	NHF D&D	4.64E+09											3.25E+02
ORNL	149.02	NHF Well P&A Debris R2	5.98E+07						4.25E+00					
ORNL	149.03	HRE Ancillary Facilities	1.16E+08										1.79E-01	
ORNL	149.04	HRE Waste Evaporator System and Sampling Station Waste R2	2.12E+08										5.10E+00	3.34E+00
ORNL	149.06	NHF Well P&A Primary Waste	5.94E+07						4.70E-03					1.35E+00
ORNL	149.07	NHF Process	2.90E+07						2.43E+00					1.34E+03
ORNL	149.09	7841 Scrap Yard Debris and Equipment	1.20E+09					1.26E+02	5.43E-01				2.31E+02	1.41E+02
ORNL	149.10	MV Tanks 454 and 455	9.91E+06						1.07E-01					1.39E+03
ORNL	155.01	K-1070-B Burial Ground Remediation	1.12E+11											
ETTP	155.02	BOS Lab Facilities Miscellaneous Wastes	1.83E+09											1.17E+00
ETTP	155.03	BOS Lab Area Soil	1.56E+08						1.14E-01					1.52E+00
ETTP	155.04	BOS Lab Area Acid Pits and Piping	1.52E+08											
ETTP	155.05	K-1015-A Laundry Pit	1.33E+08											
ETTP	157.01	K-29 Building D&D	3.63E+10						6.73E-02					3.93E-02
ORNL	164.01	Hot Storage Garden R1	3.12E+07							1.35E+02			3.06E+00	1.63E+01
ORNL	167.01	Epicor II Lysimeters, MV Soils & Sediments	7.73E+08											4.66E+00
ORNL	200.03	Facilities 3504, 3508, 3541, 3550 and 3592 Building Debris and Misc Material	5.09E+07											1.56E+00
ORNL	200.999	Comingled Waste Lot that includes Waste Lots 200.1, 2001.2 and 200.4	2.76E+09											9.12E+01
ORNL	201.01	Miscellaneous Materials from Buildings 2001, 2019 and 2024	9.07E+06			1.08E-01			3.70E-01				2.62E-01	3.13E-01
ORNL	201.02	Building 2000 Structure and Contents	1.19E+09						4.01E-01				2.96E-01	4.57E-01
ORNL	201.03	Slabs - Drains, Pipes and Slabs	5.58E+09			6.20E-02			1.28E-01	1.76E+00	4.02E-01		1.13E-01	1.26E-01
ORNL	203.01	Buildings 2011, 2017 and 3044	6.34E+08											
ORNL	207.01	3026 Hot Cells	2.47E+08	1.04E+02	8.47E-01	4.69E-01	4.04E+01	6.23E+00	3.74E-01			1.00E+01	1.07E-01	4.65E-01
Y-12	301.01	Capability Unit 29 Legacy Material Bldg 9201-5	1.05E+08											
Y-12	301.02	Legacy Material from Building 9201-5	4.98E+07											
Y-12	301.04	Legacy Material from Building 9201-5 First and Third Floor Beryllium Areas	1.10E+09											
Y-12	303.01	Old Salvage Yard Piles SY-HI (Areas 1 and 2)	7.39E+09											
Y-12	303.02	Old Salvage Yard SY-H1 Area 1 Pile, Rev 1	1.41E+09											
Y-12	304.01	Building 9211 D&D	9.04E+09						2.15E-01					1.81E-01
Y-12	304.02	Building 9769 D&D	1.86E+09											
ETTP	401.01	K-33 Building Debris and Misc Material	2.00E+11											2.28E-01
ETTP	997.01	Main Plant LR/LC Buildings	2.52E+09						2.16E-01					4.21E-02
ETTP	997.02	K-1035 Demolition Debris	5.90E+09											

Table A-5. Radionuclide Concentration Data Set (Continued)

**Units in pCi/g*

Site	Waste Lot	WL Name	Net Weight (g)	Pu-240	Pu-241	Pu-242	Pu-244	Ra-226	Ra-228	Ru-106	Sr-90	Tc-99	Th-228	Th-229
Y-12	1.0	BYBY RA	8.66E+10									2.13E+01		
ORNL	2.01	SWSA 4 Remedial Action IHP-1 RA	2.22E+10									2.83E+00		
ETTP	3.00	K-1070-A RA	2.59E+10									6.34E+00		
ETTP	4.02	PWR K-1085-401 RA	5.93E+07											
ETTP	4.03	Blair Quarry Soils	1.35E+10									1.29E+00		
ETTP	4.05	K-710	2.80E+08									7.71E+00		
ETTP	4.06	K-1085 Old Firehouse Burn Area Drum Burial Site, Area 6 Soils	1.51E+07											
ETTP	4.08	Duct Island Soil Mounds	1.47E+08											
ETTP	4.11	K-711/K-766 Debris and Soils	5.37E+08									1.48E+00		
ETTP	4.12	K-770 Scrap Yard Soils	8.81E+10									1.08E+02		
ETTP	4.14	K-1093 Scrap Yard Debris	6.63E+08									2.57E+01		
ETTP	6.01	K25 HMA-1 DD R2	3.41E+09									1.22E+01		
ETTP	6.02	K27 Units 1-7 ACM R2 (ARRA)	3.87E+08									2.85E+01		
ETTP	6.03	K25 HMA-2 DD Rev 2	1.91E+08									1.64E+02		
ETTP	6.04	K-27 Units 402-8 & 402-9 Hazardous Materials Abatement	5.90E+07									1.92E+02		
ETTP	6.06	K-25 Bldg Area 6 PER R1	2.13E+08									6.65E+01		
ETTP	6.12	K-25 Bldg Non-Purge Ext. Transite	6.80E+08									3.67E+00		
ETTP	6.13	K-25 Bldg Area 5.1 PER R0	1.36E+08									2.89E+00		
ETTP	6.14	K-1232 Tank Farm Miscellaneous Debris R0	7.86E+07									8.48E-01		
ETTP	6.16	K-601 Misc Debris	1.07E+09									1.08E+01		
ETTP	6.17	Building K-1030 Debris	9.11E+08									1.66E+00		
ETTP	6.18	Building K-1024 Debris	8.51E+08									7.37E-01		
ETTP	6.19	K-25/K-27 Bldg Struc Debris	1.92E+09									1.87E+01		
ETTP	6.27	K-25/K-27 EMR Debris Material (K-27 ARRA)	2.74E+09									1.23E+01		
ETTP	6.28	K-25 Lead Based Pain Debris	5.54E+08									2.03E+00		
ETTP	6.31	K-25 Building Northwest Bridge	5.25E+08											
ETTP	6.41	K-25 West Side Compressors Group 1 R1	6.11E+09											
ETTP	6.42	K-25 West Side Converters Group 1 R1	1.02E+09											
ETTP	6.43	K-25 West Side Converters Group 1 R1	3.49E+09											
ETTP	6.58	K25 East and North Low-Risk Converters	3.03E+09									1.20E+02		
ETTP	6.59	Building K-25 East Wing and North End Low-Risk Compressors	2.08E+09									2.88E+02		
ETTP	6.60	K-25 West Wing Post Mined Low-Risk Compressors	8.48E+07											
ETTP	6.998	Comingled waste lot that inlcudes WL's 6.49-6.57	4.63E+10									1.45E+02		
ETTP	6.999	Comingled waste lot that includes WL's 6.32, 6.33, 6.34, 6.35, 6.38, 6.39, 6.45, 6.46, 6.47, 6.48	1.66E+11											
ETTP	8.02	Building K-33 Concrete Pedestal	1.14E+10									2.17E+00		
ETTP	8.05	BNFL Compressor Blades	5.89E+08									9.30E+01		
ETTP	8.07	BNFL K-31 Concrete Pedestal Waste Lot	4.61E+09									3.92E+00		
ETTP	8.08	K-33 Concrete Floor Scabble	2.27E+09									7.35E+00		
ETTP	8.11	Non-PG/Non-Fissile Components	2.66E+08									4.75E+01		
ORNL	10.01	Old Hydrofracture Facility Remediation Wastes (Containers)	7.04E+08									3.31E+00		
ETTP	14.01	K-1303 Building Debris	1.92E+09									4.92E+00		
ETTP	14.02	K-1302 Building Debris	3.06E+08									1.44E+00		
ETTP	14.03	K-1413 Building Debris	1.10E+09									1.29E+01		
ETTP	14.04	K-1303 Metal Debris	1.61E+08											
ETTP	14.05	K-1300 Stack Debris	1.97E+08									4.79E+00		

Table A-5. Radionuclide Concentration Data Set (Continued)

**Units in pCi/g*

Site	Waste Lot	WL Name	Net Weight (g)	Pu-240	Pu-241	Pu-242	Pu-244	Ra-226	Ra-228	Ru-106	Sr-90	Tc-99	Th-228	Th-229
ETTP	14.06	K-1413 Process Piping and Equipment	7.78E+07									6.38E+01		
ETTP	14.07	Overhead Fluorine Pipelines and K-1301/K-1407 Metal Debris	2.60E+07									3.50E-01		
ETTP	14.08	K-1301, K-1405, and K-1407 Asbestos	9.08E+06									1.01E+01		
ETTP	14.11	K-1420 Equipment and Building Debris	5.28E+09									4.89E+01		
ETTP	14.14	K-1401/K-723 R4	2.43E+10									1.28E+01		
ETTP	14.15	K-1420 Calciner	5.32E+07									3.75E+02		
ETTP	14.16	Main Plant D&D Housekeeping R0	1.53E+07											
ETTP	14.17	UF6 Cylinders Wooden Saddles	2.88E+08											
ETTP	14.21	K-1066-G Scrap, Debris and Abandoned Equipment	5.12E+08									3.44E+00		
Offsite	24.0	ACAP RA	3.87E+10											
Offsite	24.01	ACAP Debris	2.46E+06											
Offsite	24.02	ACAP Soil	1.30E+09											
ETTP	30.01	ETTP OD RSM1 R1	2.07E+09									1.98E+00		
ETTP	30.02	ETTP OD CD	8.38E+08									3.00E+01		
ETTP	30.03	ETTP OD RSM 5	6.00E+07									1.71E-01		
ETTP	30.06	ETTP OD DAW R1	1.18E+09									3.82E+01		
ETTP	30.07	OD VRR-1	1.60E+09									2.86E+01		
ETTP	30.08	OD VRR-2	4.81E+08									6.56E+02		
ETTP	30.09	ETTP OD DAW-2 R1	2.19E+08									4.83E+02		
ETTP	30.10	ETTP OD DAW-3	1.78E+08	1.08E+01								2.65E+01		
Offsite	30.12	DWI 901 Stored Soils	1.83E+08	1.83E+00								1.29E+02		
ETTP	30.13	ETTP Outdoor Solids	3.53E+08									2.98E+01		
ETTP	62.01	Poplar Creek Process Facilities Building Debris and Miscellaneous Materials	6.46E+07	1.38E-01								2.50E+00		
ETTP	62.04	K-413 Building Debris and Process Equipment	7.17E+08									3.22E+00		
ETTP	62.05	K-1231 and K-1233 Demolition Debris	1.68E+09									5.97E+00		
ETTP	65.01	K-770 Scrap Yard	4.16E+10									1.79E+01		
ETTP	65.02	K-770 14 Series Piles	9.56E+08									4.85E+01		
ETTP	65.03	K-770 B-25 Boxes	8.81E+08									7.98E+01		
ETTP	66.01	KAFaD Group 1 Buildings K-724 and K-725 Excess Material Project	2.86E+06											
ETTP	66.04	K-1064 Peninsula Area	1.31E+08									8.27E-01		
ETTP	66.06	K-1025 Buildings Structural Wood	3.40E+07											
ETTP	66.07	DBOS Building Debris and Misc Materials R2	9.78E+09									1.12E+02		
ETTP	73.01	Centrifuge Equipment U	8.57E+07									6.33E+00		
ETTP	73.02	Centrifuge Equipment C	9.73E+07									6.33E+00		
ORNL	80.01	HFIR Impoundments	8.49E+09											
ORNL	80.02	HRE Pond Sediments	6.88E+09											
ORNL	81.01	T1/T2 R4 HFIR Tanks Debris R5	1.01E+09									6.43E-01		
ORNL	81.02	22-Trench Debris & Secondary Waste	8.24E+06											
ORNL	84.01	GAAT RA Waste R3	1.22E+09	4.77E+00								9.51E+00		
ORNL	84.02	ITRA Waste R1	3.15E+08	4.15E+02	5.98E+01	7.90E-02	1.63E-08				8.26E+03	1.02E-02		
ORNL	84.03	W1-A B12 Box Soil	3.18E+08	5.54E+02								1.90E+00		
ORNL	84.04	W1-A B12 Box Soil-1	1.79E+08	2.18E+03								3.07E+00		
ORNL	84.05	RASW Inactive Tanks Secondary Equipment	1.81E+06	1.11E+02								1.07E-02		
ORNL	84.06	HIC-1 FFA Inactive Tanks	4.56E+06	5.69E+02	4.67E+01	6.40E-02	1.30E-08				2.75E+03	1.44E-01		
ORNL	87.01	SIOU Bricks	6.26E+09	1.31E+02								5.64E+00		

Table A-5. Radionuclide Concentration Data Set (Continued)

**Units in pCi/g*

Site	Waste Lot	WL Name	Net Weight (g)	Pu-240	Pu-241	Pu-242	Pu-244	Ra-226	Ra-228	Ru-106	Sr-90	Tc-99	Th-228	Th-229
ORNL	87.02	SIOU Debris R2	1.00E+09									5.63E-01		
ORNL	89.01	MSRE Remedial Action	4.69E+07	4.51E+01								3.80E+02		
ORNL	102.01	Building 3026 Debris and Misc Material	8.53E+08									7.44E+00		
ORNL	111.01	Melton Valley Weir Cleanout and Bank Stabilization Project	6.63E+08								2.25E+01		9.45E-01	
Y-12	114.01	Jack Case Center Contaminated Force Main	1.96E+07									6.14E+01		
Offsite	145.01	David Witherspoon, Inc. 901 Site- Candora Soil	1.34E+10									2.58E+00		
Offsite	145.02	DWI 901 Scrap Metal and Debris R2	1.81E+09									3.61E+00		
Offsite	145.03	DWI 901 Site Building and Miscellaneous Debris	4.90E+08									1.60E+00		
Offsite	145.04	David Witherspoon, Inc. 901 Site Soil	7.29E+10									1.60E+00		
Offsite	146.01	DWI 1630 Soil and Incidental Debris R6	1.35E+11									3.43E+00		
Offsite	146.02	DWI 1630 Site: Drums and Drum Soils	4.96E+08									3.43E+00		
ORNL	149.01	NHF D&D	4.64E+09									1.87E+00		
ORNL	149.02	NHF Well P&A Debris R2	5.98E+07									1.62E-04		
ORNL	149.03	HRE Ancillary Facilities	1.16E+08								7.07E-01		3.50E-01	
ORNL	149.04	HRE Waste Evaporator System and Sampling Station Waste R2	2.12E+08								1.52E+03	6.50E-02		
ORNL	149.06	NHF Well P&A Primary Waste	5.94E+07	1.31E+00								1.05E-01		
ORNL	149.07	NHF Process	2.90E+07	8.53E+01								1.53E+02		
ORNL	149.09	7841 Scrap Yard Debris and Equipment	1.20E+09		1.21E+03	4.59E-01	4.08E-02			6.27E+04	7.52E+04	2.06E+02		
ORNL	149.10	MV Tanks 454 and 455	9.91E+06	1.06E+03								5.82E-02		
ORNL	155.01	K-1070-B Burial Ground Remediation	1.12E+11									1.37E+01		
ETTP	155.02	BOS Lab Facilities Miscellaneous Wastes	1.83E+09									1.18E+01		
ETTP	155.03	BOS Lab Area Soil	1.56E+08									3.33E+00		
ETTP	155.04	BOS Lab Area Acid Pits and Piping	1.52E+08									7.31E+00		
ETTP	155.05	K-1015-A Laundry Pit	1.33E+08											
ETTP	157.01	K-29 Building D&D	3.63E+10									3.00E+02		
ORNL	164.01	Hot Storage Garden R1	3.12E+07						1.82E+00		1.50E+03			
ORNL	167.01	Epicor II Lysimeters, MV Soils & Sediments	7.73E+08											
ORNL	200.03	Facilities 3504, 3508, 3541, 3550 and 3592 Building Debris and Misc Material	5.09E+07									4.35E+00		
ORNL	200.999	Comingled Waste Lot that includes Waste Lots 200.1, 2001.2 and 200.4	2.76E+09									1.18E+01		
ORNL	201.01	Miscellaneous Materials from Buildings 2001, 2019 and 2024	9.07E+06					3.48E-01			3.57E+00	1.27E+00	6.07E-01	
ORNL	201.02	Building 2000 Structure and Contents	1.19E+09					9.87E-01			5.25E-01	1.61E+00	5.75E-01	
ORNL	201.03	Slabs - Drains, Pipes and Slabs	5.58E+09		2.54E-01			8.94E-01	7.89E-01		6.53E-01	4.46E+00	3.35E-01	4.00E-03
ORNL	203.01	Buildings 2011, 2017 and 3044	6.34E+08									1.68E+00		
ORNL	207.01	3026 Hot Cells	2.47E+08		2.19E+01						1.40E+02	5.51E+00		
Y-12	301.01	Capability Unit 29 Legacy Material Bldg 9201-5	1.05E+08											
Y-12	301.02	Legacy Material from Building 9201-5	4.98E+07											
Y-12	301.04	Legacy Material from Building 9201-5 First and Third Floor Beryllium Areas	1.10E+09											
Y-12	303.01	Old Salvage Yard Piles SY-HI (Areas 1 and 2)	7.39E+09											
Y-12	303.02	Old Salvage Yard SY-H1 Area 1 Pile, Rev 1	1.41E+09											
Y-12	304.01	Building 9211 D&D	9.04E+09									1.67E+00		
Y-12	304.02	Building 9769 D&D	1.86E+09									3.15E+00		
ETTP	401.01	K-33 Building Debris and Misc Material	2.00E+11									8.53E+00		
ETTP	997.01	Main Plant LR/LC Buildings	2.52E+09									1.30E+01		
ETTP	997.02	K-1035 Demolition Debris	5.90E+09											

Table A-5. Radionuclide Concentration Data Set (Continued)

**Units in pCi/g*

Site	Waste Lot	WL Name	Net Weight (g)	Th-230	Th-232	U-232	U-233	U-234	U-235	U-236	U-238	Zn-65
Y-12	1.0	BYBY RA	8.66E+10					4.70E+02	1.97E+01	7.38E+00	7.78E+02	
ORNL	2.01	SWSA 4 Remedial Action IHP-1 RA	2.22E+10					1.44E+01	2.32E+00	1.40E-01	5.51E+00	
ETTP	3.00	K-1070-A RA	2.59E+10					3.26E+02	9.79E+00	5.71E+00	1.98E+02	
ETTP	4.02	PWR K-1085-401 RA	5.93E+07									
ETTP	4.03	Blair Quarry Soils	1.35E+10					1.31E+01	9.22E-01		4.65E+00	
ETTP	4.05	K-710	2.80E+08					1.19E+01	4.57E-01		9.97E+00	
ETTP	4.06	K-1085 Old Firehouse Burn Area Drum Burial Site, Area 6 Soils	1.51E+07					9.83E+01	4.73E+00		2.60E+02	
ETTP	4.08	Duct Island Soil Mounds	1.47E+08					2.85E+02	1.45E+01		7.32E+01	
ETTP	4.11	K-711/K-766 Debris and Soils	5.37E+08					8.39E-01	3.67E-01		3.51E+00	
ETTP	4.12	K-770 Scrap Yard Soils	8.81E+10					2.95E+01	3.44E+00		2.50E+01	
ETTP	4.14	K-1093 Scrap Yard Debris	6.63E+08					8.00E+00	4.12E-01		3.62E+00	
ETTP	6.01	K25 HMA-1 DD R2	3.41E+09					4.43E+01	2.82E+00	1.28E-01	4.67E+01	
ETTP	6.02	K27 Units 1-7 ACM R2 (ARRA)	3.87E+08					1.08E+01	6.78E-01	3.68E-01	9.71E+00	
ETTP	6.03	K25 HMA-2 DD Rev 2	1.91E+08					1.46E+02	2.14E+01	1.15E-01	1.01E+02	
ETTP	6.04	K-27 Units 402-8 & 402-9 Hazardous Materials Abatement	5.90E+07					3.63E+00	2.96E-01	2.54E-01	2.96E+00	
ETTP	6.06	K-25 Bldg Area 6 PER R1	2.13E+08					5.15E+02	2.24E+01	3.46E+00	1.87E+01	
ETTP	6.12	K-25 Bldg Non-Purge Ext. Transite	6.80E+08					4.87E+01	2.52E+00	4.70E-01	1.37E+00	
ETTP	6.13	K-25 Bldg Area 5.1 PER R0	1.36E+08					6.74E+02	2.34E+01	2.19E+00	2.11E+00	
ETTP	6.14	K-1232 Tank Farm Miscellaneous Debris R0	7.86E+07					1.08E+01	1.11E+00		1.14E+01	
ETTP	6.16	K-601 Misc Debris	1.07E+09					1.87E+01	1.03E+00		5.20E+00	
ETTP	6.17	Building K-1030 Debris	9.11E+08					6.93E-01	1.88E-01		1.41E+00	
ETTP	6.18	Building K-1024 Debris	8.51E+08					7.43E-01	1.36E-01		6.76E-01	
ETTP	6.19	K-25/K-27 Bldg Struc Debris	1.92E+09					5.38E+02	2.61E+01	7.47E-01	5.44E+01	
ETTP	6.27	K-25/K-27 EMR Debris Material (K-27 ARRA)	2.74E+09					2.21E+00			5.44E+01	
ETTP	6.28	K-25 Lead Based Pain Debris	5.54E+08					2.15E+00	1.38E+00		1.28E+00	
ETTP	6.31	K-25 Building Northwest Bridge	5.25E+08					8.20E-01			3.53E-01	
ETTP	6.41	K-25 West Side Compressors Group 1 R1	6.11E+09					3.26E+03	1.31E+02		1.49E+01	
ETTP	6.42	K-25 West Side Converters Group 1 R1	1.02E+09					3.52E+03	1.79E+02		2.38E+01	
ETTP	6.43	K-25 West Side Converters Group 1 R1	3.49E+09					1.26E+03	6.33E+01		5.38E+00	
ETTP	6.58	K25 East and North Low-Risk Converters	3.03E+09					8.92E+02	4.76E+01		2.64E+01	
ETTP	6.59	Building K-25 East Wing and North End Low-Risk Compressors	2.08E+09					2.95E+03	1.59E+02		8.38E+01	
ETTP	6.60	K-25 West Wing Post Mined Low-Risk Compressors	8.48E+07					2.84E+03	1.44E+02		1.80E+01	
ETTP	6.998	Comingled waste lot that inlcudes WL's 6.49-6.57	4.63E+10					1.41E+03	9.13E+01	1.26E+01	5.49E+01	
ETTP	6.999	Comingled waste lot that includes WL's 6.32, 6.33, 6.34, 6.35, 6.38, 6.39, 6.45, 6.46, 6.47, 6.48	1.66E+11					1.57E+02	1.23E+01		2.44E+01	
ETTP	8.02	Building K-33 Concrete Pedestal	1.14E+10					2.17E+00	1.08E-01	1.08E-02	2.17E+00	
ETTP	8.05	BNFL Compressor Blades	5.89E+08					1.05E+02	5.45E+00		1.75E+02	
ETTP	8.07	BNFL K-31 Concrete Pedestal Waste Lot	4.61E+09					7.08E-01	7.40E-02		8.42E-01	
ETTP	8.08	K-33 Concrete Floor Scabble	2.27E+09						7.27E-01		4.33E+00	
ETTP	8.11	Non-PG/Non-Fissile Components	2.66E+08					6.44E+00	4.47E+00		4.52E+01	
ORNL	10.01	Old Hydrofracture Facility Remediation Wastes (Containers)	7.04E+08					1.22E+02	4.03E+00	7.05E-06	2.58E+02	
ETTP	14.01	K-1303 Building Debris	1.92E+09					2.43E+00	7.00E-02	3.25E+01	1.73E+00	
ETTP	14.02	K-1302 Building Debris	3.06E+08					1.61E+01	8.00E-01	3.30E-01	3.50E+00	
ETTP	14.03	K-1413 Building Debris	1.10E+09					6.40E+00	5.00E-01	7.31E+00	9.60E+00	
ETTP	14.04	K-1303 Metal Debris	1.61E+08					2.00E-02	1.00E-02			
ETTP	14.05	K-1300 Stack Debris	1.97E+08					4.46E+02	2.25E+01	9.29E+00	1.02E+02	

Table A-5. Radionuclide Concentration Data Set (Continued)

**Units in pCi/g*

Site	Waste Lot	WL Name	Net Weight (g)	Th-230	Th-232	U-232	U-233	U-234	U-235	U-236	U-238	Zn-65
ETTP	14.06	K-1413 Process Piping and Equipment	7.78E+07					1.04E+02	1.06E+01	4.85E+00	3.42E+02	
ETTP	14.07	Overhead Fluorine Pipelines and K-1301/K-1407 Metal Debris	2.60E+07					5.50E-01	8.00E-02	5.00E-02	5.30E-01	
ETTP	14.08	K-1301, K-1405, and K-1407 Asbestos	9.08E+06					5.63E+01	3.30E+00	5.29E+00	4.62E+01	
ETTP	14.11	K-1420 Equipment and Building Debris	5.28E+09					4.18E+01	5.51E+00		7.26E+00	
ETTP	14.14	K-1401/K-723 R4	2.43E+10					1.82E+01	1.42E+00		1.71E+01	
ETTP	14.15	K-1420 Calciner	5.32E+07					5.70E+03	3.56E+02		2.65E+03	
ETTP	14.16	Main Plant D&D Housekeeping R0	1.53E+07					2.72E-01	5.34E-02		2.56E-01	
ETTP	14.17	UF6 Cylinders Wooden Saddles	2.88E+08					1.08E-01			3.04E-01	
ETTP	14.21	K-1066-G Scrap, Debris and Abandoned Equipment	5.12E+08					2.74E+00	2.45E-01		7.33E+00	
Offsite	24.0	ACAP RA	3.87E+10					2.09E+01	2.10E+00		2.31E+01	
Offsite	24.01	ACAP Debris	2.46E+06					4.89E+02	2.76E+01		5.91E+02	
Offsite	24.02	ACAP Soil	1.30E+09					5.37E-03	3.10E-04		5.51E-03	
ETTP	30.01	ETTP OD RSM1 R1	2.07E+09					1.47E+02	4.18E+00	3.67E-01	5.95E+01	
ETTP	30.02	ETTP OD CD	8.38E+08					2.72E+02	1.87E+01	4.07E+00	1.47E+02	
ETTP	30.03	ETTP OD RSM 5	6.00E+07					3.33E+01	6.08E-01	1.98E-01	2.98E+01	
ETTP	30.06	ETTP OD DAW R1	1.18E+09					3.47E+02	2.26E+01	5.06E+01	2.15E+02	
ETTP	30.07	OD VRR-1	1.60E+09					1.83E+02	7.37E+00		2.58E+02	
ETTP	30.08	OD VRR-2	4.81E+08					1.56E+03	6.40E+01		2.78E+03	
ETTP	30.09	ETTP OD DAW-2 R1	2.19E+08					3.55E+03	1.16E+02	1.37E+01	1.63E+03	
ETTP	30.10	ETTP OD DAW-3	1.78E+08				1.10E+01	1.40E+02	7.99E+00	6.35E-01	1.68E+02	
Offsite	30.12	DWI 901 Stored Soils	1.83E+08					5.37E+02	3.26E+01	7.35E+00	7.29E+02	
ETTP	30.13	ETTP Outdoor Solids	3.53E+08					4.60E+01	2.61E+00	7.63E-01	1.96E+02	
ETTP	62.01	Poplar Creek Process Facilities Building Debris and Miscellaneous Materials	6.46E+07					3.09E+01	1.71E+00		1.99E+01	
ETTP	62.04	K-413 Building Debris and Process Equipment	7.17E+08					5.97E+00	2.01E+00		2.87E+00	
ETTP	62.05	K-1231 and K-1233 Demolition Debris	1.68E+09					4.82E+00	2.12E-01		4.47E-01	
ETTP	65.01	K-770 Scrap Yard	4.16E+10					6.00E-02	1.07E+00	2.00E-02	1.82E+01	
ETTP	65.02	K-770 14 Series Piles	9.56E+08					1.27E-01	1.32E+00		2.22E+01	
ETTP	65.03	K-770 B-25 Boxes	8.81E+08				2.50E+02		1.45E+01	1.09E+01	2.57E+01	
ETTP	66.01	KAFaD Group 1 Buildings K-724 and K-725 Excess Material Project	2.86E+06					5.92E-01	6.90E-02		7.49E-01	
ETTP	66.04	K-1064 Peninsula Area	1.31E+08					2.69E+02	1.47E+01	1.19E+01	1.08E+02	
ETTP	66.06	K-1025 Buildings Structural Wood	3.40E+07					7.95E+00	4.46E-01		6.04E+00	
ETTP	66.07	DBOS Building Debris and Misc Materials R2	9.78E+09					5.42E+02	1.81E+01		4.59E+02	
ETTP	73.01	Centrifuge Equipment U	8.57E+07					1.05E+03	6.14E+01	2.38E+01	5.24E+02	
ETTP	73.02	Centrifuge Equipment C	9.73E+07					1.05E+03	6.14E+01	2.38E+01	5.24E+02	
ORNL	80.01	HFIR Impoundments	8.49E+09					1.84E+00			1.10E+00	
ORNL	80.02	HRE Pond Sediments	6.88E+09					2.10E+00			1.20E+00	
ORNL	81.01	T1/T2 R4 HFIR Tanks Debris R5	1.01E+09				3.08E-01	2.69E-01	4.24E-03	4.71E-02	5.24E-01	
ORNL	81.02	22-Trench Debris & Secondary Waste	8.24E+06					1.11E+00	1.25E-01		8.22E-01	
ORNL	84.01	GAAT RA Waste R3	1.22E+09				7.53E+00	4.99E+00	2.33E-01	1.03E-02	5.31E+00	
ORNL	84.02	ITRA Waste R1	3.15E+08				6.12E-02	1.12E+00	1.38E-07	4.17E-08	1.94E-02	
ORNL	84.03	W1-A B12 Box Soil	3.18E+08					3.17E+02	1.19E+00	4.82E-01	3.83E+00	
ORNL	84.04	W1-A B12 Box Soil-1	1.79E+08					4.07E+02	4.66E+00	1.92E+00	6.96E+00	
ORNL	84.05	RASW Inactive Tanks Secondary Equipment	1.81E+06				8.17E-03	3.77E-01	7.45E-09	4.72E-09	1.18E-03	
ORNL	84.06	HIC-1 FFA Inactive Tanks	4.56E+06				1.10E-01	5.06E+00	1.00E-07	6.32E-08	1.57E-02	
ORNL	87.01	SIOU Bricks	6.26E+09					8.21E+01	4.05E+00	2.44E+00	4.63E+01	

Table A-5. Radionuclide Concentration Data Set (Continued)

**Units in pCi/g*

Site	Waste Lot	WL Name	Net Weight (g)	Th-230	Th-232	U-232	U-233	U-234	U-235	U-236	U-238	Zn-65
ORNL	87.02	SIOU Debris R2	1.00E+09					8.21E+00	4.25E-01	2.90E-01	4.36E+00	
ORNL	89.01	MSRE Remedial Action	4.69E+07				3.09E+03	1.77E+02	2.11E-02	2.47E-02	7.61E-03	
ORNL	102.01	Building 3026 Debris and Misc Material	8.53E+08					6.13E-01			5.18E-01	
ORNL	111.01	Melton Valley Weir Cleanout and Bank Stabilization Project	6.63E+08	5.90E-01	7.60E-01			1.94E+00			2.67E+00	
Y-12	114.01	Jack Case Center Contaminated Force Main	1.96E+07					2.40E+02	8.07E+00	3.68E+00	5.41E+01	
Offsite	145.01	David Witherspoon, Inc. 901 Site- Candora Soil	1.34E+10					2.48E+02	1.93E+01	6.27E+00	2.41E+02	
Offsite	145.02	DWI 901 Scrap Metal and Debris R2	1.81E+09					7.07E+00	3.56E-01		7.83E+00	
Offsite	145.03	DWI 901 Site Building and Miscellaneous Debris	4.90E+08					2.00E+01	1.18E+00	6.08E-01	1.72E+01	
Offsite	145.04	David Witherspoon, Inc. 901 Site Soil	7.29E+10					1.27E+02	4.86E+00	1.65E+00	6.26E+01	
Offsite	146.01	DWI 1630 Soil and Incidental Debris R6	1.35E+11					4.20E+02	6.07E+00	2.81E+01	4.11E+02	
Offsite	146.02	DWI 1630 Site: Drums and Drum Soils	4.96E+08					4.20E+02	6.07E+00	2.81E+01	4.11E+02	
ORNL	149.01	NHF D&D	4.64E+09					5.05E+00			4.36E+01	
ORNL	149.02	NHF Well P&A Debris R2	5.98E+07									
ORNL	149.03	HRE Ancillary Facilities	1.16E+08	5.42E-01	2.45E-01			3.15E-01			3.28E-01	
ORNL	149.04	HRE Waste Evaporator System and Sampling Station Waste R2	2.12E+08		1.69E-04			3.01E+01	8.15E-01	3.21E-01	2.57E-02	
ORNL	149.06	NHF Well P&A Primary Waste	5.94E+07				3.44E+00	4.71E-02	9.55E-04	1.55E-09	1.32E-02	
ORNL	149.07	NHF Process	2.90E+07				2.09E+02	1.96E+01	3.43E-01		9.63E+00	
ORNL	149.09	7841 Scrap Yard Debris and Equipment	1.20E+09	8.52E+00	1.11E+01	1.65E+00	8.17E+02	1.34E+01	1.19E+00	1.08E+00	1.30E+02	
ORNL	149.10	MV Tanks 454 and 455	9.91E+06				1.42E+00	9.47E-01	1.15E-03	1.01E-02	2.47E-02	
ORNL	155.01	K-1070-B Burial Ground Remediation	1.12E+11					5.30E+02	6.01E+01		2.60E+02	
ETTP	155.02	BOS Lab Facilities Miscellaneous Wastes	1.83E+09					2.21E+02	1.33E+01		2.44E+02	
ETTP	155.03	BOS Lab Area Soil	1.56E+08					8.39E+00	4.12E-01		6.48E+00	
ETTP	155.04	BOS Lab Area Acid Pits and Piping	1.52E+08					6.98E+00	4.24E-01		1.61E+00	
ETTP	155.05	K-1015-A Laundry Pit	1.33E+08					9.80E+00	6.28E-01		1.77E+00	
ETTP	157.01	K-29 Building D&D	3.63E+10					8.44E+01	4.58E+00		1.99E+01	
ORNL	164.01	Hot Storage Garden R1	3.12E+07	3.16E+00	6.95E-01			1.21E+01	3.62E+00		1.28E+01	
ORNL	167.01	Epicor II Lysimeters, MV Soils & Sediments	7.73E+08					4.58E+00	2.14E-01	7.00E-02	2.91E-01	
ORNL	200.03	Facilities 3504, 3508, 3541, 3550 and 3592 Building Debris and Misc Material	5.09E+07					4.66E+00			4.61E-01	
ORNL	200.999	Comingled Waste Lot that includes Waste Lots 200.1, 2001.2 and 200.4	2.76E+09					3.03E+02	1.29E+00		1.19E+01	
ORNL	201.01	Miscellaneous Materials from Buildings 2001, 2019 and 2024	9.07E+06	8.21E-01	1.98E-01			5.24E-01	3.99E-01		4.52E-01	
ORNL	201.02	Building 2000 Structure and Contents	1.19E+09	7.48E-01	2.09E-01			5.58E-01	3.97E-01		4.48E-01	
ORNL	201.03	Slabs - Drains, Pipes and Slabs	5.58E+09	3.96E-01	2.50E-01		1.57E+01	6.54E+00	1.09E-01	1.08E-01	1.25E+00	
ORNL	203.01	Buildings 2011, 2017 and 3044	6.34E+08					9.03E+00	4.37E-01		5.66E-01	
ORNL	207.01	3026 Hot Cells	2.47E+08	6.78E-01	4.17E-01			2.74E+00	1.96E-01		4.23E-01	1.46E+00
Y-12	301.01	Capability Unit 29 Legacy Material Bldg 9201-5	1.05E+08					2.11E+01	1.64E-02	2.19E-01	6.60E-01	
Y-12	301.02	Legacy Material from Building 9201-5	4.98E+07						4.59E-02		2.67E-01	
Y-12	301.04	Legacy Material from Building 9201-5 First and Third Floor Beryllium Areas	1.10E+09						1.70E+00	8.80E-01	1.35E+02	
Y-12	303.01	Old Salvage Yard Piles SY-HI (Areas 1 and 2)	7.39E+09				1.10E+00	1.55E+02	8.72E+00	4.32E+00	6.72E+02	
Y-12	303.02	Old Salvage Yard SY-H1 Area 1 Pile, Rev 1	1.41E+09					1.03E+04	6.23E+02	1.45E+02	8.07E+03	
Y-12	304.01	Building 9211 D&D	9.04E+09					9.65E+01	3.56E+00		5.12E+01	
Y-12	304.02	Building 9769 D&D	1.86E+09					3.27E+01		2.71E+00	2.51E+01	
ETTP	401.01	K-33 Building Debris and Misc Material	2.00E+11					8.17E+00	3.99E-01		5.88E+00	
ETTP	997.01	Main Plant LR/LC Buildings	2.52E+09					1.81E+01	1.42E+00		1.71E+01	
ETTP	997.02	K-1035 Demolition Debris	5.90E+09					1.38E+00		5.36E-01	1.28E+00	

Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk)

Site	Waste Lot	WL Name	Net Weight (g)	Units	Ag-110m	Am-241	Am-243	Bi-214	C-14	Cm-242	Cm-243	Cm-244	Cm-245	Cm-246	Cm-247
Y-12	1.0	BYBY RA	8.66E+10	*pCi*		1.56E+10									
ORNL	2.01	SWSA 4 Remedial Action IHP-1 RA	2.22E+10	*pCi*		4.84E+11			4.66E+10						
ETTP	3.00	K-1070-A RA	2.59E+10	*pCi*		5.17E+09									
ETTP	4.02	PWR K-1085-401 RA	5.93E+07	*pCi*											
ETTP	4.03	Blair Quarry Soils	1.35E+10	*pCi*											
ETTP	4.05	K-710	2.80E+08	*pCi*											
ETTP	4.06	K-1085 Old Firehouse Burn Area Drum Burial Site, Area 6 Soils	1.51E+07	*pCi*		4.66E+06									
ETTP	4.08	Duct Island Soil Mounds	1.47E+08	*pCi*		4.69E+07									
ETTP	4.11	K-711/K-766 Debris and Soils	5.37E+08	*pCi*											
ETTP	4.12	K-770 Scrap Yard Soils	8.81E+10	*pCi*											
ETTP	4.14	K-1093 Scrap Yard Debris	6.63E+08	*pCi*		2.93E+08			1.53E+09						
ETTP	6.01	K25 HMA-1 DD R2	3.41E+09	*pCi*		2.64E+08									
ETTP	6.02	K27 Units 1-7 ACM R2 (ARRA)	3.87E+08	*pCi*		3.27E+07									
ETTP	6.03	K25 HMA-2 DD Rev 2	1.91E+08	*pCi*		8.07E+07									
ETTP	6.04	K-27 Units 402-8 & 402-9 Hazardous Materials Abatement	5.90E+07	*pCi*		3.12E+06									
ETTP	6.06	K-25 Bldg Area 6 PER R1	2.13E+08	*pCi*											
ETTP	6.12	K-25 Bldg Non-Purge Ext. Transite	6.80E+08	*pCi*		1.60E+07									
ETTP	6.13	K-25 Bldg Area 5.1 PER R0	1.36E+08	*pCi*											
ETTP	6.14	K-1232 Tank Farm Miscellaneous Debris R0	7.86E+07	*pCi*											
ETTP	6.16	K-601 Misc Debris	1.07E+09	*pCi*											
ETTP	6.17	Building K-1030 Debris	9.11E+08	*pCi*		1.63E+08									
ETTP	6.18	Building K-1024 Debris	8.51E+08	*pCi*		1.02E+08			6.79E+09						
ETTP	6.19	K-25/K-27 Bldg Struc Debris	1.92E+09	*pCi*		6.10E+08									
ETTP	6.27	K-25/K-27 EMR Debris Material (K-27 ARRA)	2.74E+09	*pCi*		1.81E+09									
ETTP	6.28	K-25 Lead Based Pain Debris	5.54E+08	*pCi*											
ETTP	6.31	K-25 Building Northwest Bridge	5.25E+08	*pCi*											
ETTP	6.41	K-25 West Side Compressors Group 1 R1	6.11E+09	*pCi*											
ETTP	6.42	K-25 West Side Converters Group 1 R1	1.02E+09	*pCi*											
ETTP	6.43	K-25 West Side Converters Group 1 R1	3.49E+09	*pCi*											
ETTP	6.58	K25 East and North Low-Risk Converters	3.03E+09	*pCi*											
ETTP	6.59	Building K-25 East Wing and North End Low-Risk Compressors	2.08E+09	*pCi*											
ETTP	6.60	K-25 West Wing Post Mined Low-Risk Compressors	8.48E+07	*pCi*											
ETTP	6.998	Comingled waste lot that inlcudes WL's 6.49-6.57	4.63E+10	*pCi*		2.00E+08									
ETTP	6.999	Comingled waste lot that includes WL's 6.32, 6.33, 6.34, 6.35, 6.38, 6.39, 6.45, 6.46, 6.47, 6.48	1.66E+11	*pCi*											
ETTP	8.02	Building K-33 Concrete Pedestal	1.14E+10	*pCi*											
ETTP	8.05	BNFL Compressor Blades	5.89E+08	*pCi*		1.18E+07									
ETTP	8.07	BNFL K-31 Concrete Pedestal Waste Lot	4.61E+09	*pCi*		7.43E+08									
ETTP	8.08	K-33 Concrete Floor Scabble	2.27E+09	*pCi*		1.12E+10									

Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) (Continued)

Site	Waste Lot	WL Name	Net Weight (g)	Units	Ag-110m	Am-241	Am-243	Bi-214	C-14	Cm-242	Cm-243	Cm-244	Cm-245	Cm-246	Cm-247
ETTP	8.11	Non-PG/Non-Fissile Components	2.66E+08	*pCi*		4.43E+07									
ORNL	10.01	Old Hydrofracture Facility Remediation Wastes (Containers)	7.04E+08	*pCi*		2.48E+11			6.30E+10						
ETTP	14.01	K-1303 Building Debris	1.92E+09	*pCi*											
ETTP	14.02	K-1302 Building Debris	3.06E+08	*pCi*		1.53E+07									
ETTP	14.03	K-1413 Building Debris	1.10E+09	*pCi*		1.65E+08									
ETTP	14.04	K-1303 Metal Debris	1.61E+08	*pCi*											
ETTP	14.05	K-1300 Stack Debris	1.97E+08	*pCi*		3.95E+06									
ETTP	14.06	K-1413 Process Piping and Equipment	7.78E+07	*pCi*		7.78E+05									
ETTP	14.07	Overhead Fluorine Pipelines and K-1301/K-1407 Metal Debris	2.60E+07	*pCi*		2.60E+05									
ETTP	14.08	K-1301, K-1405, and K-1407 Asbestos	9.08E+06	*pCi*		1.59E+07									
ETTP	14.11	K-1420 Equipment and Building Debris	5.28E+09	*pCi*											
ETTP	14.14	K-1401/K-723 R4	2.43E+10	*pCi*		2.11E+09									
ETTP	14.15	K-1420 Calciner	5.32E+07	*pCi*		3.59E+07									
ETTP	14.16	Main Plant D&D Housekeeping R0	1.53E+07	*pCi*											
ETTP	14.17	UF6 Cylinders Wooden Saddles	2.88E+08	*pCi*											
ETTP	14.21	K-1066-G Scrap, Debris and Abandoned Equipment	5.12E+08	*pCi*											
Offsite	24.0	ACAP RA	3.87E+10	*pCi*											
Offsite	24.01	ACAP Debris	2.46E+06	*pCi*											
Offsite	24.02	ACAP Soil	1.30E+09	*pCi*											
ETTP	30.01	ETTP OD RSM1 R1	2.07E+09	*pCi*											
ETTP	30.02	ETTP OD CD	8.38E+08	*pCi*											
ETTP	30.03	ETTP OD RSM 5	6.00E+07	*pCi*											
ETTP	30.06	ETTP OD DAW R1	1.18E+09	*pCi*											
ETTP	30.07	OD VRR-1	1.60E+09	*pCi*					1.37E+08						
ETTP	30.08	OD VRR-2	4.81E+08	*pCi*		2.32E+10			2.90E+09						
ETTP	30.09	ETTP OD DAW-2 R1	2.19E+08	*pCi*											
ETTP	30.10	ETTP OD DAW-3	1.78E+08	*pCi*		8.55E+10									
Offsite	30.12	DWI 901 Stored Soils	1.83E+08	*pCi*		9.37E+07									
ETTP	30.13	ETTP Outdoor Solids	3.53E+08	*pCi*		4.77E+07									
ETTP	62.01	Poplar Creek Process Facilities Building Debris and Miscellaneous Materials	6.46E+07	*pCi*		2.60E+07									
ETTP	62.04	K-413 Building Debris and Process Equipment	7.17E+08	*pCi*											
ETTP	62.05	K-1231 and K-1233 Demolition Debris	1.68E+09	*pCi*											
ETTP	65.01	K-770 Scrap Yard	4.16E+10	*pCi*											
ETTP	65.02	K-770 14 Series Piles	9.56E+08	*pCi*											
ETTP	65.03	K-770 B-25 Boxes	8.81E+08	*pCi*					1.16E+09						
ETTP	66.01	KAFaD Group 1 Buildings K-724 and K-725 Excess Material Project	2.86E+06	*pCi*											
ETTP	66.04	K-1064 Peninsula Area	1.31E+08	*pCi*		7.03E+07									
ETTP	66.06	K-1025 Buildings Structural Wood	3.40E+07	*pCi*											

Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) (Continued)

Site	Waste Lot	WL Name	Net Weight (g)	Units	Ag-110m	Am-241	Am-243	Bi-214	C-14	Cm-242	Cm-243	Cm-244	Cm-245	Cm-246	Cm-247
ETTP	66.07	DBOS Building Debris and Misc Materials R2	9.78E+09	pCi		2.40E+10									
ETTP	73.01	Centrifuge Equipment U	8.57E+07	pCi											
ETTP	73.02	Centrifuge Equipment C	9.73E+07	pCi											
ORNL	80.01	HFIR Impoundments	8.49E+09	pCi		1.12E+11			5.74E+10						
ORNL	80.02	HRE Pond Sediments	6.88E+09	pCi											
ORNL	81.01	T1/T2 R4 HFIR Tanks Debris R5	1.01E+09	pCi		5.37E+10			8.25E+08						
ORNL	81.02	22-Trench Debris & Secondary Waste	8.24E+06	pCi		1.50E+07									
ORNL	84.01	GAAT RA Waste R3	1.22E+09	pCi		8.40E+10			1.47E+10						
ORNL	84.02	ITRA Waste R1	3.15E+08	pCi		7.52E+10	2.69E+09		2.82E+07		4.03E+10	5.76E+12	8.08E+08	1.71E+09	8.43E+03
ORNL	84.03	W1-A B12 Box Soil	3.18E+08	pCi		3.18E+11			3.10E+09						
ORNL	84.04	W1-A B12 Box Soil-1	1.79E+08	pCi		7.08E+11			2.21E+09						
ORNL	84.05	RASW Inactive Tanks Secondary Equipment	1.81E+06	pCi		6.19E+07			9.87E+03						
ORNL	84.06	HIC-1 FFA Inactive Tanks	4.56E+06	pCi		3.86E+09	2.95E+07		3.32E+05		4.44E+08	2.09E+11	8.81E+06	1.93E+07	9.54E+01
ORNL	87.01	SIOU Bricks	6.26E+09	pCi		1.78E+12			2.02E+12						
ORNL	87.02	SIOU Debris R2	1.00E+09	pCi		2.90E+10			3.28E+10						
ORNL	89.01	MSRE Remedial Action	4.69E+07	pCi		1.93E+09									
ORNL	102.01	Building 3026 Debris and Misc Material	8.53E+08	pCi					1.71E+09						
ORNL	111.01	Melton Valley Weir Cleanout and Bank Stabilization Project	6.63E+08	pCi		5.68E+09			5.17E+09						
Y-12	114.01	Jack Case Center Contaminated Force Main	1.96E+07	pCi											
Offsite	145.01	David Witherspoon, Inc. 901 Site- Candora Soil	1.34E+10	pCi		3.52E+09			1.01E+11						
Offsite	145.02	DWI 901 Scrap Metal and Debris R2	1.81E+09	pCi											
Offsite	145.03	DWI 901 Site Building and Miscellaneous Debris	4.90E+08	pCi		8.73E+07			3.62E+09						
Offsite	145.04	David Witherspoon, Inc. 901 Site Soil	7.29E+10	pCi		2.84E+10									
Offsite	146.01	DWI 1630 Soil and Incidental Debris R6	1.35E+11	pCi		3.78E+11									
Offsite	146.02	DWI 1630 Site: Drums and Drum Soils	4.96E+08	pCi		1.39E+09									
ORNL	149.01	NHF D&D	4.64E+09	pCi		3.10E+11			1.53E+10						
ORNL	149.02	NHF Well P&A Debris R2	5.98E+07	pCi		5.98E+10			6.70E+08						
ORNL	149.03	HRE Ancillary Facilities	1.16E+08	pCi											
ORNL	149.04	HRE Waste Evaporator System and Sampling Station Waste R2	2.12E+08	pCi					1.12E+07						
ORNL	149.06	NHF Well P&A Primary Waste	5.94E+07	pCi		3.67E+08			1.64E+07						
ORNL	149.07	NHF Process	2.90E+07	pCi		4.90E+10			4.03E+09						
ORNL	149.09	7841 Scrap Yard Debris and Equipment	1.20E+09	pCi		8.86E+11	7.33E+08		5.39E+09	1.95E+08		1.13E+13			
ORNL	149.10	MV Tanks 454 and 455	9.91E+06	pCi		2.39E+10			1.76E+04						
ORNL	155.01	K-1070-B Burial Ground Remediation	1.12E+11	pCi		1.21E+11									
ETTP	155.02	BOS Lab Facilities Miscellaneous Wastes	1.83E+09	pCi		4.51E+09									
ETTP	155.03	BOS Lab Area Soil	1.56E+08	pCi		2.04E+08									
ETTP	155.04	BOS Lab Area Acid Pits and Piping	1.52E+08	pCi		1.79E+07									
ETTP	155.05	K-1015-A Laundry Pit	1.33E+08	pCi											

Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) (Continued)

Site	Waste Lot	WL Name	Net Weight (g)	Units	Ag-110m	Am-241	Am-243	Bi-214	C-14	Cm-242	Cm-243	Cm-244	Cm-245	Cm-246	Cm-247
ETTP	157.01	K-29 Building D&D	3.63E+10	*pCi*		2.37E+09									
ORNL	164.01	Hot Storage Garden R1	3.12E+07	*pCi*		1.17E+08									
ORNL	167.01	Epicor II Lysimeters, MV Soils & Sediments	7.73E+08	*pCi*		5.09E+09			1.47E+08						
ORNL	200.03	Facilities 3504, 3508, 3541, 3550 and 3592 Building Debris and Misc Material	5.09E+07	*pCi*											
ORNL	200.999	Comingled Waste Lot that includes Waste Lots 200.1, 2001.2 and 200.4	2.76E+09	*pCi*		3.51E+10			1.71E+10						
ORNL	201.01	Miscellaneous Materials from Buildings 2001, 2019 and 2024	9.07E+06	*pCi*		2.88E+06	3.58E+06		3.38E+07						
ORNL	201.02	Building 2000 Structure and Contents	1.19E+09	*pCi*		4.13E+08	5.18E+08		2.70E+09						
ORNL	201.03	Slabs - Drains, Pipes and Slabs	5.58E+09	*pCi*		7.36E+08	8.09E+08	2.17E+09	8.92E+09		3.90E+08		2.23E+07		2.23E+07
ORNL	203.01	Buildings 2011, 2017 and 3044	6.34E+08	*pCi*											
ORNL	207.01	3026 Hot Cells	2.47E+08	*pCi*	1.18E+08	4.53E+07			2.72E+08		3.46E+07		1.73E+07		3.64E+07
Y-12	301.01	Capability Unit 29 Legacy Material Bldg 9201-5	1.05E+08	*pCi*											
Y-12	301.02	Legacy Material from Building 9201-5	4.98E+07	*pCi*											
Y-12	301.04	Legacy Material from Building 9201-5 First and Third Floor Beryllium Areas	1.10E+09	*pCi*											
Y-12	303.01	Old Salvage Yard Piles SY-III (Areas 1 and 2)	7.39E+09	*pCi*											
Y-12	303.02	Old Salvage Yard SY-H1 Area 1 Pile, Rev 1	1.41E+09	*pCi*											
Y-12	304.01	Building 9211 D&D	9.04E+09	*pCi*					1.21E+11						
Y-12	304.02	Building 9769 D&D	1.86E+09	*pCi*		3.03E+08									
ETTP	401.01	K-33 Building Debris and Misc Material	2.00E+11	*pCi*											
ETTP	997.01	Main Plant LR/LC Buildings	2.52E+09	*pCi*		2.21E+08									
ETTP	997.02	K-1035 Demolition Debris	5.90E+09	*pCi*											
			1.29E+12	*pCi*	**1.18E+08**	**5.98E+12**	**4.78E+09**	**2.17E+09**	**2.55E+12**	**1.95E+08**	**4.11E+10**	**1.73E+13**	**8.57E+08**	**1.73E+09**	**5.87E+07**
				g	**2.47E+08**	**6.52E+11**	**8.29E+09**	**5.58E+09**	**8.74E+10**	**1.20E+09**	**6.14E+09**	**1.52E+09**	**6.14E+09**	**3.19E+08**	**6.14E+09**
				pCi/g	**4.76E-01**	**9.18E+00**	**5.77E-01**	**3.89E-01**	**2.91E+01**	**1.63E-01**	**6.69E+00**	**1.14E+04**	**1.39E-01**	**5.41E+00**	**9.55E-03**

Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) (Continued)

Site	Waste Lot	WL Name	Net Weight (g)	Units	Co-57	Co-60	Cs-134	Cs-137	Eu-152	Eu-154	Eu-155	F-59	H-3	I-129	K-40
Y-12	1.0	BYBY RA	8.66E+10	*pCi*											
ORNL	2.01	SWSA 4 Remedial Action IHP-1 RA	2.22E+10	*pCi*									1.18E+12	4.66E+10	
ETTP	3.00	K-1070-A RA	2.59E+10	*pCi*											
ETTP	4.02	PWR K-1085-401 RA	5.93E+07	*pCi*											
ETTP	4.03	Blair Quarry Soils	1.35E+10	*pCi*											
ETTP	4.05	K-710	2.80E+08	*pCi*											
ETTP	4.06	K-1085 Old Firehouse Burn Area Drum Burial Site, Area 6 Soils	1.51E+07	*pCi*											
ETTP	4.08	Duct Island Soil Mounds	1.47E+08	*pCi*											
ETTP	4.11	K-711/K-766 Debris and Soils	5.37E+08	*pCi*											
ETTP	4.12	K-770 Scrap Yard Soils	8.81E+10	*pCi*											
ETTP	4.14	K-1093 Scrap Yard Debris	6.63E+08	*pCi*									1.95E+10		
ETTP	6.01	K25 HMA-1 DD R2	3.41E+09	*pCi*											
ETTP	6.02	K27 Units 1-7 ACM R2 (ARRA)	3.87E+08	*pCi*											
ETTP	6.03	K25 HMA-2 DD Rev 2	1.91E+08	*pCi*											
ETTP	6.04	K-27 Units 402-8 & 402-9 Hazardous Materials Abatement	5.90E+07	*pCi*											
ETTP	6.06	K-25 Bldg Area 6 PER R1	2.13E+08	*pCi*											
ETTP	6.12	K-25 Bldg Non-Purge Ext. Transite	6.80E+08	*pCi*											
ETTP	6.13	K-25 Bldg Area 5.1 PER R0	1.36E+08	*pCi*											
ETTP	6.14	K-1232 Tank Farm Miscellaneous Debris R0	7.86E+07	*pCi*											
ETTP	6.16	K-601 Misc Debris	1.07E+09	*pCi*											
ETTP	6.17	Building K-1030 Debris	9.11E+08	*pCi*											
ETTP	6.18	Building K-1024 Debris	8.51E+08	*pCi*											
ETTP	6.19	K-25/K-27 Bldg Struc Debris	1.92E+09	*pCi*											
ETTP	6.27	K-25/K-27 EMR Debris Material (K-27 ARRA)	2.74E+09	*pCi*											
ETTP	6.28	K-25 Lead Based Pain Debris	5.54E+08	*pCi*											
ETTP	6.31	K-25 Building Northwest Bridge	5.25E+08	*pCi*											
ETTP	6.41	K-25 West Side Compressors Group 1 R1	6.11E+09	*pCi*											
ETTP	6.42	K-25 West Side Converters Group 1 R1	1.02E+09	*pCi*											
ETTP	6.43	K-25 West Side Converters Group 1 R1	3.49E+09	*pCi*											
ETTP	6.58	K25 East and North Low-Risk Converters	3.03E+09	*pCi*											
ETTP	6.59	Building K-25 East Wing and North End Low-Risk Compressors	2.08E+09	*pCi*											
ETTP	6.60	K-25 West Wing Post Mined Low-Risk Compressors	8.48E+07	*pCi*											
ETTP	6.998	Comingled waste lot that inlcudes WL's 6.49-6.57	4.63E+10	*pCi*											
ETTP	6.999	Comingled waste lot that includes WL's 6.32, 6.33, 6.34, 6.35, 6.38, 6.39, 6.45, 6.46, 6.47, 6.48	1.66E+11	*pCi*											
ETTP	8.02	Building K-33 Concrete Pedestal	1.14E+10	*pCi*											
ETTP	8.05	BNFL Compressor Blades	5.89E+08	*pCi*											
ETTP	8.07	BNFL K-31 Concrete Pedestal Waste Lot	4.61E+09	*pCi*											
ETTP	8.08	K-33 Concrete Floor Scabble	2.27E+09	*pCi*											

Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) (Continued)

Site	Waste Lot	WL Name	Net Weight (g)	Units	Co-57	Co-60	Cs-134	Cs-137	Eu-152	Eu-154	Eu-155	F-59	H-3	I-129	K-40
ETTP	8.11	Non-PG/Non-Fissile Components	2.66E+08	pCi											
ORNL	10.01	Old Hydrofracture Facility Remediation Wastes (Containers)	7.04E+08	pCi									5.25E+09	1.08E+07	
ETTP	14.01	K-1303 Building Debris	1.92E+09	pCi											
ETTP	14.02	K-1302 Building Debris	3.06E+08	pCi											
ETTP	14.03	K-1413 Building Debris	1.10E+09	pCi											
ETTP	14.04	K-1303 Metal Debris	1.61E+08	pCi											
ETTP	14.05	K-1300 Stack Debris	1.97E+08	pCi											
ETTP	14.06	K-1413 Process Piping and Equipment	7.78E+07	pCi											
ETTP	14.07	Overhead Fluorine Pipelines and K-1301/K-1407 Metal Debris	2.60E+07	pCi											
ETTP	14.08	K-1301, K-1405, and K-1407 Asbestos	9.08E+06	pCi											
ETTP	14.11	K-1420 Equipment and Building Debris	5.28E+09	pCi											
ETTP	14.14	K-1401/K-723 R4	2.43E+10	pCi											
ETTP	14.15	K-1420 Calciner	5.32E+07	pCi											
ETTP	14.16	Main Plant D&D Housekeeping R0	1.53E+07	pCi											
ETTP	14.17	UF6 Cylinders Wooden Saddles	2.88E+08	pCi											
ETTP	14.21	K-1066-G Scrap, Debris and Abandoned Equipment	5.12E+08	pCi											
Offsite	24.0	ACAP RA	3.87E+10	pCi											
Offsite	24.01	ACAP Debris	2.46E+06	pCi											
Offsite	24.02	ACAP Soil	1.30E+09	pCi											
ETTP	30.01	ETTP OD RSM1 R1	2.07E+09	pCi											
ETTP	30.02	ETTP OD CD	8.38E+08	pCi											
ETTP	30.03	ETTP OD RSM 5	6.00E+07	pCi											
ETTP	30.06	ETTP OD DAW R1	1.18E+09	pCi											
ETTP	30.07	OD VRR-1	1.60E+09	pCi									7.32E+09		
ETTP	30.08	OD VRR-2	4.81E+08	pCi									1.07E+11		
ETTP	30.09	ETTP OD DAW-2 R1	2.19E+08	pCi											
ETTP	30.10	ETTP OD DAW-3	1.78E+08	pCi										8.03E+05	
Offsite	30.12	DWI 901 Stored Soils	1.83E+08	pCi											
ETTP	30.13	ETTP Outdoor Solids	3.53E+08	pCi											
ETTP	62.01	Poplar Creek Process Facilities Building Debris and Miscellaneous Materials	6.46E+07	pCi											
ETTP	62.04	K-413 Building Debris and Process Equipment	7.17E+08	pCi											
ETTP	62.05	K-1231 and K-1233 Demolition Debris	1.68E+09	pCi											
ETTP	65.01	K-770 Scrap Yard	4.16E+10	pCi											
ETTP	65.02	K-770 14 Series Piles	9.56E+08	pCi											
ETTP	65.03	K-770 B-25 Boxes	8.81E+08	pCi										5.57E+08	
ETTP	66.01	KAFaD Group 1 Buildings K-724 and K-725 Excess Material Project	2.86E+06	pCi											
ETTP	66.04	K-1064 Peninsula Area	1.31E+08	pCi											
ETTP	66.06	K-1025 Buildings Structural Wood	3.40E+07	pCi											

Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) (Continued)

Site	Waste Lot	WL Name	Net Weight (g)	Units	Co-57	Co-60	Cs-134	Cs-137	Eu-152	Eu-154	Eu-155	F-59	H-3	I-129	K-40
ETTP	66.07	DBOS Building Debris and Misc Materials R2	9.78E+09	pCi											
ETTP	73.01	Centrifuge Equipment U	8.57E+07	pCi											
ETTP	73.02	Centrifuge Equipment C	9.73E+07	pCi											
ORNL	80.01	HFIR Impoundments	8.49E+09	pCi									5.92E+12		
ORNL	80.02	HRE Pond Sediments	6.88E+09	pCi											
ORNL	81.01	T1/T2 R4 HFIR Tanks Debris R5	1.01E+09	pCi									1.23E+07	5.30E+04	
ORNL	81.02	22-Trench Debris & Secondary Waste	8.24E+06	pCi											
ORNL	84.01	GAAT RA Waste R3	1.22E+09	pCi									2.19E+08	9.38E+05	
ORNL	84.02	ITRA Waste R1	3.15E+08	pCi		5.72E+10		6.23E+11	2.23E+11	1.73E+11	4.25E+11		3.21E+06	4.69E+03	
ORNL	84.03	W1-A B12 Box Soil	3.18E+08	pCi											
ORNL	84.04	W1-A B12 Box Soil-1	1.79E+08	pCi											
ORNL	84.05	RASW Inactive Tanks Secondary Equipment	1.81E+06	pCi									1.08E+03	1.43E+00	
ORNL	84.06	HIC-1 FFA Inactive Tanks	4.56E+06	pCi		8.58E+06		4.07E+10	1.36E+08	3.03E+07	4.07E+07		3.63E+04	4.79E+01	
ORNL	87.01	SIOU Bricks	6.26E+09	pCi											
ORNL	87.02	SIOU Debris R2	1.00E+09	pCi											
ORNL	89.01	MSRE Remedial Action	4.69E+07	pCi									1.77E+11	4.44E+06	
ORNL	102.01	Building 3026 Debris and Misc Material	8.53E+08	pCi									2.28E+09		
ORNL	111.01	Melton Valley Weir Cleanout and Bank Stabilization Project	6.63E+08	pCi		4.36E+12		2.54E+12					4.02E+11		
Y-12	114.01	Jack Case Center Contaminated Force Main	1.96E+07	pCi											
Offsite	145.01	David Witherspoon, Inc. 901 Site- Candora Soil	1.34E+10	pCi											
Offsite	145.02	DWI 901 Scrap Metal and Debris R2	1.81E+09	pCi											
Offsite	145.03	DWI 901 Site Building and Miscellaneous Debris	4.90E+08	pCi											
Offsite	145.04	David Witherspoon, Inc. 901 Site Soil	7.29E+10	pCi											
Offsite	146.01	DWI 1630 Soil and Incidental Debris R6	1.35E+11	pCi											
Offsite	146.02	DWI 1630 Site: Drums and Drum Soils	4.96E+08	pCi											
ORNL	149.01	NHF D&D	4.64E+09	pCi											
ORNL	149.02	NHF Well P&A Debris R2	5.98E+07	pCi									3.08E+08	2.61E+06	
ORNL	149.03	HRE Ancillary Facilities	1.16E+08	pCi				5.06E+07							
ORNL	149.04	HRE Waste Evaporator System and Sampling Station Waste R2	2.12E+08	pCi		1.31E+09		3.59E+12					3.56E+08	1.22E+06	
ORNL	149.06	NHF Well P&A Primary Waste	5.94E+07	pCi									1.16E+04	1.00E+03	
ORNL	149.07	NHF Process	2.90E+07	pCi									6.01E+06	2.57E+05	
ORNL	149.09	7841 Scrap Yard Debris and Equipment	1.20E+09	pCi		3.52E+11	2.97E+13	4.82E+13	5.47E+13	4.14E+13	1.13E+13		7.74E+09	1.24E+07	
ORNL	149.10	MV Tanks 454 and 455	9.91E+06	pCi									3.39E+05	4.03E+08	
ORNL	155.01	K-1070-B Burial Ground Remediation	1.12E+11	pCi											
ETTP	155.02	BOS Lab Facilities Miscellaneous Wastes	1.83E+09	pCi											
ETTP	155.03	BOS Lab Area Soil	1.56E+08	pCi											
ETTP	155.04	BOS Lab Area Acid Pits and Piping	1.52E+08	pCi											
ETTP	155.05	K-1015-A Laundry Pit	1.33E+08	pCi											

Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) (Continued)

Site	Waste Lot	WL Name	Net Weight (g)	Units	Co-57	Co-60	Cs-134	Cs-137	Eu-152	Eu-154	Eu-155	F-59	H-3	I-129	K-40
ETTP	157.01	K-29 Building D&D	3.63E+10	*pCi*											
ORNL	164.01	Hot Storage Garden R1	3.12E+07	*pCi*		1.54E+08		7.46E+11		4.56E+07					3.03E+08
ORNL	167.01	Epicor II Lysimeters, MV Soils & Sediments	7.73E+08	*pCi*									3.01E+12		
ORNL	200.03	Facilities 3504, 3508, 3541, 3550 and 3592 Building Debris and Misc Material	5.09E+07	*pCi*											
ORNL	200.999	Comingled Waste Lot that includes Waste Lots 200.1, 2001.2 and 200.4	2.76E+09	*pCi*											
ORNL	201.01	Miscellaneous Materials from Buildings 2001, 2019 and 2024	9.07E+06	*pCi*		1.14E+06		4.36E+06	5.59E+06	5.84E+06	2.45E+06		8.37E+06		1.45E+07
ORNL	201.02	Building 2000 Structure and Contents	1.19E+09	*pCi*		1.32E+08		1.46E+09	6.07E+08	6.27E+08	2.71E+08		6.14E+08		1.67E+09
ORNL	201.03	Slabs - Drains, Pipes and Slabs	5.58E+09	*pCi*		4.07E+08		4.07E+08	1.19E+09	1.35E+09	6.58E+08		1.91E+10	1.27E+10	2.67E+10
ORNL	203.01	Buildings 2011, 2017 and 3044	6.34E+08	*pCi*									3.98E+10		
ORNL	207.01	3026 Hot Cells	2.47E+08	*pCi*	3.66E+07	4.75E+09		1.49E+09	2.67E+08	3.29E+08		3.68E+08	8.21E+10	3.73E+08	
Y-12	301.01	Capability Unit 29 Legacy Material Bldg 9201-5	1.05E+08	*pCi*											
Y-12	301.02	Legacy Material from Building 9201-5	4.98E+07	*pCi*											
Y-12	301.04	Legacy Material from Building 9201-5 First and Third Floor Beryllium Areas	1.10E+09	*pCi*											
Y-12	303.01	Old Salvage Yard Piles SY-HI (Areas 1 and 2)	7.39E+09	*pCi*											
Y-12	303.02	Old Salvage Yard SY-H1 Area 1 Pile, Rev 1	1.41E+09	*pCi*											
Y-12	304.01	Building 9211 D&D	9.04E+09	*pCi*									3.05E+11		
Y-12	304.02	Building 9769 D&D	1.86E+09	*pCi*									3.36E+09		
ETTP	401.01	K-33 Building Debris and Misc Material	2.00E+11	*pCi*											
ETTP	997.01	Main Plant LR/LC Buildings	2.52E+09	*pCi*											
ETTP	997.02	K-1035 Demolition Debris	5.90E+09	*pCi*											
			1.29E+12	*pCi*	**3.66E+07**	**4.77E+12**	**2.97E+13**	**5.58E+13**	**5.49E+13**	**4.16E+13**	**1.17E+13**	**3.68E+08**	**1.13E+13**	**6.07E+10**	**2.86E+10**
				g	**2.47E+08**	**9.45E+09**	**1.20E+09**	**9.56E+09**	**8.54E+09**	**8.57E+09**	**8.29E+09**	**2.47E+08**	**5.91E+10**	**3.40E+10**	**6.81E+09**
				pCi/g	**1.48E-01**	**5.05E+02**	**2.48E+04**	**5.83E+03**	**6.43E+03**	**4.85E+03**	**1.41E+03**	**1.49E+00**	**1.91E+02**	**1.79E+00**	**4.21E+00**

Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) (Continued)

Site	Waste Lot	WL Name	Net Weight (g)	Units	Kr-85	Mn-54	Nb-94	Ni-59	Ni-63	Np-237	Pb-210	Pb-214	Pm-147	Pu-238	Pu-239
Y-12	1.0	BYBY RA	8.66E+10	pCi						3.08E+10					8.66E+09
ORNL	2.01	SWSA 4 Remedial Action IHP-1 RA	2.22E+10	pCi						1.69E+10					1.25E+12
ETTP	3.00	K-1070-A RA	2.59E+10	pCi						5.04E+09					2.59E+09
ETTP	4.02	PWR K-1085-401 RA	5.93E+07	pCi											
ETTP	4.03	Blair Quarry Soils	1.35E+10	pCi						8.42E+09					5.88E+08
ETTP	4.05	K-710	2.80E+08	pCi						1.75E+07					1.68E+07
ETTP	4.06	K-1085 Old Firehouse Burn Area Drum Burial Site, Area 6 Soils	1.51E+07	pCi											1.60E+06
ETTP	4.08	Duct Island Soil Mounds	1.47E+08	pCi						6.60E+07					2.01E+08
ETTP	4.11	K-711/K-766 Debris and Soils	5.37E+08	pCi											
ETTP	4.12	K-770 Scrap Yard Soils	8.81E+10	pCi											
ETTP	4.14	K-1093 Scrap Yard Debris	6.63E+08	pCi											
ETTP	6.01	K25 HMA-1 DD R2	3.41E+09	pCi						4.49E+08					9.50E+07
ETTP	6.02	K27 Units 1-7 ACM R2 (ARRA)	3.87E+08	pCi						6.26E+07					2.19E+07
ETTP	6.03	K25 HMA-2 DD Rev 2	1.91E+08	pCi						1.03E+08					8.04E+07
ETTP	6.04	K-27 Units 402-8 & 402-9 Hazardous Materials Abatement	5.90E+07	pCi						2.83E+06					3.47E+06
ETTP	6.06	K-25 Bldg Area 6 PER R1	2.13E+08	pCi						7.72E+07					
ETTP	6.12	K-25 Bldg Non-Purge Ext. Transite	6.80E+08	pCi						1.09E+07					6.82E+06
ETTP	6.13	K-25 Bldg Area 5.1 PER R0	1.36E+08	pCi						1.21E+08					7.62E+06
ETTP	6.14	K-1232 Tank Farm Miscellaneous Debris R0	7.86E+07	pCi											
ETTP	6.16	K-601 Misc Debris	1.07E+09	pCi											
ETTP	6.17	Building K-1030 Debris	9.11E+08	pCi											1.56E+08
ETTP	6.18	Building K-1024 Debris	8.51E+08	pCi						1.19E+08					
ETTP	6.19	K-25/K-27 Bldg Struc Debris	1.92E+09	pCi						5.68E+08					5.61E+08
ETTP	6.27	K-25/K-27 EMR Debris Material (K-27 ARRA)	2.74E+09	pCi						4.69E+08					7.50E+09
ETTP	6.28	K-25 Lead Based Pain Debris	5.54E+08	pCi											
ETTP	6.31	K-25 Building Northwest Bridge	5.25E+08	pCi											
ETTP	6.41	K-25 West Side Compressors Group 1 R1	6.11E+09	pCi											
ETTP	6.42	K-25 West Side Converters Group 1 R1	1.02E+09	pCi											
ETTP	6.43	K-25 West Side Converters Group 1 R1	3.49E+09	pCi											
ETTP	6.58	K25 East and North Low-Risk Converters	3.03E+09	pCi											
ETTP	6.59	Building K-25 East Wing and North End Low-Risk Compressors	2.08E+09	pCi						5.36E+08					
ETTP	6.60	K-25 West Wing Post Mined Low-Risk Compressors	8.48E+07	pCi											
ETTP	6.998	Comingled waste lot that inlcudes WL's 6.49-6.57	4.63E+10	pCi						5.91E+09					3.34E+08
ETTP	6.999	Comingled waste lot that includes WL's 6.32, 6.33, 6.34, 6.35, 6.38, 6.39, 6.45, 6.46, 6.47, 6.48	1.66E+11	pCi											
ETTP	8.02	Building K-33 Concrete Pedestal	1.14E+10	pCi											2.65E+09
ETTP	8.05	BNFL Compressor Blades	5.89E+08	pCi						2.30E+08					4.97E+07
ETTP	8.07	BNFL K-31 Concrete Pedestal Waste Lot	4.61E+09	pCi						6.07E+07					1.47E+08
ETTP	8.08	K-33 Concrete Floor Scabble	2.27E+09	pCi						1.55E+08					5.73E+09

Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) (Continued)

Site	Waste Lot	WL Name	Net Weight (g)	Units	Kr-85	Mn-54	Nb-94	Ni-59	Ni-63	Np-237	Pb-210	Pb-214	Pm-147	Pu-238	Pu-239
ETTP	8.11	Non-PG/Non-Fissile Components	2.66E+08	pCi						1.02E+08					2.22E+07
ORNL	10.01	Old Hydrofracture Facility Remediation Wastes (Containers)	7.04E+08	pCi						1.05E+09					7.37E+09
ETTP	14.01	K-1303 Building Debris	1.92E+09	pCi											1.15E+08
ETTP	14.02	K-1302 Building Debris	3.06E+08	pCi						1.22E+07					1.22E+07
ETTP	14.03	K-1413 Building Debris	1.10E+09	pCi						3.30E+07					8.80E+07
ETTP	14.04	K-1303 Metal Debris	1.61E+08	pCi											9.64E+06
ETTP	14.05	K-1300 Stack Debris	1.97E+08	pCi						3.16E+07					9.86E+06
ETTP	14.06	K-1413 Process Piping and Equipment	7.78E+07	pCi						7.00E+06					3.35E+07
ETTP	14.07	Overhead Fluorine Pipelines and K-1301/K-1407 Metal Debris	2.60E+07	pCi											
ETTP	14.08	K-1301, K-1405, and K-1407 Asbestos	9.08E+06	pCi						1.47E+07					3.99E+06
ETTP	14.11	K-1420 Equipment and Building Debris	5.28E+09	pCi											
ETTP	14.14	K-1401/K-723 R4	2.43E+10	pCi						5.50E+09					9.55E+08
ETTP	14.15	K-1420 Calciner	5.32E+07	pCi						5.15E+08					3.57E+08
ETTP	14.16	Main Plant D&D Housekeeping R0	1.53E+07	pCi											
ETTP	14.17	UF6 Cylinders Wooden Saddles	2.88E+08	pCi											
ETTP	14.21	K-1066-G Scrap, Debris and Abandoned Equipment	5.12E+08	pCi											8.36E+07
Offsite	24.0	ACAP RA	3.87E+10	pCi											
Offsite	24.01	ACAP Debris	2.46E+06	pCi											
Offsite	24.02	ACAP Soil	1.30E+09	pCi											
ETTP	30.01	ETTP OD RSM1 R1	2.07E+09	pCi						4.06E+09					1.66E+09
ETTP	30.02	ETTP OD CD	8.38E+08	pCi						5.37E+09					
ETTP	30.03	ETTP OD RSM 5	6.00E+07	pCi						1.68E+06					1.80E+05
ETTP	30.06	ETTP OD DAW R1	1.18E+09	pCi						3.24E+08					
ETTP	30.07	OD VRR-1	1.60E+09	pCi											1.09E+09
ETTP	30.08	OD VRR-2	4.81E+08	pCi						5.46E+09					1.10E+09
ETTP	30.09	ETTP OD DAW-2 R1	2.19E+08	pCi						2.95E+07					
ETTP	30.10	ETTP OD DAW-3	1.78E+08	pCi						3.00E+06					8.82E+09
Offsite	30.12	DWI 901 Stored Soils	1.83E+08	pCi						2.14E+10					
ETTP	30.13	ETTP Outdoor Solids	3.53E+08	pCi						7.77E+06					4.31E+06
ETTP	62.01	Poplar Creek Process Facilities Building Debris and Miscellaneous Materials	6.46E+07	pCi						4.39E+06					
ETTP	62.04	K-413 Building Debris and Process Equipment	7.17E+08	pCi											1.74E+07
ETTP	62.05	K-1231 and K-1233 Demolition Debris	1.68E+09	pCi											1.06E+08
ETTP	65.01	K-770 Scrap Yard	4.16E+10	pCi											
ETTP	65.02	K-770 14 Series Piles	9.56E+08	pCi											
ETTP	65.03	K-770 B-25 Boxes	8.81E+08	pCi						3.29E+08					
ETTP	66.01	KAFaD Group 1 Buildings K-724 and K-725 Excess Material Project	2.86E+06	pCi											
ETTP	66.04	K-1064 Peninsula Area	1.31E+08	pCi						9.78E+08					3.56E+07
ETTP	66.06	K-1025 Buildings Structural Wood	3.40E+07	pCi											

Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) (Continued)

Site	Waste Lot	WL Name	Net Weight (g)	Units	Kr-85	Mn-54	Nb-94	Ni-59	Ni-63	Np-237	Pb-210	Pb-214	Pm-147	Pu-238	Pu-239
ETTP	66.07	DBOS Building Debris and Misc Materials R2	9.78E+09	pCi						1.42E+09					1.14E+10
ETTP	73.01	Centrifuge Equipment U	8.57E+07	pCi											
ETTP	73.02	Centrifuge Equipment C	9.73E+07	pCi											
ORNL	80.01	HFIR Impoundments	8.49E+09	pCi											3.56E+10
ORNL	80.02	HRE Pond Sediments	6.88E+09	pCi											
ORNL	81.01	T1/T2 R4 HFIR Tanks Debris R5	1.01E+09	pCi						1.45E+07					3.31E+10
ORNL	81.02	22-Trench Debris & Secondary Waste	8.24E+06	pCi											1.65E+06
ORNL	84.01	GAAT RA Waste R3	1.22E+09	pCi						2.58E+08					5.52E+10
ORNL	84.02	ITRA Waste R1	3.15E+08	pCi						7.33E+06				2.08E+11	3.71E+10
ORNL	84.03	W1-A B12 Box Soil	3.18E+08	pCi						1.96E+09					3.28E+11
ORNL	84.04	W1-A B12 Box Soil-1	1.79E+08	pCi						2.34E+09					7.26E+11
ORNL	84.05	RASW Inactive Tanks Secondary Equipment	1.81E+06	pCi						2.79E+03					7.24E+07
ORNL	84.06	HIC-1 FFA Inactive Tanks	4.56E+06	pCi						9.40E+04				5.66E+10	4.79E+09
ORNL	87.01	SIOU Bricks	6.26E+09	pCi						8.89E+09					4.34E+12
ORNL	87.02	SIOU Debris R2	1.00E+09	pCi						1.45E+08					8.98E+10
ORNL	89.01	MSRE Remedial Action	4.69E+07	pCi						2.59E+07					5.48E+09
ORNL	102.01	Building 3026 Debris and Misc Material	8.53E+08	pCi											
ORNL	111.01	Melton Valley Weir Cleanout and Bank Stabilization Project	6.63E+08	pCi										6.30E+08	2.81E+09
Y-12	114.01	Jack Case Center Contaminated Force Main	1.96E+07	pCi						4.92E+06					2.23E+06
Offsite	145.01	David Witherspoon, Inc. 901 Site- Candora Soil	1.34E+10	pCi											1.77E+10
Offsite	145.02	DWI 901 Scrap Metal and Debris R2	1.81E+09	pCi											1.78E+08
Offsite	145.03	DWI 901 Site Building and Miscellaneous Debris	4.90E+08	pCi						4.41E+07					1.57E+08
Offsite	145.04	David Witherspoon, Inc. 901 Site Soil	7.29E+10	pCi						6.18E+09					1.27E+11
Offsite	146.01	DWI 1630 Soil and Incidental Debris R6	1.35E+11	pCi						1.15E+10					2.58E+10
Offsite	146.02	DWI 1630 Site: Drums and Drum Soils	4.96E+08	pCi						4.21E+07					9.48E+07
ORNL	149.01	NHF D&D	4.64E+09	pCi											1.51E+12
ORNL	149.02	NHF Well P&A Debris R2	5.98E+07	pCi						2.54E+08					
ORNL	149.03	HRE Ancillary Facilities	1.16E+08	pCi										2.08E+07	
ORNL	149.04	HRE Waste Evaporator System and Sampling Station Waste R2	2.12E+08	pCi										1.08E+09	7.07E+08
ORNL	149.06	NHF Well P&A Primary Waste	5.94E+07	pCi						2.79E+05					8.01E+07
ORNL	149.07	NHF Process	2.90E+07	pCi						7.05E+07					3.89E+10
ORNL	149.09	7841 Scrap Yard Debris and Equipment	1.20E+09	pCi					1.51E+11	6.50E+08				2.77E+11	1.69E+11
ORNL	149.10	MV Tanks 454 and 455	9.91E+06	pCi						1.06E+06					1.38E+10
ORNL	155.01	K-1070-B Burial Ground Remediation	1.12E+11	pCi											
ETTP	155.02	BOS Lab Facilities Miscellaneous Wastes	1.83E+09	pCi											2.14E+09
ETTP	155.03	BOS Lab Area Soil	1.56E+08	pCi						1.78E+07					2.37E+08
ETTP	155.04	BOS Lab Area Acid Pits and Piping	1.52E+08	pCi											
ETTP	155.05	K-1015-A Laundry Pit	1.33E+08	pCi											

Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) (Continued)

Site	Waste Lot	WL Name	Net Weight (g)	Units	Kr-85	Mn-54	Nb-94	Ni-59	Ni-63	Np-237	Pb-210	Pb-214	Pm-147	Pu-238	Pu-239
ETTP	157.01	K-29 Building D&D	3.63E+10	*pCi*						2.45E+09					1.43E+09
ORNL	164.01	Hot Storage Garden R1	3.12E+07	*pCi*							4.21E+09			9.53E+07	5.09E+08
ORNL	167.01	Epicor II Lysimeters, MV Soils & Sediments	7.73E+08	*pCi*											3.60E+09
ORNL	200.03	Facilities 3504, 3508, 3541, 3550 and 3592 Building Debris and Misc Material	5.09E+07	*pCi*											7.94E+07
ORNL	200.999	Comingled Waste Lot that includes Waste Lots 200.1, 2001.2 and 200.4	2.76E+09	*pCi*											2.52E+11
ORNL	201.01	Miscellaneous Materials from Buildings 2001, 2019 and 2024	9.07E+06	*pCi*			9.80E+05			3.36E+06				2.38E+06	2.84E+06
ORNL	201.02	Building 2000 Structure and Contents	1.19E+09	*pCi*						4.77E+08				3.52E+08	5.44E+08
ORNL	201.03	Slabs - Drains, Pipes and Slabs	5.58E+09	*pCi*			3.46E+08			7.14E+08	9.82E+09	2.24E+09		6.30E+08	7.03E+08
ORNL	203.01	Buildings 2011, 2017 and 3044	6.34E+08	*pCi*											
ORNL	207.01	3026 Hot Cells	2.47E+08	*pCi*	2.57E+10	2.09E+08	1.16E+08	9.99E+09	1.54E+09	9.25E+07			2.47E+09	2.65E+07	1.15E+08
Y-12	301.01	Capability Unit 29 Legacy Material Bldg 9201-5	1.05E+08	*pCi*											
Y-12	301.02	Legacy Material from Building 9201-5	4.98E+07	*pCi*											
Y-12	301.04	Legacy Material from Building 9201-5 First and Third Floor Beryllium Areas	1.10E+09	*pCi*											
Y-12	303.01	Old Salvage Yard Piles SY-HI (Areas 1 and 2)	7.39E+09	*pCi*											
Y-12	303.02	Old Salvage Yard SY-H1 Area 1 Pile, Rev 1	1.41E+09	*pCi*											
Y-12	304.01	Building 9211 D&D	9.04E+09	*pCi*						1.94E+09					1.64E+09
Y-12	304.02	Building 9769 D&D	1.86E+09	*pCi*											
ETTP	401.01	K-33 Building Debris and Misc Material	2.00E+11	*pCi*											4.55E+10
ETTP	997.01	Main Plant LR/LC Buildings	2.52E+09	*pCi*						5.44E+08					1.06E+08
ETTP	997.02	K-1035 Demolition Debris	5.90E+09	*pCi*											
			1.29E+12	*pCi*	**2.57E+10**	**2.09E+08**	**4.63E+08**	**9.99E+09**	**1.52E+11**	**1.55E+11**	**1.40E+10**	**2.24E+09**	**2.47E+09**	**5.44E+11**	**9.18E+12**
				g	**2.47E+08**	**2.47E+08**	**5.83E+09**	**2.47E+08**	**1.44E+09**	**5.34E+11**	**5.61E+09**	**5.58E+09**	**2.47E+08**	**9.56E+09**	**7.81E+11**
				pCi/g	**1.04E+02**	**8.47E-01**	**7.93E-02**	**4.04E+01**	**1.05E+02**	**2.91E-01**	**2.50E+00**	**4.02E-01**	**1.00E+01**	**5.69E+01**	**1.17E+01**

Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) (Continued)

Site	Waste Lot	WL Name	Net Weight (g)	Units	Pu-240	Pu-241	Pu-242	Pu-244	Ra-226	Ra-228	Ru-106	Sr-90	Tc-99	Th-228	Th-229
Y-12	1.0	BYBY RA	8.66E+10	pCi									1.85E+12		
ORNL	2.01	SWSA 4 Remedial Action IHP-1 RA	2.22E+10	pCi									6.28E+10		
ETTP	3.00	K-1070-A RA	2.59E+10	pCi									1.64E+11		
ETTP	4.02	PWR K-1085-401 RA	5.93E+07	pCi											
ETTP	4.03	Blair Quarry Soils	1.35E+10	pCi									1.74E+10		
ETTP	4.05	K-710	2.80E+08	pCi									2.16E+09		
ETTP	4.06	K-1085 Old Firehouse Burn Area Drum Burial Site, Area 6 Soils	1.51E+07	pCi											
ETTP	4.08	Duct Island Soil Mounds	1.47E+08	pCi											
ETTP	4.11	K-711/K-766 Debris and Soils	5.37E+08	pCi									7.95E+08		
ETTP	4.12	K-770 Scrap Yard Soils	8.81E+10	pCi									9.51E+12		
ETTP	4.14	K-1093 Scrap Yard Debris	6.63E+08	pCi									1.71E+10		
ETTP	6.01	K25 HMA-1 DD R2	3.41E+09	pCi									4.15E+10		
ETTP	6.02	K27 Units 1-7 ACM R2 (ARRA)	3.87E+08	pCi									1.10E+10		
ETTP	6.03	K25 HMA-2 DD Rev 2	1.91E+08	pCi									3.13E+10		
ETTP	6.04	K-27 Units 402-8 & 402-9 Hazardous Materials Abatement	5.90E+07	pCi									1.13E+10		
ETTP	6.06	K-25 Bldg Area 6 PER R1	2.13E+08	pCi									1.41E+10		
ETTP	6.12	K-25 Bldg Non-Purge Ext. Transite	6.80E+08	pCi									2.50E+09		
ETTP	6.13	K-25 Bldg Area 5.1 PER R0	1.36E+08	pCi									3.92E+08		
ETTP	6.14	K-1232 Tank Farm Miscellaneous Debris R0	7.86E+07	pCi									6.67E+07		
ETTP	6.16	K-601 Misc Debris	1.07E+09	pCi									1.16E+10		
ETTP	6.17	Building K-1030 Debris	9.11E+08	pCi									1.51E+09		
ETTP	6.18	Building K-1024 Debris	8.51E+08	pCi									6.27E+08		
ETTP	6.19	K-25/K-27 Bldg Struc Debris	1.92E+09	pCi									3.60E+10		
ETTP	6.27	K-25/K-27 EMR Debris Material (K-27 ARRA)	2.74E+09	pCi									3.38E+10		
ETTP	6.28	K-25 Lead Based Pain Debris	5.54E+08	pCi									1.13E+09		
ETTP	6.31	K-25 Building Northwest Bridge	5.25E+08	pCi											
ETTP	6.41	K-25 West Side Compressors Group 1 R1	6.11E+09	pCi											
ETTP	6.42	K-25 West Side Converters Group 1 R1	1.02E+09	pCi											
ETTP	6.43	K-25 West Side Converters Group 1 R1	3.49E+09	pCi											
ETTP	6.58	K25 East and North Low-Risk Converters	3.03E+09	pCi									3.63E+11		
ETTP	6.59	Building K-25 East Wing and North End Low-Risk Compressors	2.08E+09	pCi									5.98E+11		
ETTP	6.60	K-25 West Wing Post Mined Low-Risk Compressors	8.48E+07	pCi											
ETTP	6.998	Comingled waste lot that inlcudes WL's 6.49-6.57	4.63E+10	pCi									6.69E+12		
ETTP	6.999	Comingled waste lot that includes WL's 6.32, 6.33, 6.34, 6.35, 6.38, 6.39, 6.45, 6.46, 6.47, 6.48	1.66E+11	pCi											
ETTP	8.02	Building K-33 Concrete Pedestal	1.14E+10	pCi									2.46E+10		
ETTP	8.05	BNFL Compressor Blades	5.89E+08	pCi									5.48E+10		
ETTP	8.07	BNFL K-31 Concrete Pedestal Waste Lot	4.61E+09	pCi									1.81E+10		
ETTP	8.08	K-33 Concrete Floor Scabble	2.27E+09	pCi									1.67E+10		

Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) (Continued)

Site	Waste Lot	WL Name	Net Weight (g)	Units	Pu-240	Pu-241	Pu-242	Pu-244	Ra-226	Ra-228	Ru-106	Sr-90	Tc-99	Th-228	Th-229
ETTP	8.11	Non-PG/Non-Fissile Components	2.66E+08	pCi									1.26E+10		
ORNL	10.01	Old Hydrofracture Facility Remediation Wastes (Containers)	7.04E+08	pCi									2.33E+09		
ETTP	14.01	K-1303 Building Debris	1.92E+09	pCi									9.42E+09		
ETTP	14.02	K-1302 Building Debris	3.06E+08	pCi									4.40E+08		
ETTP	14.03	K-1413 Building Debris	1.10E+09	pCi									1.41E+10		
ETTP	14.04	K-1303 Metal Debris	1.61E+08	pCi											
ETTP	14.05	K-1300 Stack Debris	1.97E+08	pCi									9.45E+08		
ETTP	14.06	K-1413 Process Piping and Equipment	7.78E+07	pCi									4.96E+09		
ETTP	14.07	Overhead Fluorine Pipelines and K-1301/K-1407 Metal Debris	2.60E+07	pCi									9.09E+06		
ETTP	14.08	K-1301, K-1405, and K-1407 Asbestos	9.08E+06	pCi									9.14E+07		
ETTP	14.11	K-1420 Equipment and Building Debris	5.28E+09	pCi									2.58E+11		
ETTP	14.14	K-1401/K-723 R4	2.43E+10	pCi									3.11E+11		
ETTP	14.15	K-1420 Calciner	5.32E+07	pCi									1.99E+10		
ETTP	14.16	Main Plant D&D Housekeeping R0	1.53E+07	pCi											
ETTP	14.17	UF6 Cylinders Wooden Saddles	2.88E+08	pCi											
ETTP	14.21	K-1066-G Scrap, Debris and Abandoned Equipment	5.12E+08	pCi									1.76E+09		
Offsite	24.0	ACAP RA	3.87E+10	pCi											
Offsite	24.01	ACAP Debris	2.46E+06	pCi											
Offsite	24.02	ACAP Soil	1.30E+09	pCi											
ETTP	30.01	ETTP OD RSM1 R1	2.07E+09	pCi									4.10E+09		
ETTP	30.02	ETTP OD CD	8.38E+08	pCi									2.52E+10		
ETTP	30.03	ETTP OD RSM 5	6.00E+07	pCi									1.03E+07		
ETTP	30.06	ETTP OD DAW R1	1.18E+09	pCi									4.50E+10		
ETTP	30.07	OD VRR-1	1.60E+09	pCi									4.57E+10		
ETTP	30.08	OD VRR-2	4.81E+08	pCi									3.16E+11		
ETTP	30.09	ETTP OD DAW-2 R1	2.19E+08	pCi									1.06E+11		
ETTP	30.10	ETTP OD DAW-3	1.78E+08	pCi	1.94E+09								4.73E+09		
Offsite	30.12	DWI 901 Stored Soils	1.83E+08	pCi	3.34E+08								2.36E+10		
ETTP	30.13	ETTP Outdoor Solids	3.53E+08	pCi									1.05E+10		
ETTP	62.01	Poplar Creek Process Facilities Building Debris and Miscellaneous Materials	6.46E+07	pCi	8.91E+06								1.61E+08		
ETTP	62.04	K-413 Building Debris and Process Equipment	7.17E+08	pCi									2.31E+09		
ETTP	62.05	K-1231 and K-1233 Demolition Debris	1.68E+09	pCi									1.00E+10		
ETTP	65.01	K-770 Scrap Yard	4.16E+10	pCi									7.43E+11		
ETTP	65.02	K-770 14 Series Piles	9.56E+08	pCi									4.64E+10		
ETTP	65.03	K-770 B-25 Boxes	8.81E+08	pCi									7.03E+10		
ETTP	66.01	KAFaD Group 1 Buildings K-724 and K-725 Excess Material Project	2.86E+06	pCi											
ETTP	66.04	K-1064 Peninsula Area	1.31E+08	pCi									1.09E+08		
ETTP	66.06	K-1025 Buildings Structural Wood	3.40E+07	pCi											

Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) (Continued)

Site	Waste Lot	WL Name	Net Weight (g)	Units	Pu-240	Pu-241	Pu-242	Pu-244	Ra-226	Ra-228	Ru-106	Sr-90	Tc-99	Th-228	Th-229
ETTP	66.07	DBOS Building Debris and Misc Materials R2	9.78E+09	pCi									1.10E+12		
ETTP	73.01	Centrifuge Equipment U	8.57E+07	pCi									5.42E+08		
ETTP	73.02	Centrifuge Equipment C	9.73E+07	pCi									6.16E+08		
ORNL	80.01	HFIR Impoundments	8.49E+09	pCi											
ORNL	80.02	HRE Pond Sediments	6.88E+09	pCi											
ORNL	81.01	T1/T2 R4 HFIR Tanks Debris R5	1.01E+09	pCi									6.48E+08		
ORNL	81.02	22-Trench Debris & Secondary Waste	8.24E+06	pCi											
ORNL	84.01	GAAT RA Waste R3	1.22E+09	pCi	5.80E+09								1.16E+10		
ORNL	84.02	ITRA Waste R1	3.15E+08	pCi	1.31E+11	1.88E+10	2.49E+07	5.13E+00				2.60E+12	3.21E+06		
ORNL	84.03	W1-A B12 Box Soil	3.18E+08	pCi	1.76E+11								6.06E+08		
ORNL	84.04	W1-A B12 Box Soil-1	1.79E+08	pCi	3.91E+11								5.51E+08		
ORNL	84.05	RASW Inactive Tanks Secondary Equipment	1.81E+06	pCi	2.01E+08								1.94E+04		
ORNL	84.06	HIC-1 FFA Inactive Tanks	4.56E+06	pCi	2.60E+09	2.13E+08	2.92E+05	5.93E-02				1.25E+10	6.57E+05		
ORNL	87.01	SIOU Bricks	6.26E+09	pCi	8.19E+11								3.53E+10		
ORNL	87.02	SIOU Debris R2	1.00E+09	pCi									5.65E+08		
ORNL	89.01	MSRE Remedial Action	4.69E+07	pCi	2.12E+09								1.79E+10		
ORNL	102.01	Building 3026 Debris and Misc Material	8.53E+08	pCi									6.35E+09		
ORNL	111.01	Melton Valley Weir Cleanout and Bank Stabilization Project	6.63E+08	pCi								1.49E+10		6.27E+08	
Y-12	114.01	Jack Case Center Contaminated Force Main	1.96E+07	pCi									1.20E+09		
Offsite	145.01	David Witherspoon, Inc. 901 Site- Candora Soil	1.34E+10	pCi									3.46E+10		
Offsite	145.02	DWI 901 Scrap Metal and Debris R2	1.81E+09	pCi									6.54E+09		
Offsite	145.03	DWI 901 Site Building and Miscellaneous Debris	4.90E+08	pCi									7.83E+08		
Offsite	145.04	David Witherspoon, Inc. 901 Site Soil	7.29E+10	pCi									1.17E+11		
Offsite	146.01	DWI 1630 Soil and Incidental Debris R6	1.35E+11	pCi									4.64E+11		
Offsite	146.02	DWI 1630 Site: Drums and Drum Soils	4.96E+08	pCi									1.70E+09		
ORNL	149.01	NHF D&D	4.64E+09	pCi									8.68E+09		
ORNL	149.02	NHF Well P&A Debris R2	5.98E+07	pCi									9.70E+03		
ORNL	149.03	HRE Ancillary Facilities	1.16E+08	pCi								8.20E+07		4.06E+07	
ORNL	149.04	HRE Waste Evaporator System and Sampling Station Waste R2	2.12E+08	pCi								3.22E+11	1.38E+07		
ORNL	149.06	NHF Well P&A Primary Waste	5.94E+07	pCi	7.78E+07								6.23E+06		
ORNL	149.07	NHF Process	2.90E+07	pCi	2.47E+09								4.44E+09		
ORNL	149.09	7841 Scrap Yard Debris and Equipment	1.20E+09	pCi		1.45E+12	5.49E+08	4.88E+07			7.51E+13	9.00E+13	2.47E+11		
ORNL	149.10	MV Tanks 454 and 455	9.91E+06	pCi	1.05E+10								5.76E+05		
ORNL	155.01	K-1070-B Burial Ground Remediation	1.12E+11	pCi									1.53E+12		
ETTP	155.02	BOS Lab Facilities Miscellaneous Wastes	1.83E+09	pCi									2.15E+10		
ETTP	155.03	BOS Lab Area Soil	1.56E+08	pCi									5.19E+08		
ETTP	155.04	BOS Lab Area Acid Pits and Piping	1.52E+08	pCi									1.11E+09		
ETTP	155.05	K-1015-A Laundry Pit	1.33E+08	pCi											

Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) (Continued)

Site	Waste Lot	WL Name	Net Weight (g)	Units	Pu-240	Pu-241	Pu-242	Pu-244	Ra-226	Ra-228	Ru-106	Sr-90	Tc-99	Th-228	Th-229
ETTP	157.01	K-29 Building D&D	3.63E+10	pCi									1.09E+13		
ORNL	164.01	Hot Storage Garden R1	3.12E+07	pCi						5.68E+07		4.67E+10			
ORNL	167.01	Epicor II Lysimeters, MV Soils & Sediments	7.73E+08	pCi											
ORNL	200.03	Facilities 3504, 3508, 3541, 3550 and 3592 Building Debris and Misc Material	5.09E+07	pCi									2.22E+08		
ORNL	200.999	Comingled Waste Lot that includes Waste Lots 200.1, 2001.2 and 200.4	2.76E+09	pCi									3.26E+10		
ORNL	201.01	Miscellaneous Materials from Buildings 2001, 2019 and 2024	9.07E+06	pCi					3.16E+06			3.24E+07	1.15E+07	5.51E+06	
ORNL	201.02	Building 2000 Structure and Contents	1.19E+09	pCi					1.18E+09			6.25E+08	1.92E+09	6.85E+08	
ORNL	201.03	Slabs - Drains, Pipes and Slabs	5.58E+09	pCi		1.42E+09			4.99E+09	4.40E+09		3.64E+09	2.49E+10	1.87E+09	2.23E+07
ORNL	203.01	Buildings 2011, 2017 and 3044	6.34E+08	pCi									1.07E+09		
ORNL	207.01	3026 Hot Cells	2.47E+08	pCi		5.42E+09						3.46E+10	1.36E+09		
Y-12	301.01	Capability Unit 29 Legacy Material Bldg 9201-5	1.05E+08	pCi											
Y-12	301.02	Legacy Material from Building 9201-5	4.98E+07	pCi											
Y-12	301.04	Legacy Material from Building 9201-5 First and Third Floor Beryllium Areas	1.10E+09	pCi											
Y-12	303.01	Old Salvage Yard Piles SY-HI (Areas 1 and 2)	7.39E+09	pCi											
Y-12	303.02	Old Salvage Yard SY-H1 Area 1 Pile, Rev 1	1.41E+09	pCi											
Y-12	304.01	Building 9211 D&D	9.04E+09	pCi									1.51E+10		
Y-12	304.02	Building 9769 D&D	1.86E+09	pCi									5.85E+09		
ETTP	401.01	K-33 Building Debris and Misc Material	2.00E+11	pCi									1.71E+12		
ETTP	997.01	Main Plant LR/LC Buildings	2.52E+09	pCi									3.27E+10		
ETTP	997.02	K-1035 Demolition Debris	5.90E+09	pCi											
			1.29E+12	pCi	**1.54E+12**	**1.47E+12**	**5.75E+08**	**4.88E+07**	**6.17E+09**	**4.46E+09**	**7.51E+13**	**9.30E+13**	**3.80E+13**	**3.23E+09**	**2.23E+07**
				g	**8.87E+09**	**7.34E+09**	**1.52E+09**	**1.52E+09**	**6.78E+09**	**5.61E+09**	**1.20E+09**	**9.56E+09**	**1.04E+12**	**7.56E+09**	**5.58E+09**
				pCi/g	**1.74E+02**	**2.01E+02**	**3.79E-01**	**3.22E-02**	**9.10E-01**	**7.95E-01**	**6.27E+04**	**9.73E+03**	**3.67E+01**	**4.27E-01**	**4.00E-03**

Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) (Continued)

Site	Waste Lot	WL Name	Net Weight (g)	Units	Th-230	Th-232	U-232	U-233	U-234	U-235	U-236	U-238	Zn-65
Y-12	1.0	BYBY RA	8.66E+10	pCi					4.07E+13	1.71E+12	6.39E+11	6.74E+13	
ORNL	2.01	SWSA 4 Remedial Action IHP-1 RA	2.22E+10	pCi					3.20E+11	5.15E+10	3.11E+09	1.22E+11	
ETTP	3.00	K-1070-A RA	2.59E+10	pCi					8.42E+12	2.53E+11	1.48E+11	5.12E+12	
ETTP	4.02	PWR K-1085-401 RA	5.93E+07	pCi									
ETTP	4.03	Blair Quarry Soils	1.35E+10	pCi					1.77E+11	1.25E+10		6.28E+10	
ETTP	4.05	K-710	2.80E+08	pCi					3.33E+09	1.28E+08		2.79E+09	
ETTP	4.06	K-1085 Old Firehouse Burn Area Drum Burial Site, Area 6 Soils	1.51E+07	pCi					1.49E+09	7.16E+07		3.94E+09	
ETTP	4.08	Duct Island Soil Mounds	1.47E+08	pCi					4.18E+10	2.13E+09		1.07E+10	
ETTP	4.11	K-711/K-766 Debris and Soils	5.37E+08	pCi					4.51E+08	1.97E+08		1.89E+09	
ETTP	4.12	K-770 Scrap Yard Soils	8.81E+10	pCi					2.60E+12	3.03E+11		2.20E+12	
ETTP	4.14	K-1093 Scrap Yard Debris	6.63E+08	pCi					5.30E+09	2.73E+08		2.40E+09	
ETTP	6.01	K25 HMA-1 DD R2	3.41E+09	pCi					1.51E+11	9.60E+09	4.36E+08	1.59E+11	
ETTP	6.02	K27 Units 1-7 ACM R2 (ARRA)	3.87E+08	pCi					4.19E+09	2.63E+08	1.43E+08	3.76E+09	
ETTP	6.03	K25 HMA-2 DD Rev 2	1.91E+08	pCi					2.78E+10	4.09E+09	2.19E+07	1.93E+10	
ETTP	6.04	K-27 Units 402-8 & 402-9 Hazardous Materials Abatement	5.90E+07	pCi					2.14E+08	1.75E+07	1.50E+07	1.75E+08	
ETTP	6.06	K-25 Bldg Area 6 PER R1	2.13E+08	pCi					1.10E+11	4.77E+09	7.37E+08	3.97E+09	
ETTP	6.12	K-25 Bldg Non-Purge Ext. Transite	6.80E+08	pCi					3.31E+10	1.71E+09	3.20E+08	9.35E+08	
ETTP	6.13	K-25 Bldg Area 5.1 PER R0	1.36E+08	pCi					9.15E+10	3.18E+09	2.97E+08	2.87E+08	
ETTP	6.14	K-1232 Tank Farm Miscellaneous Debris R0	7.86E+07	pCi					8.46E+08	8.69E+07		8.97E+08	
ETTP	6.16	K-601 Misc Debris	1.07E+09	pCi					2.00E+10	1.10E+09		5.56E+09	
ETTP	6.17	Building K-1030 Debris	9.11E+08	pCi					6.31E+08	1.71E+08		1.28E+09	
ETTP	6.18	Building K-1024 Debris	8.51E+08	pCi					6.32E+08	1.16E+08		5.75E+08	
ETTP	6.19	K-25/K-27 Bldg Struc Debris	1.92E+09	pCi					1.03E+12	5.01E+10	1.44E+09	1.05E+11	
ETTP	6.27	K-25/K-27 EMR Debris Material (K-27 ARRA)	2.74E+09	pCi					6.05E+09			1.49E+11	
ETTP	6.28	K-25 Lead Based Pain Debris	5.54E+08	pCi					1.19E+09	7.63E+08		7.10E+08	
ETTP	6.31	K-25 Building Northwest Bridge	5.25E+08	pCi					4.30E+08			1.85E+08	
ETTP	6.41	K-25 West Side Compressors Group 1 R1	6.11E+09	pCi					1.99E+13	8.03E+11		9.08E+10	
ETTP	6.42	K-25 West Side Converters Group 1 R1	1.02E+09	pCi					3.60E+12	1.83E+11		2.44E+10	
ETTP	6.43	K-25 West Side Converters Group 1 R1	3.49E+09	pCi					4.39E+12	2.21E+11		1.88E+10	
ETTP	6.58	K25 East and North Low-Risk Converters	3.03E+09	pCi					2.70E+12	1.44E+11		8.00E+10	
ETTP	6.59	Building K-25 East Wing and North End Low-Risk Compressors	2.08E+09	pCi					6.14E+12	3.30E+11		1.74E+11	
ETTP	6.60	K-25 West Wing Post Mined Low-Risk Compressors	8.48E+07	pCi					2.41E+11	1.22E+10		1.52E+09	
ETTP	6.998	Comingled waste lot that inlcudes WL's 6.49-6.57	4.63E+10	pCi					6.54E+13	4.23E+12	5.82E+11	2.54E+12	
ETTP	6.999	Comingled waste lot that includes WL's 6.32, 6.33, 6.34, 6.35, 6.38, 6.39, 6.45, 6.46, 6.47, 6.48	1.66E+11	pCi					2.62E+13	2.05E+12		4.06E+12	
ETTP	8.02	Building K-33 Concrete Pedestal	1.14E+10	pCi					2.46E+10	1.23E+09	1.23E+08	2.46E+10	
ETTP	8.05	BNFL Compressor Blades	5.89E+08	pCi					6.18E+10	3.21E+09		1.03E+11	
ETTP	8.07	BNFL K-31 Concrete Pedestal Waste Lot	4.61E+09	pCi					3.26E+09	3.41E+08		3.88E+09	
ETTP	8.08	K-33 Concrete Floor Scabble	2.27E+09	pCi						1.65E+09		9.85E+09	

Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) (Continued)

Site	Waste Lot	WL Name	Net Weight (g)	Units	Th-230	Th-232	U-232	U-233	U-234	U-235	U-236	U-238	Zn-65
ETTP	8.11	Non-PG/Non-Fissile Components	2.66E+08	*pCi*					1.71E+09	1.19E+09		1.20E+10	
ORNL	10.01	Old Hydrofracture Facility Remediation Wastes (Containers)	7.04E+08	*pCi*					8.57E+10	2.84E+09	4.96E+03	1.82E+11	
ETTP	14.01	K-1303 Building Debris	1.92E+09	*pCi*					4.65E+09	1.34E+08	6.22E+10	3.31E+09	
ETTP	14.02	K-1302 Building Debris	3.06E+08	*pCi*					4.91E+09	2.45E+08	1.01E+08	1.07E+09	
ETTP	14.03	K-1413 Building Debris	1.10E+09	*pCi*					7.04E+09	5.50E+08	8.04E+09	1.06E+10	
ETTP	14.04	K-1303 Metal Debris	1.61E+08	*pCi*					3.21E+06	1.61E+06			
ETTP	14.05	K-1300 Stack Debris	1.97E+08	*pCi*					8.81E+10	4.44E+09	1.83E+09	2.02E+10	
ETTP	14.06	K-1413 Process Piping and Equipment	7.78E+07	*pCi*					8.09E+09	8.22E+08	3.77E+08	2.66E+10	
ETTP	14.07	Overhead Fluorine Pipelines and K-1301/K-1407 Metal Debris	2.60E+07	*pCi*					1.43E+07	2.08E+06	1.30E+06	1.38E+07	
ETTP	14.08	K-1301, K-1405, and K-1407 Asbestos	9.08E+06	*pCi*					5.11E+08	3.00E+07	4.80E+07	4.19E+08	
ETTP	14.11	K-1420 Equipment and Building Debris	5.28E+09	*pCi*					2.21E+11	2.91E+10		3.83E+10	
ETTP	14.14	K-1401/K-723 R4	2.43E+10	*pCi*					4.42E+11	3.45E+10		4.16E+11	
ETTP	14.15	K-1420 Calciner	5.32E+07	*pCi*					3.03E+11	1.90E+10		1.41E+11	
ETTP	14.16	Main Plant D&D Housekeeping R0	1.53E+07	*pCi*					4.16E+06	8.14E+05		3.91E+06	
ETTP	14.17	UF6 Cylinders Wooden Saddles	2.88E+08	*pCi*					3.13E+07			8.78E+07	
ETTP	14.21	K-1066-G Scrap, Debris and Abandoned Equipment	5.12E+08	*pCi*					1.40E+09	1.25E+08		3.75E+09	
Offsite	24.0	ACAP RA	3.87E+10	*pCi*					8.08E+11	8.13E+10		8.94E+11	
Offsite	24.01	ACAP Debris	2.46E+06	*pCi*					1.20E+09	6.79E+07		1.45E+09	
Offsite	24.02	ACAP Soil	1.30E+09	*pCi*					6.99E+06	4.03E+05		7.17E+06	
ETTP	30.01	ETTP OD RSM1 R1	2.07E+09	*pCi*					3.04E+11	8.65E+09	7.59E+08	1.23E+11	
ETTP	30.02	ETTP OD CD	8.38E+08	*pCi*					2.28E+11	1.57E+10	3.41E+09	1.23E+11	
ETTP	30.03	ETTP OD RSM 5	6.00E+07	*pCi*					2.00E+09	3.65E+07	1.19E+07	1.79E+09	
ETTP	30.06	ETTP OD DAW R1	1.18E+09	*pCi*					4.09E+11	2.66E+10	5.96E+10	2.53E+11	
ETTP	30.07	OD VRR-1	1.60E+09	*pCi*					2.92E+11	1.18E+10		4.11E+11	
ETTP	30.08	OD VRR-2	4.81E+08	*pCi*					7.49E+11	3.08E+10		1.34E+12	
ETTP	30.09	ETTP OD DAW-2 R1	2.19E+08	*pCi*					7.77E+11	2.53E+10	3.01E+09	3.57E+11	
ETTP	30.10	ETTP OD DAW-3	1.78E+08	*pCi*				1.96E+09	2.50E+10	1.43E+09	1.13E+08	3.01E+10	
Offsite	30.12	DWI 901 Stored Soils	1.83E+08	*pCi*					9.81E+10	5.95E+09	1.34E+09	1.33E+11	
ETTP	30.13	ETTP Outdoor Solids	3.53E+08	*pCi*					1.63E+10	9.22E+08	2.70E+08	6.93E+10	
ETTP	62.01	Poplar Creek Process Facilities Building Debris and Miscellaneous Materials	6.46E+07	*pCi*					2.00E+09	1.10E+08		1.29E+09	
ETTP	62.04	K-413 Building Debris and Process Equipment	7.17E+08	*pCi*					4.28E+09	1.44E+09		2.06E+09	
ETTP	62.05	K-1231 and K-1233 Demolition Debris	1.68E+09	*pCi*					8.09E+09	3.56E+08		7.50E+08	
ETTP	65.01	K-770 Scrap Yard	4.16E+10	*pCi*					2.50E+09	4.45E+10	8.33E+08	7.58E+11	
ETTP	65.02	K-770 14 Series Piles	9.56E+08	*pCi*					1.21E+08	1.26E+09		2.12E+10	
ETTP	65.03	K-770 B-25 Boxes	8.81E+08	*pCi*				2.20E+11		1.28E+10	9.60E+09	2.26E+10	
ETTP	66.01	KAFaD Group 1 Buildings K-724 and K-725 Excess Material Project	2.86E+06	*pCi*					1.69E+06	1.97E+05		2.14E+06	
ETTP	66.04	K-1064 Peninsula Area	1.31E+08	*pCi*					3.54E+10	1.93E+09	1.56E+09	1.42E+10	
ETTP	66.06	K-1025 Buildings Structural Wood	3.40E+07	*pCi*					2.70E+08	1.51E+07		2.05E+08	

Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) (Continued)

Site	Waste Lot	WL Name	Net Weight (g)	Units	Th-230	Th-232	U-232	U-233	U-234	U-235	U-236	U-238	Zn-65
ETTP	66.07	DBOS Building Debris and Misc Materials R2	9.78E+09	*pCi*					5.30E+12	1.77E+11		4.49E+12	
ETTP	73.01	Centrifuge Equipment U	8.57E+07	*pCi*					9.00E+10	5.26E+09	2.04E+09	4.49E+10	
ETTP	73.02	Centrifuge Equipment C	9.73E+07	*pCi*					1.02E+11	5.97E+09	2.32E+09	5.10E+10	
ORNL	80.01	HFIR Impoundments	8.49E+09	*pCi*					1.56E+10			9.33E+09	
ORNL	80.02	HRE Pond Sediments	6.88E+09	*pCi*					1.44E+10			8.25E+09	
ORNL	81.01	T1/T2 R4 HFIR Tanks Debris R5	1.01E+09	*pCi*				3.10E+08	2.71E+08	4.27E+06	4.74E+07	5.28E+08	
ORNL	81.02	22-Trench Debris & Secondary Waste	8.24E+06	*pCi*					9.14E+06	1.03E+06		6.77E+06	
ORNL	84.01	GAAT RA Waste R3	1.22E+09	*pCi*				9.16E+09	6.07E+09	2.83E+08	1.25E+07	6.46E+09	
ORNL	84.02	ITRA Waste R1	3.15E+08	*pCi*				1.93E+07	3.52E+08	4.34E+01	1.31E+01	6.10E+06	
ORNL	84.03	W1-A B12 Box Soil	3.18E+08	*pCi*					1.01E+11	3.80E+08	1.53E+08	1.22E+09	
ORNL	84.04	W1-A B12 Box Soil-1	1.79E+08	*pCi*					7.31E+10	8.36E+08	3.45E+08	1.25E+09	
ORNL	84.05	RASW Inactive Tanks Secondary Equipment	1.81E+06	*pCi*				1.48E+04	6.84E+05	1.35E-02	8.56E-03	2.14E+03	
ORNL	84.06	HIC-1 FFA Inactive Tanks	4.56E+06	*pCi*				5.02E+05	2.31E+07	4.56E-01	2.88E-01	7.16E+04	
ORNL	87.01	SIOU Bricks	6.26E+09	*pCi*					5.14E+11	2.54E+10	1.53E+10	2.90E+11	
ORNL	87.02	SIOU Debris R2	1.00E+09	*pCi*					8.23E+09	4.26E+08	2.91E+08	4.37E+09	
ORNL	89.01	MSRE Remedial Action	4.69E+07	*pCi*				1.45E+11	8.29E+09	9.88E+05	1.16E+06	3.57E+05	
ORNL	102.01	Building 3026 Debris and Misc Material	8.53E+08	*pCi*					5.23E+08			4.42E+08	
ORNL	111.01	Melton Valley Weir Cleanout and Bank Stabilization Project	6.63E+08	*pCi*	3.91E+08	5.04E+08			1.29E+09			1.77E+09	
Y-12	114.01	Jack Case Center Contaminated Force Main	1.96E+07	*pCi*					4.70E+09	1.58E+08	7.21E+07	1.06E+09	
Offsite	145.01	David Witherspoon, Inc. 901 Site- Candora Soil	1.34E+10	*pCi*					3.32E+12	2.58E+11	8.40E+10	3.23E+12	
Offsite	145.02	DWI 901 Scrap Metal and Debris R2	1.81E+09	*pCi*					1.28E+10	6.45E+08		1.42E+10	
Offsite	145.03	DWI 901 Site Building and Miscellaneous Debris	4.90E+08	*pCi*					9.79E+09	5.78E+08	2.98E+08	8.42E+09	
Offsite	145.04	David Witherspoon, Inc. 901 Site Soil	7.29E+10	*pCi*					9.26E+12	3.54E+11	1.20E+11	4.57E+12	
Offsite	146.01	DWI 1630 Soil and Incidental Debris R6	1.35E+11	*pCi*					5.68E+13	8.20E+11	3.80E+12	5.56E+13	
Offsite	146.02	DWI 1630 Site: Drums and Drum Soils	4.96E+08	*pCi*					2.09E+11	3.01E+09	1.40E+10	2.04E+11	
ORNL	149.01	NHF D&D	4.64E+09	*pCi*					2.35E+10			2.02E+11	
ORNL	149.02	NHF Well P&A Debris R2	5.98E+07	*pCi*									
ORNL	149.03	HRE Ancillary Facilities	1.16E+08	*pCi*	6.29E+07	2.84E+07			3.65E+07			3.80E+07	
ORNL	149.04	HRE Waste Evaporator System and Sampling Station Waste R2	2.12E+08	*pCi*		3.58E+04			6.38E+09	1.73E+08	6.81E+07	5.45E+06	
ORNL	149.06	NHF Well P&A Primary Waste	5.94E+07	*pCi*				2.04E+08	2.80E+06	5.67E+04	9.20E-02	7.84E+05	
ORNL	149.07	NHF Process	2.90E+07	*pCi*				6.06E+09	5.69E+08	9.95E+06		2.79E+08	
ORNL	149.09	7841 Scrap Yard Debris and Equipment	1.20E+09	*pCi*	1.02E+10	1.33E+10	1.98E+09	9.78E+11	1.60E+10	1.42E+09	1.29E+09	1.56E+11	
ORNL	149.10	MV Tanks 454 and 455	9.91E+06	*pCi*				1.41E+07	9.38E+06	1.13E+04	1.00E+05	2.44E+05	
ORNL	155.01	K-1070-B Burial Ground Remediation	1.12E+11	*pCi*					5.93E+13	6.73E+12		2.91E+13	
ETTP	155.02	BOS Lab Facilities Miscellaneous Wastes	1.83E+09	*pCi*					4.04E+11	2.43E+10		4.46E+11	
ETTP	155.03	BOS Lab Area Soil	1.56E+08	*pCi*					1.31E+09	6.43E+07		1.01E+09	
ETTP	155.04	BOS Lab Area Acid Pits and Piping	1.52E+08	*pCi*					1.06E+09	6.45E+07		2.45E+08	
ETTP	155.05	K-1015-A Laundry Pit	1.33E+08	*pCi*					1.30E+09	8.34E+07		2.35E+08	

Table A-6. Mass Weighted Average Data Set (Natural Phenomenon and Transportation Risk) (Continued)

Site	Waste Lot	WL Name	Net Weight (g)	Units	Th-230	Th-232	U-232	U-233	U-234	U-235	U-236	U-238	Zn-65
ETTP	157.01	K-29 Building D&D	3.63E+10	*pCi*					3.07E+12	1.66E+11		7.23E+11	
ORNL	164.01	Hot Storage Garden R1	3.12E+07	*pCi*	9.86E+07	2.17E+07			3.78E+08	1.13E+08		4.00E+08	
ORNL	167.01	Epicor II Lysimeters, MV Soils & Sediments	7.73E+08	*pCi*					3.54E+09	1.65E+08	5.41E+07	2.25E+08	
ORNL	200.03	Facilities 3504, 3508, 3541, 3550 and 3592 Building Debris and Misc Material	5.09E+07	*pCi*					2.37E+08			2.35E+07	
ORNL	200.999	Comingled Waste Lot that includes Waste Lots 200.1, 2001.2 and 200.4	2.76E+09	*pCi*					8.37E+11	3.56E+09		3.29E+10	
ORNL	201.01	Miscellaneous Materials from Buildings 2001, 2019 and 2024	9.07E+06	*pCi*	7.45E+06	1.80E+06			4.75E+06	3.62E+06		4.10E+06	
ORNL	201.02	Building 2000 Structure and Contents	1.19E+09	*pCi*	8.91E+08	2.49E+08			6.64E+08	4.73E+08		5.33E+08	
ORNL	201.03	Slabs - Drains, Pipes and Slabs	5.58E+09	*pCi*	2.21E+09	1.39E+09		8.76E+10	3.65E+10	6.08E+08	6.02E+08	6.97E+09	
ORNL	203.01	Buildings 2011, 2017 and 3044	6.34E+08	*pCi*					5.72E+09	2.77E+08		3.59E+08	
ORNL	207.01	3026 Hot Cells	2.47E+08	*pCi*	1.68E+08	1.03E+08			6.78E+08	4.85E+07		1.05E+08	3.61E+08
Y-12	301.01	Capability Unit 29 Legacy Material Bldg 9201-5	1.05E+08	*pCi*					2.22E+09	1.72E+06	2.30E+07	6.94E+07	
Y-12	301.02	Legacy Material from Building 9201-5	4.98E+07	*pCi*						2.28E+06		1.33E+07	
Y-12	301.04	Legacy Material from Building 9201-5 First and Third Floor Beryllium Areas	1.10E+09	*pCi*						1.87E+09	9.67E+08	1.48E+11	
Y-12	303.01	Old Salvage Yard Piles SY-HI (Areas 1 and 2)	7.39E+09	*pCi*				8.13E+09	1.14E+12	6.44E+10	3.19E+10	4.96E+12	
Y-12	303.02	Old Salvage Yard SY-H1 Area 1 Pile, Rev 1	1.41E+09	*pCi*					1.46E+13	8.81E+11	2.05E+11	1.14E+13	
Y-12	304.01	Building 9211 D&D	9.04E+09	*pCi*					8.72E+11	3.22E+10		4.63E+11	
Y-12	304.02	Building 9769 D&D	1.86E+09	*pCi*					6.08E+10		5.03E+09	4.66E+10	
ETTP	401.01	K-33 Building Debris and Misc Material	2.00E+11	*pCi*					1.63E+12	7.97E+10		1.18E+12	
ETTP	997.01	Main Plant LR/LC Buildings	2.52E+09	*pCi*					4.56E+10	3.58E+09		4.31E+10	
ETTP	997.02	K-1035 Demolition Debris	5.90E+09	*pCi*					8.15E+09		3.16E+09	7.56E+09	
			1.29E+12	*pCi*	**1.40E+10**	**1.56E+10**	**1.98E+09**	**1.46E+12**	**3.45E+14**	**2.04E+13**	**5.81E+12**	**2.05E+14**	**3.61E+08**
				g	**9.03E+09**	**9.24E+09**	**1.20E+09**	**1.79E+10**	**1.28E+12**	**1.25E+12**	**5.10E+11**	**1.29E+12**	**2.47E+08**
				pCi/g	**1.55E+00**	**1.69E+00**	**1.65E+00**	**8.13E+01**	**2.69E+02**	**1.63E+01**	**1.14E+01**	**1.60E+02**	**1.46E+00**

Table A-7. Chemical Concentration Data Set

		Site	Y-12	ORNL	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP
		Waste Lot	1.0	2.01	4.03	4.05	4.06	4.08	4.11	4.12	4.14	6.01	6.02	6.03	6.04	6.06	6.12	6.13	6.14	6.16	6.17	6.18
WL Name (pink indicates co-mingled waste lots)			BYBY RA	SWSA 4 Remedial Action IHP-1 RA	Blair Quarry Soils	K-710	K-1085 Old Firehouse Burn Area Drum Burial Site, Area 6 Soils	Duct Island Soil Mounds	K-711/K-766 Debris and Soils	K-770 Scrap Yard Soils	K-1093 Scrap Yard Debris	K25 HMA-1 DD R2	K27 Units 1-7 ACM R2 (ARRA)	K25 HMA-2 DD Rev 2	K-27 Units 402-8 & 402-9 Hazardous Materials Abatement	K-25 Bldg Area 6 PER R1	K-25 Bldg Non-Purge Ext. Transite	K-25 Bldg Area 5.1 PER R0	K-1232 Tank Farm Miscellaneous Debris R0	K-601 Misc Debris	Building K-1030 Debris	Building K-1024 Debris
Waste Lot mass (grams)		1.27E+12	8.66E+10	2.22E+10	1.35E+10	2.80E+08	1.51E+07	1.47E+08	5.37E+08	8.81E+10	6.63E+08	3.41E+09	3.87E+08	1.91E+08	5.90E+07	2.13E+08	6.8E+08	1.4E+08	7.9E+07	1.1E+09	9.1E+08	8.5E+08
ID	EMWMF SRC FOR WL	Units																				
14	Antimony	mg/kg		0.51	4.83E-01	7.25E-01		2.33E+00	7.27E+01	1.12E+01	1.55E+01	5.21E-02	0.02	0.052	1.76E-02	2.24E+00		2.24E+00		4.23E+00	4.94E-01	8.31E-01
15	Barium	mg/kg	486.1	167.4	4.54E+02	1.65E+02	6.72E+02	2.50E+02	4.71E+01	1.19E+02	2.94E+02	4.82E-01	0.56	0.482	5.64E-01				3.53E+02	7.67E+02	3.70E+02	2.99E+02
N84	Boron	mg/kg						1.07E+01		7.34E+00												2.31E+01
16	Chromium [total]	mg/kg	184.271	38.0	3.97E+01	4.11E+01	9.15E+01	9.76E+03	3.70E+02	4.99E+02	2.87E+03	7.40E-02	0.08	0.074	7.85E-02	2.93E+03		2.93E+03	3.64E+03	5.20E+01	1.03E+03	3.19E+02
17	Lead	mg/kg	906.6	55.9	2.82E+02	1.05E+02	1.82E+02	2.27E+02	6.89E+01	6.65E+01	1.67E+02	4.71E+00	1.84	4.71	2.01E+00	9.65E+01		9.65E+01		8.20E+01	1.10E+03	1.18E+02
N72	Manganese	mg/kg				1.57E+03	3.26E+02	1.15E+02	5.76E+02	6.40E+02	1.82E+03									1.32E+03		1.03E+03
N73	Molybdenum	mg/kg					3.67E+00	6.22E+01	5.68E+00	1.34E+01	7.04E+01											7.48E+00
18	Selenium	mg/kg		0.57	2.05E+00	7.12E-01		3.56E+00	8.33E-01	4.51E+00	2.80E+02	3.81E-03	0.00	0.0038	7.08E-04	4.64E+01		4.64E+01	3.53E+01	2.23E+01	3.70E+01	6.63E+00
19	Strontium	mg/kg		18.16		7.35E+00	4.41E+01	6.90E+00	9.78E+01		5.71E+01											
20	Tin	mg/kg		10.5			1.21E+01	1.86E+01	5.88E+00	5.67E+01	1.74E+02	7.50E-02	0.19	0.075	1.63E-01	2.81E+01		2.81E+01				
21	Vanadium	mg/kg		24.8	2.11E+01	1.21E+01	8.60E+01	2.73E+01	1.08E+01	2.23E+01	4.90E+01	3.70E-02	0.03	0.037	3.04E-02				2.12E+02	2.12E+01	2.22E+02	6.94E+00
N33	2,4-D	mg/kg																				
N34	2,4,5-T [Silvex]	mg/kg							8.42E-02													
22	Acenaphthene	mg/kg	3.6		3.85E+01	3.52E+00			1.68E+02	3.27E-01	4.59E-01										3.84E+01	4.86E+00
N59	Acenaphthylene	mg/kg								1.64E-01	5.21E-01											1.70E+00
23	Acetone	mg/kg	0.020		2.44E-02	5.06E-02			8.67E-03	6.13E-02										8.93E-01		
N99	Acetonitrile	mg/kg																				
N74	Acetophenone	mg/kg							7.06E+01		4.78E+00									3.95E-01		
N100	Acrolein	mg/kg																				
N101	Acrylonitrile	mg/kg																				
N45	Aldrin	mg/kg							1.47E-02													
N47	Aroclor-1221	mg/kg																				
N48	Aroclor-1232	mg/kg																				
24	Benzene	mg/kg																				
N120	Benzidine	mg/kg																				
N60	Benzoic Acid	mg/kg							7.02E+01	1.75E-01	1.24E+01										1.67E+03	8.15E+00
N67	Benzyl Alcohol	mg/kg																				3.70E+00
N52	alpha-BHC	mg/kg																				
N53	beta-BHC	mg/kg							9.28E-02													
N54	delta-BHC	mg/kg							1.39E-02													
N102	Bromodichloromethane	mg/kg																				
N103	Bromoform	mg/kg																				
N104	Bromomethane	mg/kg																				
N105	Butylbenzene	mg/kg																				
25	Carbazole	mg/kg	2.71	0.38	4.89E+01				6.79E+01	3.14E-01	5.19E-01										4.59E+01	1.17E+01
26	Carbon tetrachloride	mg/kg					3.98E+00															
N75	Carbon Disulfide	mg/kg																				
N35	Chlordane	mg/kg							1.24E+00													
N01	Chlorobenzene	mg/kg																				
27	Chloroform	mg/kg				3.08E-02	1.06E+00				8.62E-02					1.67E+00		1.67E+00		5.50E-04		
N106	Chloromethane (Methyl Chloride)	mg/kg																				
N112	o-Chlorotoluene	mg/kg																				
N27	m-Cresol	mg/kg																				5.04E+00
N26	o-Cresol	mg/kg																				1.61E+00
N28	p-Cresol	mg/kg								2.27E-01												
N76	Cumene (Isopropylbenzene)	mg/kg																		9.76E-03		2.20E+00
N09	Cyanide	mg/kg																				
N49	DDD	mg/kg							2.20E-01													
N50	DDE	mg/kg							4.21E-01													
29	Di-n-butylphthalate	mg/kg	3.49	0.22	1.89E+00			1.12E-01			4.54E+00									3.94E-01	9.93E+01	3.76E+00
N107	Dibromochloromethane	mg/kg																				
N02	1,2-Dichlorobenzene	mg/kg																				
N03	1,3-Dichlorobenzene	mg/kg																				
N04	1,4-Dichlorobenzene	mg/kg						5.70E-02														
N93	1,2,-cis-Dichloroethylene	mg/kg																				
N96	1,2-trans-Dichloroethylene	mg/kg																				
N108	Dichlorodifluoromethane	mg/kg																				
N94	1,2-Dichloropropane	mg/kg																				
28	Dieldrin	mg/kg	0.049						1.47E-02													
N62	Diethylphthalate	mg/kg																			3.54E+01	3.61E-01
N95	1,2-Dimethylbenzene	mg/kg																				4.74E-01
N63	2,4-Dimethylphenol	mg/kg																				1.43E+00

Table A-7. Chemical Concentration Data Set (Continued)

		Site	Y-12	ORNL	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP
		Waste Lot	1.0	2.01	4.03	4.05	4.06	4.08	4.11	4.12	4.14	6.01	6.02	6.03	6.04	6.06	6.12	6.13	6.14	6.16	6.17	6.18
WL Name (pink indicates co-mingled waste lots)			BYBY RA	SWSA 4 Remedial Action IHP-1 RA	Blair Quarry Soils	K-710	K-1085 Old Firehouse Burn Area Drum Burial Site, Area 6 Soils	Duct Island Soil Mounds	K-711/K-766 Debris and Soils	K-770 Scrap Yard Soils	K-1093 Scrap Yard Debris	K25 HMA-1 DD R2	K27 Units 1-7 ACM R2 (ARRA)	K25 HMA-2 DD Rev 2	K-27 Units 403-8 & 403-9 Hazardous Materials Abatement	K-25 Bldg Area 6 PER R1	K-25 Bldg Non-Purge Ext. Transite	K-25 Bldg Area 5.1 PER R0	K-1232 Tank Farm Miscellaneous Debris R0	K-601 Misc Debris	Building K-1030 Debris	Building K-1024 Debris
N64	Dimethylphthalate	mg/kg									9.25E+00										3.26E+01	6.07E-02
N86	2,4 Dinitrotoluene	mg/kg																				
N87	2,6 Dinitrotoluene	mg/kg																				
N69	Endosulfan and Metabolites	mg/kg							4.68E-01													
N36	Endrin	mg/kg																				
N70	Endrin Aldehyde	mg/kg							7.00E-02													
N71	Endrin Ketone	mg/kg							1.31E-01													
N77	Ethylbenzene	mg/kg																		3.42E-03		2.08E-01
N78	Ethylchloride	mg/kg																				
N37	Heptachlor	mg/kg							2.55E-02													
N38	Heptachlor Epoxide	mg/kg																				
N42	Hexachlorobenzene	mg/kg																				
N29	Hexachlorobutadiene	mg/kg					4.55E+00															
N30	Hexachloroethane	mg/kg																				
N111	n-Hexane	mg/kg																				
N118	1-Hexanol	mg/kg																				
N79	2-Hexanone	mg/kg																		6.83E-03		
30	Isophorone	mg/kg																				
N44	Lindane	mg/kg																				
N41	Lithium	mg/kg																				
N109	Methanol	mg/kg																				
N110	Methylene Chloride	mg/kg																				
N05	Methylcyclohexane	mg/kg																				
N80	Methyl Isobutyl Ketone	mg/kg																				
N85	Methyl Methacrylate	mg/kg																				
N98	1-Methyl-4-(1-methylethyl)-benzene	mg/kg																				3.97E-01
N57	2-Methylnaphthalene	mg/kg				1.67E+01		7.04E-02	6.94E+01	1.01E-01	3.62E+00									5.17E-02		3.37E+00
N88	(1-Methylpropyl)benzene	mg/kg																				1.82E-01
31	Naphthalene	mg/kg	1.04		1.21E+01			4.60E-02	6.99E+01	1.57E-01	1.71E-01									5.62E-02	2.93E+01	9.20E+00
N83	4-Nitrobenzenamine (4-Nitroaniline)	mg/kg																				
N31	Nitrobenzene	mg/kg																				
N58	2-Nitrophenol	mg/kg																				
N82	4-Nitrophenol	mg/kg																				
32	N-nitroso-di-n-propylamine	mg/kg																				
N14	N-Nitrosodiphenylamine	mg/kg																				
33	Phenol	mg/kg							7.11E+01	3.14E-01											3.18E+01	4.89E+00
N113	Propylbenzene	mg/kg																				3.80E-01
N114	Propylene Glycol	mg/kg																				
N43	Pyridine	mg/kg																				
N115	Styrene	mg/kg																				
N89	1,1,1,2-Tetrachloroethane	mg/kg																				
N90	1,1,2,2-Tetrachloroethane	mg/kg																				
34	Tetrachloroethene	mg/kg	0.009				2.10E+00													6.00E-04		
N66	2,3,4,6-Tetrachlorophenol	mg/kg																				3.04E+00
35	Toluene	mg/kg	0.004	0.17		2.09E+00					9.52E-02									2.60E-03	1.56E+00	1.01E+00
N06	1,2,4-Trichlorobenzene	mg/kg			1.41E+00																	
36	Trichloroethene	mg/kg	0.005			1.35E+00	1.08E+01									1.93E+00		1.93E+00		5.11E-03		
N116	Trichlorofluoromethane	mg/kg																				
N32	2,4,6-Trichlorophenol	mg/kg																				
N91	1,2,3-Trichloropropane	mg/kg																				
N117	Trimethylbenzene (mixed isomers)	mg/kg																				
N92	1,2,4-Trimethylbenzene	mg/kg																				5.03E+00
N97	1,3,5-Trimethylbenzene	mg/kg																				2.03E+00
N25	Vinyl Chloride	mg/kg																				
N15	Xylene (mixture of isomers)	mg/kg																				1.03E+00

Table A-7. Chemical Concentration Data Set (Continued)

		Site	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ORNL	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP
		Waste Lot	6.19	6.27	6.28	6.31	6.41	6.42	6.43	6.58	6.59	6.60	6.998	6.999	10.01	14.01	14.02	14.03	14.04	14.05	14.06	14.07	14.08	14.11	14.14	14.15	14.16
	WL Name (pink indicates co-mingled waste lots)		K-25/K-27 Bldg Struc Debris	K-25/K-27 EMR Debris Material (K-27 ARRA)	K-25 Lead Based Pain Debris	K-25 Building Northwest Bridge	K-25 West Side Compressors Group 1 R1	K-25 West Side Converters Group 1 R1	K-25 West Side Converters Group 1 R1	K25 East and North Low-Risk Converters	Building K-25 East Wing and North End Low-Risk Compressors	K-25 West Wing Post Mined Low-Risk Compressors	Comingled waste lot tha includes WL's 6.49-6.57	Comingled waste lot tha includes WL's 6.32, 6.33, 6.34, 6.35, 6.38, 6.39, 6.45, 6.46, 6.47,	Old Hydrofracture Facility Remediation Wastes (Containers)	K-1303 Building Debris	K-1302 Building Debris	K-1413 Building Debris	K-1303 Metal Debris	K-1300 Stack Debris	K-1413 Process Piping and Equipment	Overhead Fluorine Pipelines and K-1301/K-1407 Metal Debris	K-1301, K-1405, and K-1407 Asbestos	K-1420 Equipment and Building Debris	K-1401/K-723 R4	K-1420 Calciner	Main Plant D&D Housekeeping R0
	Waste Lot mass (grams)	1.27E+12	1.9E+09	2.7E+09	5.5E+08	5.2E+08	6.1E+09	1.0E+09	3.5E+09	3.0E+09	2.1E+09	8.5E+07	4.6E+10	1.7E+11	7.0E+08	######	3.1E+08	######	######	######	7.8E+07	######	9E+06	5E+09	2.4E+10	5.3E+07	1.5E+07
ID	EMWMF SRC FOR WL	Units																									
14	Antimony	mg/kg		3.55E+01			7.10E+01	7.10E+01			1.28E+02	7.10E+01	3.45E+00	3.96E+00	50.8		3.2	0.8	11.90		21.78	11.54			1.87E+01	8.00E-02	
15	Barium	mg/kg	4.48E+02	7.63E+02		8.97E-01							2.83E+01	8.15E-03	8.0E-05	115.68	115.7	174.55	5.06	74.16	31.07	7.12			3.73E+02	7.00E-02	1.27E+02
N84	Boron	mg/kg		1.30E+03									1.55E+02	6.31E+01													
16	Chromium [total]	mg/kg	9.37E+02	3.33E+04	2.11E+04	7.28E+02	1.51E+03	1.51E+03	1.24E+02	2.03E+02	3.37E+03	1.51E+03	1.13E+02	2.28E+02	5637	14.5	718	17	231.88	11.05	30833.54	353.08			1.04E+03	4.20E+00	1.21E+01
17	Lead	mg/kg		1.46E+02		5.17E+02	3.80E+01	3.80E+01			1.17E+02	3.80E+01	3.02E+02	2.65E+01	0.001	34.0	13.250	294.53	276.33	7.27	220.57	357.90			5.31E+02	9.00E-02	6.83E+00
N72	Manganese	mg/kg		7.67E+02		5.23E+03	9.71E+03	9.71E+03	8.82E+03	8.23E+03	9.45E+03	9.71E+03	4.57E+03	2.72E+05											3.44E+02	4.68E-01	2.92E+02
N73	Molybdenum	mg/kg											1.45E+01	3.12E+01													1.32E+00
18	Selenium	mg/kg	4.48E+01	5.04E+00		1.27E+01							3.98E+01	1.54E+02	14.8	0.305		0.4	5.72		11.36	7.23			3.73E+01	1.00E-01	
19	Strontium	mg/kg		1.45E+02	2.08E+01								1.45E+02	7.30E+02	0.099	123.32	15.692		0.80	168.60	15.19	0.59			3.45E+01		1.78E+02
20	Tin	mg/kg		8.09E+02	2.82E+01	1.10E+02	5.96E+02	5.96E+02	6.90E+01	1.20E+01	1.10E+03	5.96E+02	3.12E+01	8.89E+01	959.5	1.7			60.02	1.45	93.67	62.07			4.65E+02		1.01E+00
21	Vanadium	mg/kg	2.69E+02	2.19E+01		2.82E+00							1.21E+02	3.17E+01	64.5	12.2	77.4		23.36	12.15	177.33	5.66			2.24E+02		9.97E+00
N33	2,4-D	mg/kg																									
N34	2,4,5-T [Silvex]	mg/kg																									
22	Acenaphthene	mg/kg											1.68E+01	5.64E+01													
N59	Acenaphthylene	mg/kg																									
23	Acetone	mg/kg													0.008	22.965			0.02								
N99	Acetonitrile	mg/kg																									
N74	Acetophenone	mg/kg												2.02E-05													
N100	Acrolein	mg/kg																									
N101	Acrylonitrile	mg/kg																									
N45	Aldrin	mg/kg																									
N47	Aroclor-1221	mg/kg																									
N48	Aroclor-1232	mg/kg																									
24	Benzene	mg/kg													0.002												
N120	Benzidine	mg/kg																									
N60	Benzoic Acid	mg/kg											4.53E+01	2.21E+00													
N67	Benzyl Alcohol	mg/kg																									
N52	alpha-BHC	mg/kg																									
N53	beta-BHC	mg/kg																							5.05E-02		
N54	delta-BHC	mg/kg																									
N102	Bromodichloromethane	mg/kg																									
N103	Bromoform	mg/kg																									
N104	Bromomethane	mg/kg																									
N105	Butylbenzene	mg/kg																									
25	Carbazole	mg/kg											2.37E+01	1.70E+02													
26	Carbon tetrachloride	mg/kg													1.62E-04												
N75	Carbon Disulfide	mg/kg																									
N35	Chlordane	mg/kg											3.13E-02	1.36E-01											4.15E-02		
N01	Chlorobenzene	mg/kg																									
27	Chloroform	mg/kg													0.012												
N106	Chloromethane (Methyl Chloride)	mg/kg																									
N112	o-Chlorotoluene	mg/kg																									
N27	m-Cresol	mg/kg																									
N26	o-Cresol	mg/kg																									
N28	p-Cresol	mg/kg																									
N76	Cumene (Isopropylbenzene)	mg/kg																									
N09	Cyanide	mg/kg																									
N49	DDD	mg/kg											1.14E-02	1.56E-01													
N50	DDE	mg/kg											7.57E-02	4.19E+00											1.11E-01		
29	Di-n-butylphthalate	mg/kg											7.54E+00	1.49E+00	6.22E-12										1.90E-01		
N107	Dibromochloromethane	mg/kg																									
N02	1,2-Dichlorobenzene	mg/kg																									
N03	1,3-Dichlorobenzene	mg/kg																									
N04	1,4-Dichlorobenzene	mg/kg																									
N93	1,2,-cis-Dichloroethylene	mg/kg																									
N96	1,2-trans-Dichloroethylene	mg/kg																									
N108	Dichlorodifluoromethane	mg/kg																									
N94	1,2-Dichloropropane	mg/kg																									
28	Dieldrin	mg/kg											1.90E-03												3.60E-02		
N62	Diethylphthalate	mg/kg												4.33E-06													
N95	1,2-Dimethylbenzene	mg/kg																									
N63	2,4-Dimethylphenol	mg/kg																									

Table A-7. Chemical Concentration Data Set (Continued)

		Site	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ORNL	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP
		Waste Lot	6.19	6.27	6.28	6.31	6.41	6.42	6.43	6.58	6.59	6.60	6.998	6.999	10.01	14.01	14.02	14.03	14.04	14.05	14.06	14.07	14.08	14.11	14.14	14.15	14.16
	WL Name (pink indicates co-mingled waste lots)		K-25/K-27 Bldg Struc Debris	K-25/K-27 EMR Debris Material (K-27 ARRA)	K-25 Lead Based Pain Debris	K-25 Building Northwest Bridge	K-25 West Side Compressors Group 1 R1	K-25 West Side Converters Group 1 R1	K-25 West Side Converters Group 1 R1	K25 East and North Low-Risk Converters	Building K-25 East Wing and North End Low-Risk Compressors	K-25 West Wing Post Mined Low-Risk Compressors	Comingled waste lot tha inlcudes WL's 6.49-6.57	Comingled waste lot tha includes WL's 6.32, 6.33, 6.34, 6.35, 6.38, 6.39, 6.45, 6.46, 6.47,	Old Hydrofracture Facility Remediation Wastes (Containers)	K-1303 Building Debris	K-1302 Building Debris	K-1413 Building Debris	K-1303 Metal Debris	K-1300 Stack Debris	K-1413 Process Piping and Equipment	Overhead Fluorine Pipelines and K-1301/K-1407 Metal Debris	K-1301, K-1405, and K-1407 Asbestos	K-1420 Equipment and Building Debris	K-1401/K-723 R4	K-1420 Calciner	Main Plant D&D Housekeeping R0
N64	Dimethylphthalate	mg/kg																									
N86	2,4 Dinitrotoluene	mg/kg																									
N87	2,6 Dinitrotoluene	mg/kg																									
N69	Endosulfan and Metabolites	mg/kg																							6.25E-02		
N36	Endrin	mg/kg																							4.65E-02		
N70	Endrin Aldehyde	mg/kg																									
N71	Endrin Ketone	mg/kg																									
N77	Ethylbenzene	mg/kg																									
N78	Ethylchloride	mg/kg																									
N37	Heptachlor	mg/kg																									
N38	Heptachlor Epoxide	mg/kg											1.45E-03												1.44E-02		
N42	Hexachlorobenzene	mg/kg																									
N29	Hexachlorobutadiene	mg/kg																									
N30	Hexachloroethane	mg/kg																									
N111	n-Hexane	mg/kg																									
N118	1-Hexanol	mg/kg																									
N79	2-Hexanone	mg/kg																									
30	Isophorone	mg/kg																									
N44	Lindane	mg/kg																									
N41	Lithium	mg/kg																									
N109	Methanol	mg/kg																									
N110	Methylene Chloride	mg/kg																									
N05	Methylcyclohexane	mg/kg																									
N80	Methyl Isobutyl Ketone	mg/kg																									
N85	Methyl Methacrylate	mg/kg																									
N98	1-Methyl-4-(1-methylethyl)-benzene	mg/kg																									
N57	2-Methylnaphthalene	mg/kg											1.45E+01	3.12E+01													
N88	(1-Methylpropyl)benzene	mg/kg																									
31	Naphthalene	mg/kg											6.38E+01	1.08E+02													
N83	4-Nitrobenzenamine (4-Nitroaniline)	mg/kg																									
N31	Nitrobenzene	mg/kg																									
N58	2-Nitrophenol	mg/kg																									
N82	4-Nitrophenol	mg/kg																									
32	N-nitroso-di-n-propylamine	mg/kg																									
N14	N-Nitrosodiphenylamine	mg/kg																									
33	Phenol	mg/kg																							5.20E-01		
N113	Propylbenzene	mg/kg																									
N114	Propylene Glycol	mg/kg																									
N43	Pyridine	mg/kg																									
N115	Styrene	mg/kg																									
N89	1,1,1,2-Tetrachloroethane	mg/kg																									
N90	1,1,2,2-Tetrachloroethane	mg/kg																									
34	Tetrachloroethene	mg/kg		2.36E-02																							
N66	2,3,4,6-Tetrachlorophenol	mg/kg												7.27E-01													
35	Toluene	mg/kg													0.003												
N06	1,2,4-Trichlorobenzene	mg/kg																									
36	Trichloroethene	mg/kg		3.57E-02										1.11E-03	3.25E-04												
N116	Trichlorofluoromethane	mg/kg																									
N32	2,4,6-Trichlorophenol	mg/kg																									
N91	1,2,3-Trichloropropane	mg/kg																									
N117	Trimethylbenzene (mixed isomers)	mg/kg																									
N92	1,2,4-Trimethylbenzene	mg/kg																									
N97	1,3,5-Trimethylbenzene	mg/kg																									
N25	Vinyl Chloride	mg/kg																									
N15	Xylene [mixture of isomers]	mg/kg																									

Table A-7. Chemical Concentration Data Set Ccontinued)

		Site	ETTP	ETTP	Offsite	Offsite	Offsite	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	Offsite	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP
		Waste Lot	14.17	14.21	24.0	24.01	24.02	30.01	30.02	30.03	30.06	30.07	30.08	30.09	30.10	30.12	30.13	62.01	62.04	62.05	65.01	65.02	65.03	66.01	66.04	66.06
	WL Name (pink indicates co-mingled waste lots)		UF6 Cylinders Wooden Saddles	K-1066-G Scrap Debris and Abandoned Equipment	ACAP RA	ACAP Debris	ACAP Soil	ETTP OD FoMf RI	ETTP OD CD	ETTP OD RSM 5	ETTP OD DAW RI	OD VRR-1	OD VRR-2	ETTP OD DAW-3 RI	ETTP DAW-3	DWI 901 Stored Soils	ETTP Outdoor Solids	Poplar Creek Process Facilities Building Debris and Miscellaneous Materials	K-413 Building Debris and Process Equipment	K-1231 and K-1233 Demolition Debris	K-770 Scrap Yard	K-770 14 Scrap Piles	K-770 B-25 Boxes	KAFAD Group 1 Buildings K-724 and K-725 Excess Material Project	K-1064 Peninsula Area	K-1025 Buildings Structural Wood
	Waste Lot mass (grams)	1.27E+12	2.9E+08	5.1E+08	######	2.5E+06	1.3E+09	2.1E+09	######	######	1.2E+09	#####	4.8E+08	2.2E+08	1.8E+08	1.8E+08	3.5E+08	6.5E+07	7.2E+08	1.7E+09	4.2E+10	9.6E+08	8.8E+08	2.9E+06	1.3E+08	3.4E+07
ID	EMWMF SRC FOR WL	Units																								
14	Antimony	mg/kg		5.26E+01	4.9	4.92E+00	4.92E+00						1.15E+02				2.12E+00	6.33E+00		6.34E+00						
15	Barium	mg/kg		1.77E+02	114.8	1.15E+02	1.70E+02						1.64E+02			1.87E+02	2.15E+02	1.59E+02	2.99E+02	1.04E+02	5.70	5.051	5.51E+01	188.890	9.78E+00	1.05E+01
N84	Boron	mg/kg																								
16	Chromium [total]	mg/kg		2.97E+04	103	1.03E+02	6.35E+01	9.50E+03	58.385	19122.0	4.62E+02		3.38E+02	2.82E+04	1.46E+02	6.15E+01	1.72E+02	1.58E+02	1.99E+01	1.68E+01	2601.40	391.600	2.10E+03	104.783	1.43E+00	1.41E+00
17	Lead	mg/kg		1.15E+02	273.984	2.74E+02	6.11E+01	1.27E+02	73.137	255.2	3.22E+01		5.87E+02			3.94E+03	1.05E+02	1.03E+03	2.26E+02	2.59E+01	34.05	67.617	7.13E+01	127.333	1.25E+02	1.09E+02
N72	Manganese	mg/kg		2.87E+03														1.32E+03	1.89E+02	6.23E+02						
N73	Molybdenum	mg/kg		3.13E+03														1.60E+01	2.25E+00	6.90E+00						
18	Selenium	mg/kg		2.78E+01	1.5	1.48E+00							1.00E+00			2.38E+00		2.33E+00	6.30E-01	8.23E+00				0.329	5.20E-01	5.67E-01
19	Strontium	mg/kg		4.38E+01													7.30E+00	2.67E+02	8.30E+01	3.37E+02			5.85E+01			
20	Tin	mg/kg		4.66E+01	162.5	1.63E+02	1.63E+02											9.33E+00			56.78	50.083	1.62E+02			
21	Vanadium	mg/kg		1.88E+02	24.3	2.43E+01	2.43E+01						1.62E+01				4.41E+01	2.70E+01	9.03E+00	1.77E+01	26.12	79.955	3.13E+01	5.483		
N33	2,4-D	mg/kg																								
N34	2,4,5-T [Silvex]	mg/kg																								
22	Acenaphthene	mg/kg	2.03E+03	3.32E+01	1.175	9.53E-02	8.55E-01									9.53E-02										
N59	Acenaphthylene	mg/kg	3.35E+01																							
23	Acetone	mg/kg			0.093	9.27E-02										4.20E-02		5.87E-01		2.77E+00						
N99	Acetonitrile	mg/kg																								
N74	Acetophenone	mg/kg																								
N100	Acrolein	mg/kg																								
N101	Acrylonitrile	mg/kg																								
N45	Aldrin	mg/kg																								
N47	Aroclor-1221	mg/kg																								
N48	Aroclor-1232	mg/kg																								
24	Benzene	mg/kg																								
N120	Benzidine	mg/kg																								
N60	Benzoic Acid	mg/kg																6.32E+00		6.47E+01						
N67	Benzyl Alcohol	mg/kg																								
N52	alpha-BHC	mg/kg	3.71E-02																							
N53	beta-BHC	mg/kg																								
N54	delta-BHC	mg/kg	5.22E-02																	9.30E-03						
N102	Bromodichloromethane	mg/kg																								
N103	Bromoform	mg/kg																								
N104	Bromomethane	mg/kg																								
N105	Butylbenzene	mg/kg																								
25	Carbazole	mg/kg	3.50E+02																							
26	Carbon tetrachloride	mg/kg																								
N75	Carbon Disulfide	mg/kg																								
N35	Chlordane	mg/kg	5.49E-01															1.71E-01								
N01	Chlorobenzene	mg/kg					1.59E-02																			
27	Chloroform	mg/kg														6.68E-02										
N106	Chloromethane (Methyl Chloride)	mg/kg																								
N112	o-Chlorotoluene	mg/kg																								
N27	m-Cresol	mg/kg	5.28E+01																							
N26	o-Cresol	mg/kg	1.70E+01																							
N28	p-Cresol	mg/kg																								2.27E-01
N76	Cumene (Isopropylbenzene)	mg/kg		1.44E-02																3.50E-01						
N09	Cyanide	mg/kg																								
N49	DDD	mg/kg	2.19E+00																							
N50	DDE	mg/kg																								
29	Di-n-butylphthalate	mg/kg		1.74E+01	1.20	1.20E+00	1.20E+00									4.76E-01			6.43E+00	4.05E+00						
N107	Dibromochloromethane	mg/kg																								
N02	1,2-Dichlorobenzene	mg/kg		1.47E-02			5.37E-02																			
N03	1,3-Dichlorobenzene	mg/kg					1.27E-01																			
N04	1,4-Dichlorobenzene	mg/kg					9.17E-02																			
N93	1,2,-cis-Dichloroethylene	mg/kg																								
N96	1,2-trans-Dichloroethylene	mg/kg																								
N108	Dichlorodifluoromethane	mg/kg																								
N94	1,2-Dichloropropane	mg/kg																								
28	Dieldrin	mg/kg																								
N62	Diethylphthalate	mg/kg																		3.90E+00						
N95	1,2-Dimethylbenzene	mg/kg		1.51E-02														9.54E-02								
N63	2,4-Dimethylphenol	mg/kg	2.06E+01																							

Table A-7. Chemical Concentration Data Set (Continued)

		Site	ETTP	ETTP	Offsite	Offsite	Offsite	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	Offsite	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP	ETTP
		Waste Lot	14.17	14.21	24.0	24.01	24.02	30.01	30.02	30.03	30.06	30.07	30.08	30.09	30.10	30.12	30.13	62.01	62.04	62.05	65.01	65.02	65.03	66.01	66.04	66.06
	WL Name (pink indicates co-mingled waste lots)		UF6 Cylinders Wooden Saddles	K-1066-G Scrap, Debris and Abandoned Equipment	ACAP RA	ACAP Debris	ACAP Soil	ETTP OD RSMI R1	ETTP OD CD	ETTP OD RSM5	ETTP OD DAW R1	OD V RR-1	OD V RR-2	ETTP OD DAW-2 R1	ETTP OD DAW-3	DWI 901 Stored Soils	ETTP Outdoor Solids	Poplar Creek Process Facilities Building Debris and Miscellaneous Materials	K-413 Building Debris and Process Equipment	K-1231 and K-1233 Demolition Debris	K-770 Scrap Yard	K-770 14 Series Piles	K-770 B-25 Boxes	KAFaD Group I Buildings K-724 and K-725 Excess Material Project	K-1064 Peninsula Area	K-1025 Buildings Structural Wood
N64	Dimethylphthalate	mg/kg																		1.12E+02						
N86	2,4 Dinitrotoluene	mg/kg																								
N87	2,6 Dinitrotoluene	mg/kg																								
N69	Endosulfan and Metabolites	mg/kg	2.68E-01																							
N36	Endrin	mg/kg																								
N70	Endrin Aldehyde	mg/kg	1.06E+00																							
N71	Endrin Ketone	mg/kg																								
N77	Ethylbenzene	mg/kg		1.47E-02																						
N78	Ethylchloride	mg/kg																								
N37	Heptachlor	mg/kg	6.01E-02																	7.80E-03						
N38	Heptachlor Epoxide	mg/kg																1.71E-02		7.90E-03						
N42	Hexachlorobenzene	mg/kg																								
N29	Hexachlorobutadiene	mg/kg																								
N30	Hexachloroethane	mg/kg																								
N111	n-Hexane	mg/kg																								
N118	1-Hexanol	mg/kg																								
N79	2-Hexanone	mg/kg																								
30	Isophorone	mg/kg																								
N44	Lindane	mg/kg																								
N41	Lithium	mg/kg															1.63E+01									
N109	Methanol	mg/kg																								
N110	Methylene Chloride	mg/kg		7.25E-02														6.26E-02		4.24E-01						
N05	Methylcyclohexane	mg/kg					5.00E-03																			
N80	Methyl Isobutyl Ketone	mg/kg																								
N85	Methyl Methacrylate	mg/kg																								
N98	1-Methyl-4-(1-methylethyl)-benzene	mg/kg		1.47E-02																						
N57	2-Methylnaphthalene	mg/kg	1.79E+03	1.14E+01																						
N88	(1-Methylpropyl)benzene	mg/kg		1.64E-02																						
31	Naphthalene	mg/kg	1.75E+03	4.67E+01	1.980	1.98E+00	3.55E-01									4.43E-02										
N83	4-Nitrobenzenamine (4-Nitroaniline)	mg/kg																								
N31	Nitrobenzene	mg/kg																								
N58	2-Nitrophenol	mg/kg																								
N82	4-Nitrophenol	mg/kg																								
32	N-nitroso-di-n-propylamine	mg/kg																								
N14	N-Nitrosodiphenylamine	mg/kg																								
33	Phenol	mg/kg	3.03E+01	1.74E+01														3.46E+01		3.98E+00						
N113	Propylbenzene	mg/kg		1.58E-02																						
N114	Propylene Glycol	mg/kg																								
N43	Pyridine	mg/kg																								
N115	Styrene	mg/kg																		7.07E-01						
N89	1,1,1,2-Tetrachloroethane	mg/kg																								
N90	1,1,2,2-Tetrachloroethane	mg/kg																								
34	Tetrachloroethene	mg/kg																								
N66	2,3,4,6-Tetrachlorophenol	mg/kg																								
35	Toluene	mg/kg		1.56E-02		1.35E-02	1.54E-03									6.08E-03				3.56E+00						
N06	1,2,4-Trichlorobenzene	mg/kg					1.02E+01																			
36	Trichloroethene	mg/kg			0.014																					
N116	Trichlorofluoromethane	mg/kg																								
N32	2,4,6-Trichlorophenol	mg/kg																								
N91	1,2,3-Trichloropropane	mg/kg																								
N117	Trimethylbenzene (mixed isomers)	mg/kg		3.59E-02																						
N92	1,2,4-Trimethylbenzene	mg/kg		2.77E-02														2.13E-01								
N97	1,3,5-Trimethylbenzene	mg/kg		1.79E-02														4.13E-01		3.50E-01						
N25	Vinyl Chloride	mg/kg																								
N15	Xylene (mixture of isomers)	mg/kg		2.87E-02																						

Table A-7. Chemical Concentration Data Set (Continued)

		Site	ETTP	ETTP	ETTP	ORNL	ORNL	ORNL	ORNL	ORNL	ORNL	ORNL	ORNL	ORNL	ORNL	ORNL	ORNL	ORNL	ORNL	ORNL	Y-12	Offsite	Offsite	Offsite	Offsite	Offsite
		Waste Lot	66.07	73.01	73.02	80.01	80.02	81.01	81.02	84.01	84.02	84.03	84.04	84.05	84.06	87.01	87.02	89.01	102.01	111.01	114.01	145.01	145.02	145.03	145.04	146.01
	WL Name (pink indicates co-mingled waste lots)		DBOS Building Debris and Misc Materials R2	Centrifuge Equipment U	Centrifuge Equipment C	HFIR Impoundments	HRE Pond Sediments	T1/T2 R4 HFIR Tanks Debris R5	22-Trench Debris & Secondary Waste	GAAT RA Waste R3	ITRA Waste R1	W1-A B12 Box Soil	W1-A B12 Box Soil-1	RASW Inactive Tanks Secondary Equipment	HIC-1 FFA Inactive Tanks	SIOU Bricks	SIOU Debris R2	MSRE Remedial Action	Building 3026 Debris and Misc Material	Melton Valley Weir Cleanout and Bank Stabilization Project	Jack Case Center Contaminated Force Main	David Witherspoon, Inc 901 Site- Candora Soil	DWI 901 Scrap Metal and Debris R2	DWI 901 Site Building and Miscellaneous Debris	David Witherspoon, Inc 901 Site Soil	DWI 1630 Soil and Incidental Debris R6
	Waste Lot mass (grams)	1.27E+12	9.8E+09	8.6E+07	9.7E+07	######	6.9E+09	1.0E+09	8.2E+06	1.2E+09	3.1E+08	######	1.8E+08	1.8E+06	4.6E+06	######	1.0E+09	4.7E+07	8.5E+08	6.6E+08	2.0E+07	1.3E+10	1.8E+09	4.9E+08	7.3E+10	1.4E+11
ID	EMWMF SRC FOR WL	Units																								
14	Antimony	mg/kg	9.88E+01							9.15E-03	4.12E-04			2.08E-05	2.80E-04				6.57E-05	1.45E+00	9.63E-03	3.80E+01	2.38E-01	7.79E-01	3.78E+01	2.44E+01
15	Barium	mg/kg	3.60E+03			376.38	3.37E+02	4.36E+01	2.85E+02	4.85E-02	2.49E-02	190.00	177.59	1.29E-03	1.72E-02	166.32	1.7E+01	4.04E+01	3.58E-03	3.47E+02	2.72E+00	4.71E+02	4.53E+02	1.90E+02	4.57E+02	2.64E+02
N84	Boron	mg/kg																	1.91E-04	8.15E+02						
16	Chromium [total]	mg/kg	1.73E+02	1.07E+04	4.44E+02	2074	5.05E+01	6.65E+02	4.24E+01	1.90E-01	8.63E-03	729.89	740.82	4.35E-04	5.82E-03	397.81	41	1.22E+01	1.36E+00	1.50E+02	1.32E+00	2.72E+03	3.71E+03	1.23E+02	2.72E+03	2.72E+02
17	Lead	mg/kg	1.65E+03	7.40E+01	5.43E+01	354.147	1.27E+01	1.45E+02	1.19E+01	3.91E-01	5.98E-02	1366.55	1277.29	8.78E+03	4.06E-02	1175.00	125.282		6.07E-01	1.20E+02	3.38E-01	1.87E+03	6.63E+01	5.41E+01	1.81E+03	2.88E+03
N72	Manganese	mg/kg		4.01E+03	6.40E+03			7.55E+01	8.81E+02										6.89E+00	1.94E+03	5.00E+03				1.45E+04	7.16E+03
N73	Molybdenum	mg/kg		6.39E+03	1.33E+02														1.99E-04	1.64E+00						3.24E+00
18	Selenium	mg/kg	1.46E+01			1.1		4.55E-01	3.86E-01	7.32E-04	1.71E-03			8.83E-05	1.18E-03				6.39E-05	5.33E+00		6.00E+00	4.53E+01	4.45E-01	5.93E+00	8.63E+02
19	Strontium	mg/kg	2.35E+02			188.389	7.28E+01	1.91E-08		1.55E-02	8.01E-04			4.44E-05	5.95E-04			5.51E+00	1.41E-03	6.70E+01		7.02E+01			7.00E+01	7.00E+01
20	Tin	mg/kg	1.38E+03			17.1					9.34E-05			4.71E-06	6.31E-05				7.43E-02	2.09E+01		5.47E+01	5.38E+02		5.46E+01	5.46E+01
21	Vanadium	mg/kg	1.11E+02			19.8	3.14E+01		3.17E+01	1.64E-03	1.21E-04	26.54	24.81	6.70E-06	8.93E-05	24.35	2.4		5.60E-05	2.15E+01		3.83E+01	2.72E+02	2.11E+01	3.73E+01	3.04E+01
N33	2,4-D	mg/kg																								
N34	2,4,5-T [Silvex]	mg/kg																								
22	Acenaphthene	mg/kg	1.24E-01									4.01	3.75			3.68	0.369			4.23E+00						3.69E+00
N59	Acenaphthylene	mg/kg																								4.64E+00
23	Acetone	mg/kg	2.71E-01			0.056	6.51E-02				1.72E-03	0.15	0.141	2.61E-05	3.49E-04	0.15	0.014			6.00E-02		1.39E-01			1.29E-01	3.88E-01
N99	Acetonitrile	mg/kg																								
N74	Acetophenone	mg/kg																								
N100	Acrolein	mg/kg																								
N101	Acrylonitrile	mg/kg																								
N45	Aldrin	mg/kg																								8.32E-01
N47	Aroclor-1221	mg/kg																								
N48	Aroclor-1232	mg/kg																								
24	Benzene	mg/kg									2.03E-05			3.09E-07	4.14E-06											
N120	Benzidine	mg/kg																			2.78E-02					
N60	Benzoic Acid	mg/kg	2.52E+00																9.51E+00	1.12E+00						
N67	Benzyl Alcohol	mg/kg																								
N52	alpha-BHC	mg/kg																								
N53	beta-BHC	mg/kg																								
N54	delta-BHC	mg/kg																								
N102	Bromodichloromethane	mg/kg																								
N103	Bromoform	mg/kg																								
N104	Bromomethane	mg/kg																								
N105	Butylbenzene	mg/kg																								
25	Carbazole	mg/kg	1.09E+01									4.90	4.58			4.49	0.450			9.36E-01	1.99E-02	1.21E+01				5.12E+00
26	Carbon tetrachloride	mg/kg																								
N75	Carbon Disulfide	mg/kg																								
N35	Chlordane	mg/kg																	9.88E-02							
N01	Chlorobenzene	mg/kg																								
27	Chloroform	mg/kg																								
N106	Chloromethane (Methyl Chloride)	mg/kg																								
N112	o-Chlorotoluene	mg/kg																								
N27	m-Cresol	mg/kg																								
N26	o-Cresol	mg/kg																								
N28	p-Cresol	mg/kg																								
N76	Cumene (Isopropylbenzene)	mg/kg																								
N09	Cyanide	mg/kg																								5.65E+00
N49	DDD	mg/kg	4.37E-02																							1.68E+00
N50	DDE	mg/kg	1.25E-01																1.98E-01							5.85E+00
29	Di-n-butylphthalate	mg/kg	4.14E-01							1.69E-03	3.88E-01	4.21	3.94	2.00E-03	2.69E-02	1.80	3.87E-01		2.31E+00	9.12E-01		1.21E+01			6.08E+00	2.96E+01
N107	Dibromochloromethane	mg/kg																								
N02	1,2-Dichlorobenzene	mg/kg																								
N03	1,3-Dichlorobenzene	mg/kg																								
N04	1,4-Dichlorobenzene	mg/kg																								
N93	1,2,-cis-Dichloroethylene	mg/kg																								
N96	1,2-trans-Dichloroethylene	mg/kg																								
N108	Dichlorodifluoromethane	mg/kg																								
N94	1,2-Dichloropropane	mg/kg																								
28	Dieldrin	mg/kg																	1.98E-01							1.68E+00
N62	Diethylphthalate	mg/kg																								
N95	1,2-Dimethylbenzene	mg/kg																								
N63	2,4-Dimethylphenol	mg/kg																								

Table A-7. Chemical Concentration Data Set (Continued)

		Site	ETTP	ETTP	ETTP	ORNL	ORNL	ORNL	ORNL	ORNL	ORNL	ORNL	ORNL	ORNL	ORNL	ORNL	ORNL	ORNL	ORNL	ORNL	Y-12	Offsite	Offsite	Offsite	Offsite	Offsite
		Waste Lot	66.07	73.01	73.02	80.01	80.02	81.01	81.02	84.01	84.02	84.03	84.04	84.05	84.06	87.01	87.02	89.01	102.01	111.01	114.01	145.01	145.02	145.03	145.04	146.01
	WL Name (pink indicates co-mingled waste lots)		DBOS Building Debris and Misc Materials R2	Centrifuge Equipment U	Centrifuge Equipment C	HFIR Impoundments	HRE Pond Sediments	T1/T2 R4 HFIR Tanks Debris R5	22-Trench Debris & Secondary Waste	GAAT RA Waste R3	ITRA Waste R1	W1-A B12 Box Soil	W1-A B12 Box Soil-1	RASW Inactive Tanks Secondary Equipment	HIC-1 FFA Inactive Tanks	SIOU Bricks	SIOU Debris R2	MSRE Remedial Action	Building 3026 Debris and Misc Material	Melton Valley Weir Cleanout and Bank Stabilization Project	Jack Case Center Contaminated Force Main	David Witherspoon, Inc 901 Site-Candora Soil	DWI 901 Scrap Metal and Debris R2	DWI 901 Site Building and Miscellaneous Debris	David Witherspoon, Inc 901 Site Soil	DWI 1630 Soil and Incidental Debris R6
N64	Dimethylphthalate	mg/kg																								
N86	2,4 Dinitrotoluene	mg/kg																								
N87	2,6 Dinitrotoluene	mg/kg																								
N69	Endosulfan and Metabolites	mg/kg																								1.68E+00
N36	Endrin	mg/kg																								1.68E+00
N70	Endrin Aldehyde	mg/kg																								1.68E+00
N71	Endrin Ketone	mg/kg																								
N77	Ethylbenzene	mg/kg																								
N78	Ethylchloride	mg/kg																								
N37	Heptachlor	mg/kg																								
N38	Heptachlor Epoxide	mg/kg																								
N42	Hexachlorobenzene	mg/kg																								
N29	Hexachlorobutadiene	mg/kg																								
N30	Hexachloroethane	mg/kg																								
N111	n-Hexane	mg/kg																								
N118	1-Hexanol	mg/kg																								
N79	2-Hexanone	mg/kg																								
30	Isophorone	mg/kg										4.91	4.59			3.16	0.451									
N44	Lindane	mg/kg																								
N41	Lithium	mg/kg																								
N109	Methanol	mg/kg																								
N110	Methylene Chloride	mg/kg																								
N05	Methylcyclohexane	mg/kg																								
N80	Methyl Isobutyl Ketone	mg/kg																								
N85	Methyl Methacrylate	mg/kg																								
N98	1-Methyl-4-(1-methylethyl)-benzene	mg/kg																								1.05E-02
N57	2-Methylnaphthalene	mg/kg	1.44E-01																	2.97E-01		1.21E+01			6.08E+00	4.63E+00
N88	(1-Methylpropyl)benzene	mg/kg																								
31	Naphthalene	mg/kg	2.34E-01							7.70E-04		4.91	4.58			3.67	0.451			9.09E-01		1.21E+01			6.05E+00	4.63E+00
N83	4-Nitrobenzenamine (4-Nitroaniline)	mg/kg																								
N31	Nitrobenzene	mg/kg																								
N58	2-Nitrophenol	mg/kg																								
N82	4-Nitrophenol	mg/kg																								
32	N-nitroso-di-n-propylamine	mg/kg																								
N14	N-Nitrosodiphenylamine	mg/kg																								
33	Phenol	mg/kg										4.83	4.52			3.28	0.444			9.57E-01						
N113	Propylbenzene	mg/kg																								
N114	Propylene Glycol	mg/kg																								
N43	Pyridine	mg/kg																								
N115	Styrene	mg/kg																								5.47E-03
N89	1,1,1,2-Tetrachloroethane	mg/kg																								
N90	1,1,2,2-Tetrachloroethane	mg/kg																								
34	Tetrachloroethene	mg/kg								7.00E-04																
N66	2,3,4,6-Tetrachlorophenol	mg/kg	3.93E-01																			1.21E+01				
35	Toluene	mg/kg									5.92E-07	0.04	0.036	8.92E-09	1.20E-07	0.03	0.004			7.00E-03		1.76E-01			1.71E-01	9.56E-03
N06	1,2,4-Trichlorobenzene	mg/kg																								
36	Trichloroethene	mg/kg					7.81E-03				3.23E-05			3.19E-07	4.28E-06											8.36E-03
N116	Trichlorofluoromethane	mg/kg																								
N32	2,4,6-Trichlorophenol	mg/kg																								
N91	1,2,3-Trichloropropane	mg/kg																								
N117	Trimethylbenzene (mixed isomers)	mg/kg																								
N92	1,2,4-Trimethylbenzene	mg/kg																								
N97	1,3,5-Trimethylbenzene	mg/kg																								
N25	Vinyl Chloride	mg/kg																								
N15	Xylene (mixture of isomers)	mg/kg																								

Table A-7. Chemical Concentration Data Set (Continued)

		Site	Offsite	ORNL	ORNL	ORNL	ORNL	ORNL	ORNL	ORNL	ORNL	ORNL	ETTP	ETTP	ETTP	ETTP	ETTP	ORNL	ORNL	ORNL	ORNL	ORNL	ORNL	ORNL	ORNL	ORNL
		Waste Lot	146.02	149.01	149.02	149.03	149.04	149.06	149.07	149.09	149.10	155.01	155.02	155.03	155.04	155.05	157.01	164.01	167.01	200.03	200.999	201.01	201.02	201.03	203.01	207.01
WL Name (pink indicates co-mingled waste lots)			DWI 1630 Site: Drums and Drum Soils	NHF D&D	NHF Well P&A Debris R2	HRE Ancillary Facilities	HRE Waste Evaporator System and Sampling Station Waste R2	NHF Well P&A Primary Waste	NHF Process	7841 Scrap Yard Debris and Equipment	MV Tanks 454 and 455	K-1070-B Burial Ground Remediation	BOS Lab Facilities Miscellaneous Wastes	BOS Lab Area Soil	BOS Lab Area Acid Pits and Piping	K-1015-A Laundry Pit	K-29 Building D&D	Hot Storage Garden R1	Epicor II Lysimeters, MV Soils & Sediments	Facilities 3504, 3508, 3541, 3550 and 3592 Building Debris and Misc Material	Comingled Waste Lot that includes Waste Lots 200.1, 200.2 and 200.4	Miscellaneous Materials from Buildings 2001, 2019 and 2024	Building 2000 Structure and Contents	Slabs - Drains, Pipes and Slabs	Buildings 2011, 2017 and 3044	3026 Hot Cells
Waste Lot mass (grams)		1.27E+12	5.0E+08	4.6E+09	6.0E+07	1.2E+08	2.1E+08	5.9E+07	2.9E+07	1.2E+09	9.9E+06	1.1E+11	1.8E+09	1.6E+08	1.5E+08	1.3E+08	3.6E+10	3.1E+07	7.7E+08	5.1E+07	2.8E+09	9.1E+06	1.2E+09	5.6E+09	6.3E+08	2.5E+08
ID	EMWMF SRC FOR WL	Units																								
14	Antimony	mg/kg			4.33E-02	6.99E+00		3.88E-04				4.08E-02	1.73E+00	2.08E-01	2.98E-01	3.82E-01	4.57E+00		4.44E-01	1.81E+01	8.26E+01	6.90E-01	2.26E+00	2.00E+00	1.98E+01	2.64E+00
15	Barium	mg/kg	6.50E+01	9.80E+01	4.99E+00	1.42E+02		8.50E-04		5.00E+03	9.40E-01	2.48E+02	1.09E+02	9.60E+01	3.36E+01	2.42E+01	5.82E+01		1.40E+02	3.20E+02	8.13E+02	1.68E+01	3.40E+00	1.43E+02	2.09E+02	5.12E+01
N84	Boron	mg/kg										1.16E+01		2.65E+00	2.53E+00	5.55E+00				1.22E+03	7.86E+02	1.55E-01	4.94E-01	8.94E+00	4.23E+01	1.36E+01
16	Chromium [total]	mg/kg	1.81E+01	2.18E+01	2.47E-01	4.00E+04	1.80E+05	1.63E-03	5.72E+04	1.38E+03	8.97E+04	3.47E+01	1.11E+02	1.66E+01	2.39E+01	1.09E+01	2.75E+02	7.04E+02	2.79E+02	1.20E+03	3.17E+04	7.53E+01	7.72E+00	9.63E+00	4.58E+01	3.19E+02
17	Lead	mg/kg	9.49E+01	9.86E+01	6.48E-02	5.20E+01		6.53E-03		6.30E+01	8.24E-01	5.91E+01	1.28E+02	3.46E+01	2.30E+01	1.14E+01	6.11E+02	4.15E+01	9.02E+00	1.31E+02	5.65E+03	5.75E+02	2.47E+02	2.20E+02	1.37E+02	9.16E+01
N72	Manganese	mg/kg	2.86E+02			3.44E+03	2.00E+04		6.50E+03	1.26E+02	7.65E+03	1.19E+03	3.34E+02	1.34E+03	1.20E+02	1.45E+02				1.43E+03	8.90E+03	3.30E+01	1.49E+02	3.21E+02	7.88E+02	1.26E+03
N73	Molybdenum	mg/kg				5.11E+03					9.32E+03	1.09E+00	6.88E+00	1.70E-01	3.61E-01	1.01E+00				3.71E+01	4.68E+02	2.18E+01	1.50E+00	1.88E+00	2.20E+01	4.07E+01
18	Selenium	mg/kg		3.53E+00	3.87E-02	1.98E+00		1.44E-05		1.70E+00	3.76E-02	2.17E+00		1.51E+00			8.35E-01			3.25E+00	1.08E+01		6.01E-01			
19	Strontium	mg/kg	1.04E+02		8.01E+01	3.74E+02		6.92E-03		1.76E+02		3.23E+02			5.35E+01	1.53E+02			1.20E+01	4.03E+02	7.25E+01	3.75E-01	6.65E-01	1.28E+00	5.05E+02	1.63E+02
20	Tin	mg/kg	3.67E+00			5.90E+00		2.11E-04							1.91E+01	4.30E+00			1.06E+00	9.70E+02	4.93E+02	1.94E+01	4.24E+00	4.51E+00	4.99E+01	
21	Vanadium	mg/kg	1.36E+01		1.38E-02	1.99E+01		7.25E-05		1.15E+01	1.00E+02	3.91E+01	1.21E+01	2.31E+01	1.74E+01	5.70E+00	1.48E+01		2.84E+01	1.55E+01	7.97E+01	6.16E+02	8.71E-01	6.12E+00	7.34E+00	2.78E+01
N33	2,4-D	mg/kg																								
N34	2,4,5-T [Silvex]	mg/kg																								
22	Acenaphthene	mg/kg	8.36E+00									1.48E+00	1.87E+00				3.51E+00									
N59	Acenaphthylene	mg/kg	6.92E+00									3.67E-01								5.84E+00						
23	Acetone	mg/kg	9.81E+00		1.08E-03	2.93E-02						2.04E-01			2.33E-01				7.41E+00							
N99	Acetonitrile	mg/kg																								
N74	Acetophenone	mg/kg																								
N100	Acrolein	mg/kg																								
N101	Acrylonitrile	mg/kg																								
N45	Aldrin	mg/kg																					3.03E-04		3.01E-02	
N47	Aroclor-1221	mg/kg																								
N48	Aroclor-1232	mg/kg																								
24	Benzene	mg/kg			3.03E-04														2.77E-03						6.57E-02	
N120	Benzidine	mg/kg																								5.75E-01
N60	Benzoic Acid	mg/kg																		2.13E+01			1.00E+00		2.04E+01	
N67	Benzyl Alcohol	mg/kg																					1.57E-01			
N52	alpha-BHC	mg/kg																					8.08E-04		3.02E-02	
N53	beta-BHC	mg/kg																								
N54	delta-BHC	mg/kg																								
N102	Bromodichloromethane	mg/kg																								
N103	Bromoform	mg/kg																								
N104	Bromomethane	mg/kg																								
N105	Butylbenzene	mg/kg																								
25	Carbazole	mg/kg	6.67E+00									3.67E+00	9.03E-01				9.18E+00			7.78E+00					5.81E+00	
26	Carbon tetrachloride	mg/kg																								
N75	Carbon Disulfide	mg/kg										3.00E-02			2.05E-01											
N35	Chlordane	mg/kg																					1.15E-03		1.03E-01	
N01	Chlorobenzene	mg/kg																	2.62E-03							
27	Chloroform	mg/kg																	2.64E-03							
N106	Chloromethane (Methyl Chloride)	mg/kg																								
N112	o-Chlorotoluene	mg/kg																								
N27	m-Cresol	mg/kg															4.17E+00									
N26	o-Cresol	mg/kg															1.20E+00									
N28	p-Cresol	mg/kg																								
N76	Cumene (Isopropylbenzene)	mg/kg	2.62E+00																							
N09	Cyanide	mg/kg													1.90E-01											
N49	DDD	mg/kg																								
N50	DDE	mg/kg											1.08E-01							9.10E-02			3.05E-03		3.86E-01	
29	Di-n-butylphthalate	mg/kg			1.70E-03			2.66E-04					1.56E-01				2.60E-01						1.78E-01		6.52E+00	
N107	Dibromochloromethane	mg/kg																								
N02	1,2-Dichlorobenzene	mg/kg																								
N03	1,3-Dichlorobenzene	mg/kg																								
N04	1,4-Dichlorobenzene	mg/kg																	1.62E-01							
N93	1,2,-cis-Dichloroethylene	mg/kg										2.83E+01														
N96	1,2-trans-Dichloroethylene	mg/kg																								
N108	Dichlorodifluoromethane	mg/kg																								
N94	1,2-Dichloropropane	mg/kg																								
28	Dieldrin	mg/kg																		7.57E-01			3.01E-04		4.30E-02	
N62	Diethylphthalate	mg/kg																								
N95	1,2-Dimethylbenzene	mg/kg	2.72E+00																						2.69E-01	
N63	2,4-Dimethylphenol	mg/kg																								

Table A-7. Chemical Concentration Data Set (Continued)

		Site	Offsite	ORNL	ORNL	ORNL	ORNL	ORNL	ORNL	ORNL	ORNL	ORNL	ETTP	ETTP	ETTP	ETTP	ETTP	ORNL	ORNL	ORNL	ORNL	ORNL	ORNL	ORNL	ORNL	ORNL
		Waste Lot	146.02	149.01	149.02	149.03	149.04	149.06	149.07	149.09	149.10	155.01	155.02	155.03	155.04	155.05	157.01	164.01	167.01	200.03	200.999	201.01	201.02	201.03	203.01	207.01
	WL Name (pink indicates co-mingled waste lots)		DWI 1630 Site: Drums and Drum Soils	NHF D&D	NHF Well P&A Debris R2	HRE Ancillary Facilities	HRE Waste Evaporator System and Sampling Station Waste R2	NHF Well P&A Primary Waste	NHF Process	7841 Scrap Yard Debris and Equipment	MV Tanks 454 and 455	K-1070-B Burial Ground Remediation	BOS Lab Facilities Miscellaneous Wastes	BOS Lab Area Soil	BOS Lab Area Acid Pits and Piping	K-1015-A Laundry Pit	K-29 Building D&D	Hot Storage Garden R1	Epicor II Lysimeters, MV Soils & Sediments	Facilities 3504, 3508, 3541, 3550 and 3592 Building Debris and Misc Material	Comingled Waste Lot that includes Waste Lots 200.1, 200.2 and 200.4	Miscellaneous Materials from Buildings 2001, 2019 and 2024	Building 2000 Structure and Contents	Slabs - Drains, Pipes and Slabs	Buildings 2011, 2017 and 3044	3026 Hot Cells
N64	Dimethylphthalate	mg/kg																								
N86	2,4 Dinitrotoluene	mg/kg																								
N87	2,6 Dinitrotoluene	mg/kg																								
N69	Endosulfan and Metabolites	mg/kg																					2.91E-03		3.02E-02	
N36	Endrin	mg/kg																								
N70	Endrin Aldehyde	mg/kg																								
N71	Endrin Ketone	mg/kg																								
N77	Ethylbenzene	mg/kg	7.63E+01									2.79E-02													7.52E-02	
N78	Ethylchloride	mg/kg										2.80E-02														
N37	Heptachlor	mg/kg																								
N38	Heptachlor Epoxide	mg/kg																								
N42	Hexachlorobenzene	mg/kg																								
N29	Hexachlorobutadiene	mg/kg																								
N30	Hexachloroethane	mg/kg																								
N111	n-Hexane	mg/kg													2.19E-01											
N118	1-Hexanol	mg/kg																								
N79	2-Hexanone	mg/kg																								
30	Isophorone	mg/kg																								
N44	Lindane	mg/kg																							3.12E-02	
N41	Lithium	mg/kg						7.97E-03																		
N109	Methanol	mg/kg																								
N110	Methylene Chloride	mg/kg												4.14E-02												
N05	Methylcyclohexane	mg/kg																							6.27E-02	
N80	Methyl Isobutyl Ketone	mg/kg																							1.79E+00	
N85	Methyl Methacrylate	mg/kg																								
N98	1-Methyl-4-(1-methylethyl)-benzene	mg/kg	2.55E+00																							
N57	2-Methylnaphthalene	mg/kg	6.70E+01									4.87E-01	3.37E-01				3.34E+00			3.76E+00						
N88	(1-Methylpropyl)benzene	mg/kg																								
31	Naphthalene	mg/kg	1.82E+01		2.92E-04	3.33E-03		1.94E-05				1.65E+00	8.84E-01				2.17E+01			8.11E+00						
N83	4-Nitrobenzenamine (4-Nitroaniline)	mg/kg																								
N31	Nitrobenzene	mg/kg																								
N58	2-Nitrophenol	mg/kg																								
N82	4-Nitrophenol	mg/kg																								
32	N-nitroso-di-n-propylamine	mg/kg																								
N14	N-Nitrosodiphenylamine	mg/kg																								
33	Phenol	mg/kg	1.34E+02														2.89E-01									
N113	Propylbenzene	mg/kg	2.04E+00																							
N114	Propylene Glycol	mg/kg																							2.43E+01	
N43	Pyridine	mg/kg																								
N115	Styrene	mg/kg	1.46E+02																						6.02E-02	
N89	1,1,1,2-Tetrachloroethane	mg/kg																								
N90	1,1,2,2-Tetrachloroethane	mg/kg																								
34	Tetrachloroethene	mg/kg													1.41E-01				3.13E-03							
N66	2,3,4,6-Tetrachlorophenol	mg/kg																								
35	Toluene	mg/kg	1.37E+01		4.43E-04	7.28E-04									1.28E-01				2.85E-03						6.27E-02	
N06	1,2,4-Trichlorobenzene	mg/kg																								
36	Trichloroethene	mg/kg										1.72E-01			2.52E+00				2.62E-03							
N116	Trichlorofluoromethane	mg/kg																								
N32	2,4,6-Trichlorophenol	mg/kg																								
N91	1,2,3-Trichloropropane	mg/kg																								
N117	Trimethylbenzene (mixed isomers)	mg/kg													8.67E-01											
N92	1,2,4-Trimethylbenzene	mg/kg	3.27E+00												8.61E-02										5.92E-02	
N97	1,3,5-Trimethylbenzene	mg/kg	2.65E+00																							
N25	Vinyl Chloride	mg/kg										2.79E-02														
N15	Xylene [mixture of isomers]	mg/kg	2.72E+00									1.64E-03													1.82E-01	

Table A-7. Chemical Concentration Data Set (Continued)

		Site	Y-12	Y-12	Y-12	Y-12	Y-12	Y-12	Y-12	ETTP	ETTP	ETTP
		Waste Lot	301.01	301.02	301.04	303.01	303.02	304.01	304.02	401.01	997.01	997.02
	WL Name (pink indicates co-mingled waste lots)		Capability Unit 29 Legacy Material Bldg 9201-5	Legacy Material from Building 9201-5	Legacy Material from Building 9201-5 First and Third Floor Beryllium Areas	Old Salvage Yard Piles SY-HI (Areas 1 and 2)	Old Salvage Yard SY-HI Area 1 Pile, Rev 1	Building 9211 D&D	Building 9769 D&D	K-33 Building Debris and Misc Material	Main Plant LR/LC Buildings	K-1035 Demolition Debris
	Waste Lot mass (grams)	**1.27E+12**	1.1E+08	5.0E+07	1.1E+09	7.4E+09	1.4E+09	9.0E+09	1.9E+09	2.0E+11	2.5E+09	5.9E+09
ID	**EMWMF SRC FOR WL**	**Units**										
14	Antimony	mg/kg	1.99E+01	2.16E+01	3.29E+01	1.26E+01	6.03E+01	3.92E+00	2.38E+01	1.74E+01	1.87E+01	9.15E+00
15	Barium	mg/kg	3.05E+01	1.36E+02	1.22E+02	2.53E+00	1.01E+03	4.48E+02	4.35E+01	3.49E+02	5.93E+02	9.79E+02
N84	Boron	mg/kg	1.40E+02	4.74E+02	1.61E+02	1.40E+02	4.25E+01	4.75E+02	1.71E+03	1.54E+01		1.97E+02
16	Chromium [total]	mg/kg	1.55E+02	6.10E+02	4.93E+02	1.23E+02	9.28E+00	7.05E+01	5.62E+01	1.50E+03	1.04E+03	4.75E+01
17	Lead	mg/kg	2.51E+02	1.18E+03	2.33E+02	1.54E+03	1.78E+02	5.79E+01	2.56E+02	1.43E+02	1.60E+03	4.85E+02
N72	Manganese	mg/kg	3.39E+03	2.42E+03	1.99E+04	2.40E+02	1.58E+02	1.63E+03	7.15E+01	1.89E+03	1.49E+04	7.21E+02
N73	Molybdenum	mg/kg	3.62E+01	5.12E+01	2.41E+02	7.96E+01	7.29E+01	3.10E+00	2.33E+00	1.52E+02	1.28E+02	7.69E+00
18	Selenium	mg/kg	9.93E-01	1.13E+01	1.24E+01			1.19E+00	4.11E-01	1.18E+01	3.73E+01	1.28E+01
19	Strontium	mg/kg	4.47E+00	3.43E+01	8.94E+00	8.35E+00	1.36E+01	5.01E+01	3.02E+02	1.70E+02	3.45E+01	4.30E+02
20	Tin	mg/kg	1.25E+03	2.53E+01	2.49E+02	2.36E+01	4.60E+01	1.40E+02	3.41E+01	1.01E+02	4.65E+02	6.93E+01
21	Vanadium	mg/kg	3.02E+01	6.09E+01	6.55E+01	1.39E+01	4.09E+01	1.92E+01	7.27E+00	6.13E+01	2.24E+02	1.30E+01
N33	2,4-D	mg/kg								1.07E-02		
N34	2,4,5-T [Silvex]	mg/kg										
22	Acenaphthene	mg/kg								1.04E+02		
N59	Acenaphthylene	mg/kg										
23	Acetone	mg/kg						5.79E-01	8.54E+01	9.75E-01	1.47E+01	1.30E-01
N99	Acetonitrile	mg/kg										
N74	Acetophenone	mg/kg	1.58E+00						4.50E+01		3.95E-01	
N100	Acrolein	mg/kg										
N101	Acrylonitrile	mg/kg										
N45	Aldrin	mg/kg										
N47	Aroclor-1221	mg/kg										
N48	Aroclor-1232	mg/kg										
24	Benzene	mg/kg							8.13E-01			2.19E-02
N120	Benzidine	mg/kg										
N60	Benzoic Acid	mg/kg	5.51E+00	5.73E-01	8.42E+02				1.71E+02	1.13E+02		4.64E+02
N67	Benzyl Alcohol	mg/kg									9.67E-02	
N52	alpha-BHC	mg/kg										
N53	beta-BHC	mg/kg						6.67E-03	3.74E-01		5.05E-02	
N54	delta-BHC	mg/kg										
N102	Bromodichloromethane	mg/kg										
N103	Bromoform	mg/kg										
N104	Bromomethane	mg/kg										
N105	Butylbenzene	mg/kg										
25	Carbazole	mg/kg								1.39E+02		
26	Carbon tetrachloride	mg/kg										
N75	Carbon Disulfide	mg/kg										9.66E-02
N35	Chlordane	mg/kg								1.43E-01	4.15E-02	
N01	Chlorobenzene	mg/kg										
27	Chloroform	mg/kg									5.50E-04	
N106	Chloromethane (Methyl Chloride)	mg/kg										
N112	o-Chlorotoluene	mg/kg										
N27	m-Cresol	mg/kg										
N26	o-Cresol	mg/kg										
N28	p-Cresol	mg/kg										
N76	Cumene (Isopropylbenzene)	mg/kg							5.40E+00	6.83E-02	9.76E-03	1.91E-02
N09	Cyanide	mg/kg										
N49	DDD	mg/kg							3.74E-01			
N50	DDE	mg/kg				1.28E-02	3.34E-01	4.42E-02	3.76E-01	1.43E-01	1.11E-01	
29	Di-n-butylphthalate	mg/kg	9.16E-01					3.08E+01	1.11E+02		4.90E-01	2.25E+01
N107	Dibromochloromethane	mg/kg										
N02	1,2-Dichlorobenzene	mg/kg										
N03	1,3-Dichlorobenzene	mg/kg										
N04	1,4-Dichlorobenzene	mg/kg										1.90E-02
N93	1,2,-cis-Dichloroethylene	mg/kg										
N96	1,2-trans-Dichloroethylene	mg/kg										
N108	Dichlorodifluoromethane	mg/kg										
N94	1,2-Dichloropropane	mg/kg										
28	Dieldrin	mg/kg									3.60E-02	
N62	Diethylphthalate	mg/kg	2.56E-01					3.08E+01			4.90E+00	1.69E+03
N95	1,2-Dimethylbenzene	mg/kg							8.13E-01	6.13E-02		2.33E-02
N63	2,4-Dimethylphenol	mg/kg										

Table A-7. Chemical Concentration Data Set (Continued)

		Site	Y-12	Y-12	Y-12	Y-12	Y-12	Y-12	Y-12	ETTP	ETTP	ETTP
		Waste Lot	301.01	301.02	301.04	303.01	303.02	304.01	304.02	401.01	997.01	997.02
	WL Name (pink indicates co-mingled waste lots)		Capability Unit 29 Legacy Material Bldg 9201-5	Legacy Material from Building 9201-5	Legacy Material from Building 9201-5 First and Third Floor Beryllium Areas	Old Salvage Yard Piles SY-HI (Areas 1 and 2)	Old Salvage Yard SY-HI Area 1 Pile, Rev 1	Building 9211 D&D	Building 9769 D&D	K-33 Building Debris and Misc Material	Main Plant LR/LC Buildings	K-1035 Demolition Debris
N64	Dimethylphthalate	mg/kg						3.07E+01	2.45E+03			
N86	2,4 Dinitrotoluene	mg/kg										
N87	2,6 Dinitrotoluene	mg/kg										
N69	Endosulfan and Metabolites	mg/kg						9.17E-03	1.43E+00		6.25E-02	
N36	Endrin	mg/kg									4.65E-02	
N70	Endrin Aldehyde	mg/kg				1.84E-02	2.67E+00		3.74E-01			
N71	Endrin Ketone	mg/kg					3.89E-03					
N77	Ethylbenzene	mg/kg							1.02E+01	5.80E-02	3.42E-03	
N78	Ethylchloride	mg/kg										
N37	Heptachlor	mg/kg										
N38	Heptachlor Epoxide	mg/kg							3.74E-01	1.43E-01	1.44E-02	
N42	Hexachlorobenzene	mg/kg										
N29	Hexachlorobutadiene	mg/kg										
N30	Hexachloroethane	mg/kg										
N111	n-Hexane	mg/kg										
N118	1-Hexanol	mg/kg										
N79	2-Hexanone	mg/kg									6.83E-03	9.64E-02
30	Isophorone	mg/kg							2.45E+01			
N44	Lindane	mg/kg										
N41	Lithium	mg/kg										
N109	Methanol	mg/kg										
N110	Methylene Chloride	mg/kg								1.33E-01	1.91E-03	
N05	Methylcyclohexane	mg/kg										
N80	Methyl Isobutyl Ketone	mg/kg										9.63E-02
N85	Methyl Methacrylate	mg/kg										
N98	1-Methyl-4-(1-methylethyl)-benzene	mg/kg								9.97E-02		
N57	2-Methylnaphthalene	mg/kg								8.26E+01	8.62E-02	
N88	(1-Methylpropyl)benzene	mg/kg										
31	Naphthalene	mg/kg								1.69E+02	9.82E-02	1.13E+02
N83	4-Nitrobenzenamine (4-Nitroaniline)	mg/kg										
N31	Nitrobenzene	mg/kg										
N58	2-Nitrophenol	mg/kg										
N82	4-Nitrophenol	mg/kg										
32	N-nitroso-di-n-propylamine	mg/kg										
N14	N-Nitrosodiphenylamine	mg/kg										
33	Phenol	mg/kg						3.08E+01	2.44E+01		2.62E+00	
N113	Propylbenzene	mg/kg							2.22E+00			
N114	Propylene Glycol	mg/kg							2.55E+01			
N43	Pyridine	mg/kg										
N115	Styrene	mg/kg							9.15E+02	1.90E-01		
N89	1,1,1,2-Tetrachloroethane	mg/kg										
N90	1,1,2,2-Tetrachloroethane	mg/kg										
34	Tetrachloroethene	mg/kg									6.00E-04	
N66	2,3,4,6-Tetrachlorophenol	mg/kg										
35	Toluene	mg/kg							1.17E+00	7.47E-02	2.60E-03	4.52E-02
N06	1,2,4-Trichlorobenzene	mg/kg										
36	Trichloroethene	mg/kg									5.11E-03	
N116	Trichlorofluoromethane	mg/kg										
N32	2,4,6-Trichlorophenol	mg/kg										
N91	1,2,3-Trichloropropane	mg/kg										
N117	Trimethylbenzene (mixed isomers)	mg/kg										
N92	1,2,4-Trimethylbenzene	mg/kg							8.13E-01	1.40E-01		
N97	1,3,5-Trimethylbenzene	mg/kg								5.98E-02		1.90E-02
N25	Vinyl Chloride	mg/kg										
N15	Xylene (mixture of isomers)	mg/kg							2.40E+00	2.32E-01	7.63E-03	3.97E-02

2. REFERENCES

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APPENDIX B:
WASTE VOLUME REDUCTION

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CONTENTS

FIGURES

TABLES

ACRONYMS

ACM	asbestos-containing material
ANSI	American National Standards Institute
ARAR	applicable or relevant and appropriate requirement
BJC	Bechtel Jacobs Company LLC
BNFL	British Nuclear Fuels Limited
C&D	construction and demolition
CARAR	Capacity Assurance Remedial Action Reports
CERCLA	Comprehensive Response, Compensation, and Liability Act of 1980
D&D	deactivation and decommissioning
DOE	U.S. Department of Energy
EBCV	East Bear Creek Valley
EMDF	Environmental Management Disposal Facility
EMWMF	Environmental Management Waste Management Facility
EPA	U.S. Environmental Protection Agency
ETTP	East Tennessee Technology Park
FEMP	Fernald Environmental Management Project
FTE	full-time equivalent
HEPA	high-efficiency particulate air
HPS	Health Physics Society
K	Thousand
IAEA	International Atomic Energy Agency
LANL	Los Alamos National Laboratory
LLNL	Lawrence Livermore National Laboratory
LLW	low-level waste
M	Million
NNSS	Nevada National Security Site
NRC	Nuclear Regulatory Commission
OREM	Oak Ridge Office of Environmental Management
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
PPE	personal protective equipment
RA	remedial action
RCRA	Resource Conservation and Recovery Act of 1976
RI/FS	Remedial Investigation/Feasibility Study
ROM	rough order of magnitude

TDEC	Tennessee Department of Environment and Conservation
TSCA	Toxic Substances Control Act of 1976
U.S.	United States
VR	volume reduction
WAC	Waste Acceptance Criteria
WGF	Waste Generation Forecast
WMPP	Waste Management Program Plan
WSSRAP	Weldon Spring Site Remedial Action Project
Y-12	Y-12 National Security Complex

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1. INTRODUCTION

The Remedial Investigation/Feasibility Study (RI/FS) for Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) waste evaluates alternatives that will address disposal of waste generated by CERCLA actions on the Oak Ridge Reservation (ORR). Measures that reduce the volume of waste material can potentially reduce disposal costs by reducing the size of the proposed landfill and associated costs for the On-site Disposal Alternative, and reducing the cost of transportation and disposal fees for the Off-site Disposal Alternative. For the On-site Disposal Alternative, consolidated disposal of most future-generated CERCLA waste would utilize a newly-constructed landfill facility in Bear Creek Valley on the ORR, referred to as the Environmental Management Disposal Facility (EMDF). This facility may be located at one of several proposed sites. This appendix is written to be independent of the site location; costs are determined based on the East Bear Creek Valley (EBCV) site, but may be scaled to waste volumes that would be disposed at the various locations. The Off-site Disposal Alternative would provide for the transportation of future CERCLA candidate waste streams to an approved off-site disposal facility. The purpose of this Appendix is to review and assess different approaches for reducing the volume of the CERCLA waste and evaluate the potential benefits.

Volume reduction (VR) almost always requires additional effort to characterize or process the waste in a manner that reduces volume and cost. Therefore, it is necessary to evaluate VR methods to determine if the additional effort is beneficial. Approaches to VR include the following:

- Those that divert waste materials from the EMDF or from off-site landfill disposal.
- Methods that reduce the quantity of clean fill required for EMDF landfill operations.
- Physical methods to reduce the volume of waste prior to placement in the EMDF landfill or prior to off-site waste transportation.

The Oak Ridge Office of Environmental Management follows a hierarchy for dispositioning waste generated through cleanup projects to minimize disposition volumes and costs, and reduce needed landfill capacity (see Figure B-1). The foundation of the strategy is built on evaluating waste materials for recycle or beneficial reuse instead of disposing of them as waste. The second priority is to make use of onsite Subtitle D landfills for final disposal instead of the CERCLA landfill.

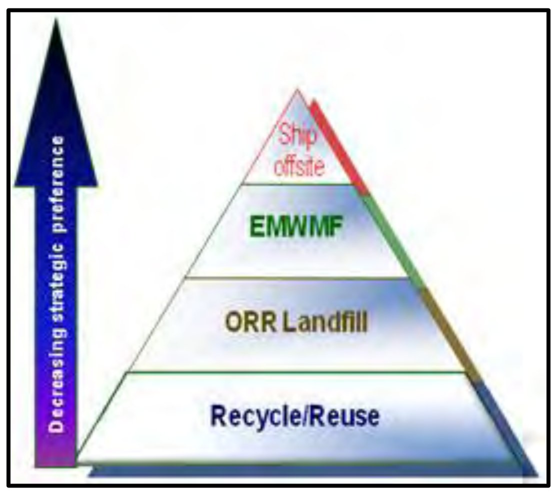

Figure B-1. Hierarchy for Waste Disposal on the ORR

One of the purposes of facility characterization prior to demolition is to identify materials for potential recycle and to plan for the separation of contaminated and clean waste material (segregation). Clean materials to be recycled are removed prior to demolition and, if it is feasible and safe to do so, highly contaminated sections of a facility may be selectively removed and disposed of separately in the CERLA landfill or off-site. Clean or lightly contaminated waste materials may be disposed in the Subtitle D ORR Landfill.

Clean fill occupies a substantial fraction of landfill space. It is used to fill debris void space and to provide structural stability to the landfill. Remedial action projects that involve removal of contaminated soil are evaluated for the potential to use waste soil in place of clean fill. Size reduction processing of waste can be considered as a way to reduce debris void space and reduce the fill requirements for waste placement.

The additional effort and cost for each of these methods was evaluated to determine the potential benefits for CERCLA waste disposal.

2. SCOPE

The scope of the study is limited to a preliminary evaluation of various approaches that have potential or have proven to be effective in reducing the volume of CERCLA materials requiring disposal. The study evaluates recycling possibilities, enhanced segregation of waste, modified project sequencing, and physical size reducing methods for volume reduction. The study estimates potential cost savings and identifies challenges, both technical and administrative, associated with implementing the approaches. In order to define a basis, it was necessary to use waste generation forecast data to estimate potential quantities of the types of waste materials that could be recycled, segregated, or size reduced. The evaluations are thus dependent on the accuracy of these predictions. In addition, implementation of the methods is dependent on the availability of funding and the ability to implement broad programmatic approaches for VR efforts.

The issues associated with recycling materials from the United States (U.S.) Department of Energy (DOE) nuclear facilities are discussed herein and the potential benefits explored. Improved segregation of waste materials involves additional waste characterization to verify that the wastes meet the criteria for disposal at the ORR Landfill, thus conserving disposal capacity at the EMDF. The possibility and potential benefits of project sequencing, whereby projects are scheduled in order to make optimal use of waste soil as fill material during placement of debris, are examined. The physical treatment methods evaluated include those that are typically used for commercial construction and demolition (C&D) projects or at recycling facilities by private industry. Estimates developed for deployment of size reduction equipment are preliminary only and would require additional effort to increase confidence in the potential cost of implementation. The study utilizes the waste volume estimates in Chapter 2 and Appendix A of this RI/FS and information from the Environmental Management Waste Management Facility (EMWMF) Capacity Assurance Remedial Action Reports (CARAR) (DOE 2004, 2010, 2011a, 2012a) to determine waste volumes, waste types, and clean fill requirements.

VR costs were estimated and potential gains determined as a consequence of reduced debris void space, reduced clean fill requirement, and reduced landfill size. Methods that divert CERCLA waste from disposal operations include both recycle and segregation based on contamination level. Project sequencing allows for efficient utilization of waste soil to replace clean fill while size reduction processing reduces debris void space and also reduces clean fill requirements. Assumptions were made and documented during the study to account for uncertainties that exist due to lack of information or inability to predict future conditions.

3. APPROACH

Evaluation of VR methods was performed through literature reviews, reliable internet sources, budgetary cost information from commercial vendors, interviews with VR equipment operations personnel, and information from previous estimates. Applicability and timeliness of the information for current economic conditions was considered.

The study utilized estimated waste volumes and waste material types from several representative buildings that are scheduled for deactivation and decommissioning (D&D) in the future at the Oak Ridge National Laboratory (ORNL) and the Y-12 National Security Complex (Y-12). These facilities also represent a significant fraction of the future D&D work load. This information was used to determine an overall breakdown of waste types to apply against the total estimated volume of CERCLA waste. Information from CARAR reports (DOE 2004, 2010, 2011a, 2012a) was used to estimate the benefits of VR in terms of reduced clean fill required to isolate and fill voids in the wastes.

The cost effectiveness of physical VR options was evaluated by comparing the cost of implementing the VR method to the cost of on-site and off-site disposal of unprocessed material. The On-site and Off-site Disposal Alternative cost estimates developed for EMDF and described in Appendix G of this RI/FS were used to determine potential VR cost benefits.

4. WASTE MATERIALS

The benefits of VR depend upon the volume and characteristics of the waste materials. Descriptions of types and quantities available from demolition planning activities for several facilities from ORNL and Y-12 were used to predict the composition and volume of materials to be managed as CERCLA waste. For the purposes of the VR evaluation, this composition was assumed to be representative for the total volume forecasted for the 2022 to 2043 time frame given in Table B-1. It was assumed that only debris that was not either classified or mixed with materials regulated under the Resource Conservation and Recovery Act (RCRA) or the Toxic Substance Control Act (TSCA) would be considered for VR actions. The values in the table are in terms of as-generated volumes; that is, they include estimated void space dependent upon the type of material. Table B-2 is a summary of waste types and volumes for the selected facilities. The waste materials from all the buildings were summed to provide a representative percentage by waste type for materials to be disposed. The representative fractional quantities given in the table were applied against the projected as-generated debris volume from Table B-1 to determine the total quantity of debris material that could possibly benefit from application of VR methods.

A large fraction of the waste generated by building demolition is amenable to VR. Only items that are highly contaminated and hazardous materials such as lead brick and asbestos-containing materials (ACM) do not lend themselves easily to VR measures. Materials that are highly contaminated with radioactive constituents, mercury, or beryllium would be addressed prior to facility demolition using existing infrastructure and localized containment in order to extract these materials prior to open-air demolition of the remaining structure. Lead brick and sheet would be separated for either recycling as shield materials or transported for off-site treatment. ACM cannot be recycled or size reduced by shredding or compaction due to the hazards of spreading and dispersing airborne asbestos particles. ACM can be vitrified if necessary; however, vitrification processing is very expensive and would not be a cost effective VR option.

Concrete rubble including reinforced concrete, block, and brick masonry can be crushed and possibly recycled for construction or used as fill material in landfill operations. Light steel materials such as ventilation duct, conduit, thin-walled pipe, and sheet metal siding can potentially be recycled. These materials along with siding, flooring, wood materials, and roof materials can be shredded to reduce landfill volume and to reduce transportation costs. Heavy gauge metal materials (structural steel, large diameter, thick walled piping, process vessels, and equipment items that have a large void fraction) are also good candidates for recycle, although the effort required for decontamination of these materials could be significant. Shearing machines such as those used in shipyards and commercial metal recycling facilities may be used to size reduce heavy steel items to reduce transportation costs or to reduce landfill space requirements. The three building project (BNFL 2001) performed at the East Tennessee Technology Park (ETTP) in 2001 successfully used a “supercompactor” shearing machine to size reduce large equipment items and heavy gauge steel for disposal. Additional segregation of the materials discussed above could be considered for alternative, lower-cost, disposal options. Segregation would involve additional contamination surveys to verify that the materials meet appropriate disposal criteria for an alternative landfill.

As shown in Table B-3, about 98.8% of D&D debris materials could be considered for VR. The waste soil quantities given in Table B-1 are an important element of VR because they can be used to replace clean fill soil that is used to fill the void space inherent in demolition debris. Oak Ridge Office of Environmental Management (OREM) projects must be sequenced such that the waste soil is available to replace clean fill at the time that the debris is placed in the landfill. The quantity of debris generated during this time period is 1,341,090 yd^3 including 25% uncertainty. Classified debris and debris that is mixed with hazardous constituents would not be considered for VR, reducing the total for VR actions to 1,151,440 yd^3. Table B-3 applies a fractional value for debris volumes based on the assumption that a lower fraction of the debris would not be processed by VR due to logistical limitations, contamination issues, or other unexpected circumstances. After applying these factors, the final estimated volume for VR processing is 758,299 yd^3.

Table B-1. Forecasted As-generated CERCLA Waste Volume

Waste Type	Material Type	Total FY 2022 – FY 2043 yd^3
LLW (includes LLW/TSCA)	Debris	921,152
	Debris/Classified	28,489
	Soil	432,092
Mixed (LLW/RCRA, LLW/RCRA/TSCA)	Debris	119,534
	Debris/Classified	3,697
	Soil	53,882
Subtotal		**1,558,847**
25% Uncertainty		389,712
Total Waste Volume with Uncertainty		1,948,558
Total Debris Volume with Uncertainty		1,341,090
Total Debris Volume with Uncertainty (not including Classified or Mixed LLW)		**1,151,440**

Table B-2. Waste Streams for Representative Buildings by Material Type

Debris Type	Description	ORNL Facilities			Y-12 Facilities					Total Volume (yd^3)	Fraction of Total Volume (%)	Debris Volume*
		4501 & 4505 (yd^3)	7600 (yd^3)	Isotopes (yd^3)	9201-4 Alpha-4 (yd^3)	9201-5 Alpha-5 (yd^3)	9204-4 Beta-4 (yd^3)	9207 Biology Complex (yd^3)	9212 (yd^3)			
Asbestos containing materials	Insulation, floor tiles	457	47	266	310	550	550	2,041	355	4,576	0.99%	11,354
Transite	Transite	8	165	0	148	265	120	0	146	853	0.18%	2,117
Lead	Bricks, sheet	0	0	94	0	0		2	0	96	0.02%	239
Equipment	Thick walled steel, glove boxes, hoods, heavy-walled equipment, cranes	3,234	2,334	1,028	5,279	25,736	5,030	2,609	39,609	84,859	18.28%	210,539
Heavy steel	Pipe, tanks, structural steel	1,174	7,584	1,314	14,215	31,972	32,489	3,793	21,074	113,616	24.48%	281,886
Concrete and masonry	Reinforced concrete, block, brick, shield walls	16,363	34,380	437	27,688	46,298	26,741	17,118	27,122	196,147	42.26%	486,647
Demolition (general)	Small buildings, cooling towers, structural framing, interior and exterior finishes, floors, wood	0	0	0	0	11,609	14,212	0	6,749	32,570	7.02%	80,807
Light gauge metals and siding	Air ductwork, small diameter pipe, siding, panels	770	860	599	1,432	3,565	2,501	97	4,154	13,979	3.01%	34,683
Roofing materials (asphalt)	Asphalt shingles, low-slope built-up roofs, vapor barrier, insulation, roof vents, flashing, felt	703	440	342	2,808	2,630	1,619	3,296	4,511	16,349	3.52%	40,562
Legacy material	Containers, furniture, trash	0	0	27	838	0	0	0	48	913	0.20%	2,265
Packaged for EMWMF	Legacy containerized waste	0	0	84	0	0	0	0	0	84	0.02%	209
Off-site disposal	Mixed waste designated for off-site disposal	0	0	53	0	0	0	0	0	53	0.01%	132
Total		**22,709**	**45,811**	**4,245**	**52,720**	**122,624**	**83,262**	**28,956**	**103,770**	**464,129**	**100%**	1,151,440

* Debris volume based on Table A-3, Appendix A as-generated debris forecast including 25% contingency (1,536,610 yd^3)

Table B-3. Predicted Debris Types and Quantities for Volume Reduction

Debris Type	Fraction of Total	Total Volume Projected (yd^3)	Fraction for Processing	Volume for Processing (yd^3)	Bulk Density (lb/yd^3)	Weight for Processing (tons)
Thick walled steel, glove boxes, hoods, heavy-walled equipment, cranes*	18.28%	210,539	0.3	63,162	680	21,475
Piping, tanks, structural steel*	24.48%	281,886	0.75	211,415	1,040	109,936
Concrete and masonry: reinforced concrete, block, brick, shield walls	42.26%	486,647	0.75	364,985	2,600	474,481
Small structures: small cooling towers, structural framing, interior and exterior finishes, wood	7.02%	80,807	0.75	60,605	1,620	49,090
Metal (light gauge): ventilation ductwork, small diameter piping, siding, panels*	3.01%	34,683	0.75	26,012	1,040	13,526
Roofing materials: shingles, built-up roofs, vapor barrier, insulation, roof vents, flashing	3.52%	40,562	0.75	30,422	1,520	23,121
Legacy material: containers, furniture, trash, wood	0.20%	2,265	0.75	1,698	640	544
Total	98.8%	**1,137,389**		**758,299**		**692,172**

*Considered for recycle (see Section 5.1.2).

5. VOLUME REDUCTION METHODS AND BENEFITS

Volume reduction methods evaluated in this report include recycling, project sequencing, improved segregation, and physical size reduction. Advantages and disadvantages are discussed along with cost data collected from various sources. The discussion considers administrative aspects, technical applicability, the cost of implementing, and the magnitude of VR that can potentially be achieved. This information is used to determine the viability and cost of VR and the amount of landfill space that could be gained or the number of waste shipments that could be avoided. Using EMDF cost information from the On-site Disposal Alternative for the EBCV Site Option, the impact of VR to various cost elements associated with construction, operations, and maintenance was estimated. Results would be expected to be similar for the other siting Options. In addition, the cost of transporting and disposing of debris at an off-site facility was evaluated to determine potential benefits of VR for the Off-site Disposal Alternative.

5.1 RECYCLING

5.1.1 Regulatory Climate

The U.S. Environmental Protection Agency (EPA) has raised awareness and promoted C&D debris recycling through many initiatives and programs that provide information, incentives, research funding, and guidance to resolve technical issues and increase nationwide recycling of C&D materials. Many states, including Tennessee, have adopted these principals and encouraged C&D recycling efforts. In some states and cities, where landfill space is limited, regulations have been adopted that require recycling of C&D materials. California Law AB 939 requires recycling of 50% of waste materials of all types and many cities, such as San Francisco, mandate the recycling of all C&D materials in order to conserve limited landfill space. New Jersey municipalities must meet the State Recycling Mandate which requires all C&D waste to be recycled.

There are several examples that document DOE's efforts to recycle D&D materials. During demolition of a 149,987 ft^2 building at Lawrence Livermore National Laboratory (LLNL) in 2007, 89% of demolished materials were either recycled or reused (LLNL 2008). This included 1,665 tons of metals, 7,399 tons of concrete, and 14,580 gallons (gal) of dielectric fluid. Recycling reportedly reduced the project cost by 11%. Since 2002, LLNL has recycled or reused 32,075 tons of asphalt/concrete, more than 5,000 tons of metal, 673 lb of freon, and 201 yd^3 of wood. A DOE Inspector General audit report reviewing ORNL's waste diversion effort reported that in 2011, ORNL successfully diverted over 5,100 of 9,500 metric tons of solid waste through recycling and reuse (DOE 2012b). At Los Alamos National Laboratory (LANL), more than 136 tons of metal saved from demolished buildings were recycled during demolition projects under the American Recovery and Reinvestment Act of 2009 (LANL 2009). This was largely due to efforts by heavy equipment operators to remove recyclable materials from the buildings before they were demolished.

The majority of the facilities identified for D&D in Oak Ridge were used for nuclear energy research and development and thus are categorized under DOE-STD-1027-92, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports* (DOE 1992) as Nuclear or Radiological facilities. In 2000, DOE placed a moratorium on the recycling of volumetrically contaminated metals and a suspension on the recycling of metals located within Radiological facilities. This moratorium seeks to prevent public exposure to radiation above background resulting from recycling/reuse of contaminated DOE material in consumer products. The moratorium will continue until the U.S. Nuclear Regulatory Commission (NRC) establishes a set of national standards regarding allowable contamination levels in recycled steel. The moratorium does allow for reuse of demolition materials for specific purposes by DOE-authorized nuclear facilities, the commercial nuclear industry, and NRC licensees authorized to possess the material. Restricting recycled materials usage to sites and facilities owned by DOE is a potential, albeit limited alternative.

In 2005, the NRC completed an exhaustive study and proposed rule: Radiological Criteria for Controlling the Disposition of Solid Materials, RIN 3150-AH18 (NRC 2005a). The rule is an effort by NRC to develop a basis to support decisions on rules that would set specific requirements on controlling releases of solid materials from NRC licensed nuclear facilities. The materials include metals, concrete, soils, equipment, furniture, etc., which are present at licensed nuclear facilities during routine operations. Historically, these materials have been released on a case-by-case basis, without a consistent approach for clearance surveys. The report provides information regarding the measurement of residual radioactivity in materials that are to be cleared, including guidance about designing, performing, and documenting radiological surveys to address the need for survey consistency. The rule was disapproved in 2005, although not for technical reasons, but rather to defer the rulemaking until additional resources are available (NRC 2005b).

An option routinely considered when planning D&D work for nuclear facilities involves selectively removing materials from contaminated zones first, then re-characterizing the facility and performing an additional hazard screening to downgrade the facility to the "Other Industrial" category. This would allow for unrestricted recycle of demolition materials, however, the cost of characterization and hazard analysis reduces the cost effectiveness of this approach. A manual that provides guidance for survey and assessment of materials and equipment for release, Multi-Agency Radiation Survey and Assessment of Materials and Equipment Manual was developed by DOE, the U.S. Department of Defense, EPA, and NRC (DOE 2009). The manual currently refers to the release criteria given in DOE Order 5400.5, *Radiation Protection of the Public and the Environment* (DOE 1993), later replaced by DOE Order 458.1 (DOE 2011b) though the new order refers to DOE 5400.5 for the release criteria. The release criteria require survey of 100% of the surface of the material being evaluated for release, which is a labor intensive and costly effort.

In 1999, American National Standards Institute (ANSI)/Health Physics Society (HPS) N13.12 *Surface and Volume Radioactivity Standards for Clearance* (ANSI-1999) was issued to provide a technically sound basis for release of solid materials containing trace levels of activity. However, the standard was not fully adopted by U.S. Federal agencies because the technical basis was considered inadequate to be applied on a broad basis. The International Atomic Energy Agency (IAEA) published RS-G-1.7, *Application of the Concepts of Exclusion, Exemption and Clearance*, along with *Derivation of Activity Concentration Values for Exclusion, Exemption and Clearance* (IAEA-2004). An ongoing effort has been initiated to revise ANSI/HPS N13.12 to complement the guidance provided in the IAEA publications and become the new basis for the DOE Order 458.1 release criteria. The recycling of demolition materials from radiological facilities remains a complex issue that is not fully resolved, but should continue to be evaluated on a case-by-case basis.

5.1.2 Recycling Potential

The two materials that would be most likely to be beneficial for recycle would be concrete and metals. Clean concrete could be recycled to use as aggregate for new concrete or for base material or roads or new facilities. Demolition concrete that is clean and cleared for release could be crushed and screened on site to be used for other DOE applications in close proximity to the demolition site. The commercial value of aggregate is about $4.41 per ton in Tennessee (USGS 2011). The crushing operations would require the use of an industrial crushing machine and an excavator for placing the concrete debris in the crusher feed hopper and for managing the crushed product. Table B-4 provides estimated costs for a concrete crushing operation. This operation assumes the concrete is clean and the quantity is equal to the estimated quantity given in Table B-3. Based on this estimate, the cost of processing alone at $7.15/lb is higher than the commercial value of aggregate. With additional costs added for storage and transportation, it is even less likely that concrete recycling would be cost effective.

Table B-4. Cost Summary for Clean Concrete Crusher Operations

Cost Element	Crusher	Excavator
Equipment	$512,400	$228,479
Operations labor	$711,721	$626,315
Fuel and maintenance	$553,591	$ 268,937
Engineering/procurement	$17,500	$17,500
Indirect costs	$309,297	$146,411
Total cost	$2,104,509	$1,287,642
Cost per hr, including capital	$222	$136
Cost/ton (474,481 tons)	$4.44	$2.71
Total cost/ton for crusher operations		$7.15

Recycling metals is a potential option for demolition materials. Metal recyclers in Tennessee purchase steel materials at about $0.10 per lb. The U.S. market value for steel beams is about $0.32 per lb and the value of shredded scrap metal is about $0.07 per lb according to RecycleInMe.com, a worldwide scrap metal trading web site. According to Table B-3, the quantity of metallic waste (equipment, heavy steel, and light gauge metals) to consider for recycle is about 300,588 yd^3 total. Of this total, it is assumed that 50% of the material is targeted for recycle. This material is surveyed for contamination and it is assumed that 80% of the material meets the clean release criteria. After applying bulk density values, the total weight of metal for recycle is 57,975 tons. Bechtel Jacobs Company LLC (BJC) developed a cost estimate for contamination surveys that would be required for clean release of metals from D&D projects (BJC 2004). The approach is based on DOE 5400.5 requirements and includes radiation control technician support, personal protective equipment (PPE), survey instruments, and scanning operations. The estimated cost is $32 per yd^3 of recycled material. For the 150,294 yd^3 targeted for recycle, the cost of contamination surveys would be $4.8 Million (M). At an average value of $0.15 per lb, the commercial value of the metals (57,975 tons) would be about $17.4M. Transporting the metals to a local recycler would cost about $220 per 10 yd^3 or about $2.6M. EMDF capacity gains would be realized from metal recycling including the as-disposed volume that would have been required for the metals along with the required clean-fill. For the 57,975 tons of metal estimated for recycle, the clean fill required if disposed at the EMDF would be approximately 72,903 yd^3 based on CARAR requirements. The value of clean fill is $6.5 per ton, so at 1.24 tons per yd^3 the cost savings would be about $588 Thousand (K). After deducting survey and transportation costs, the net gain for recycling would be about $9.9M.

Metal melt provides another opportunity to recycle contaminated metals. This technology is available at the Energy*Solutions* Bear Creek facility in Oak Ridge at a (FY 2011) cost of approximately $3 per lb. An induction furnace is used to melt the material before being poured into blocked forms for controlled reuse, usually in high-energy accelerator facilities around the world. To date, this process has not been utilized by DOE facilities because of the relatively high cost compared to disposal.

There is a potential for significant cost savings from metal recycle, although without a clear set of approved regulations regarding survey of materials for clean release, there is a significant risk associated with the cost of certifying metals for clean release. Effective regulations would reduce the risk of accidentally releasing contaminated materials into the commercial market place and unintentionally exposing the public to radiation, however, public concern would need to be addressed and the ban on DOE metal recycling would have to be lifted before recycling could be considered.

5.2 PROJECT SEQUENCING

As shown in Table B-5 (derived from Table A-4 of Appendix A), clean fill occupies over 1 M yd^3 of the landfill capacity and is a major cost element of landfill operations. As such, it is important that measures be taken to avoid exceeding the predicted clean fill requirement. Project sequencing involves the scheduling of OREM projects so that waste soil is available to replace clean fill soil at the time that debris is placed in the landfill. Information from the RI/FS waste volume forecast was reviewed to verify that future D&D and remedial action (RA) projects are projected to be sequenced such that virtually all RA soil waste can be used for filling the voids of waste materials and not become "excess waste fill." In order to eliminate excess fill and minimize the quantity of clean fill required, the ratio of soil to debris generated in a particular time period should be at a level that ensures that all of the waste soil is utilized as fill. Sequencing of planned projects is based on assumptions such as funding level, project prioritization, and contracting schedules that can be uncertain and subject to change.

Table B-5. Projected EMDF Waste Types and Volume with 25% Uncertainty

Waste Type	Total As-Disposed Waste Volume (yd^3)
Debris	666,264
Waste soil	468,030
Clean fill	1,048,743
Total with Uncertainty	**2,183,037**

Table B-5 indicates an as-disposed volume of waste soil of 468,030 yd^3 (including 25% uncertainty) will be generated during the operational life of the EMDF along with 666,264 yd^3 of debris. The quantity of fill needed for this quantity of debris is approximately 1,048,743 yd^3. Current predictions for clean fill demand assume that nearly all of the waste soil is used to replace clean fill that would otherwise be needed for placement of the debris.

Sequencing projects in a way that makes use of waste soil as fill material results in cost benefits and conserves disposal capacity of the landfill. It is recommended that, as much as possible, demolition work be sequenced with soil remediation work to take advantage of using waste soil as fill material for debris. The OREM baseline sequencing of projects intersperses demolition and remediation projects to take advantage of this approach. The current remediation schedule and sequencing plan indicates that only a minor amount (~8,800 yd^3) of soil waste would not be available as fill material. In practice, it is challenging to implement sequencing for a number of reasons: (1) demolition of a facility must occur first in order to access the soils underneath/beside the facility; (2) demolition and soil remediation are generally awarded as two separate contracts; and (3) the amount of soil that may be staged in a working cell(s) is limited due to safety basis requirements, equipment limitations, and double-handling logistics. EMWMF operating personnel report that the use of waste soil to replace clean fill is performed when possible. To the extent possible, project sequencing will continue to be used as a way to conserve landfill capacity.

5.3 IMPROVED SEGREGATION

Waste segregation is an important element of waste minimization that is emphasized in planning of all DOE D&D projects. Significant effort and funding is provided for initial characterization of nuclear facilities in order to provide health and safety information for worker protection, to determine the disposal path for waste materials of all types, to identify areas that are not contaminated and have not been exposed to radiological materials, to separate highly contaminated materials that require costly treatment and disposal options, and to develop waste lot information for disposal. Improved segregation involves the additional effort required to separate clean from contaminated materials in order to divert a greater volume of clean materials to the ORR Landfill.

Both construction and operating costs for the ORR Landfill are lower than CERCLA disposal facility costs and overall disposal costs would be reduced by segregating more waste material to the ORR Landfills which use Class II and Class IV design as defined by the Tennessee Department of Environment and Conservation (TDEC) Division of Solid and Hazardous Waste Management. Design of the CERCLA landfill requires a much more substantial liner and capping system with additional geomembrane layers, an additional biointrusion layer, and an additional leachate leak detection system. These requirements more than double the construction costs of the CERCLA landfill compared to the ORR Landfill.

When waste generation forecasts (WGFs) are developed for D&D projects, facility type and characterization data are used to determine waste disposition. D&D materials from facilities that are classified "other industrial" in accordance with DOE-EM-STD-5502-94, *DOE Limited Standard, Hazard Baseline Documentation* (DOE 1994) are assumed to be acceptable at the ORR Landfill. In most cases, D&D materials from facilities that are classified as "nuclear" in accordance with DOE-STD-1027-92 (DOE 1992) or "radiological" per DOE-EM-STD-5502-94 are assumed to be disposed at the EMWMF. However, there may be clean areas associated with contaminated facilities that could possibly be demolished in a manner that avoids co-mingling with materials from potentially contaminated zones, thus creating an opportunity for disposing at least a portion of debris at the ORR Landfill. Additional segregation may be performed in these cases, if it is considered safe and cost effective. Radiological or nuclear facilities that include relatively small contaminated zones can be downgraded to a non-radiological category if the contaminated area can be selectively removed. After downgrading, the balance of the facility demolition materials can be disposed at the ORR Landfill. In many cases, the size of the contaminated area or degree of contamination in the facility makes it either unsafe or not cost effective to attempt to selectively remove contamination. In these cases, clean, but potentially contaminated demolition materials associated with radiological facilities are disposed at the EMWMF. Enhanced segregation activities would require more intensive characterization efforts to verify that waste materials meet the ORR Landfill Waste Acceptance Criteria (WAC). As discussed in Section 5.1.2 on recycling, contamination surveys of demolition material would be a labor intensive and costly effort that should be evaluated to determine the benefits prior to executing during a demolition project. This approach may also involve an effort to revise the ORR Landfill WAC to accept slightly contaminated debris and soil from CERCLA projects. While potentially beneficial from a cost standpoint, additional segregation would carry the risk of releasing contaminated materials into the landfill that exceed the ORR Landfill WAC and cause contamination of leachate with associated treatment and disposal complications.

An expansion of the ORR Industrial Landfill V that provided an additional 384,500 yd^3 of disposal capacity was completed with American Recovery and Reinvestment Act of 2009 funding in 2011. The need for the expansion was identified based on analysis of WGF projections. Capacity at the ORR Landfills is now sufficient for the near term and will be monitored for future capacity needs.

Plans for segregating clean materials for disposal at the ORR landfill will continue to be part of D&D planning activities and should include a cost/benefit evaluation that balances potential cost savings against the cost of additional facility safety analysis and contamination surveys, and the risk of negative consequences brought about by placing contaminated material in the ORR landfill.

5.4 DEBRIS SIZE REDUCTION

The physical treatment methods evaluated were limited to those that are typically used for commercial demolition projects or at recycling facilities by private industry. Commercially available size reduction equipment is capable of reducing the size and void space associated with bulk demolition materials of all kinds. Many models with various production capacities are available as stationary units or mobile units that can be located at the demolition site or at the landfill site. Deployment at the demolition site takes advantage of reduced costs for transporting processed materials from the demolition site to the landfill, however, the infrastructure costs for multiple deployments of size reduction equipment would be cost prohibitive.

5.4.1 Size Reduction Equipment

Equipment used to size reduce debris materials includes crushers, shredders, compactors, and shears. These machines are capable of processing at sufficiently high rates so as not to significantly impact the overall demolition project schedule. Demolition equipment such as excavators with cutting and crushing attachments are normally used to size reduce materials to meet the requirements for transportation and placement in a landfill. The same equipment and size requirements are applicable for preparing the materials for VR processors. Excavators with various boom attachments may be used to manage the product. Alternatively, the VR machines can be equipped with conveyors to move the processed materials to a waste container or collection area.

Shredder and crusher controls may be adjusted for sizes in a range that allows for elimination of void space while maximizing output and ease of transport and handling. Crushers are typically designed to produce a range of product size distributions. If they are equipped with screens, concrete can be processed to meet specific material specifications for recycle as aggregate for construction base material or to be mixed with new concrete.

5.4.1.1 Shredders

Shredder design depends on the application. Demolition debris shredders are typically low-speed, high-torque machines that utilize dual shaft counter-rotating, custom-designed cutter blades that interlace in a way that optimizes shearing, tearing, and impact forces (see Figure B-2). The design of the cutters depends on the application. New designs have been developed that minimize repair costs through simple and speedy replacement of cutter components or the entire cutter/shaft assembly. Electrically driven stationary units generally cost less to operate, but are more prone to jamming situations and more likely to incur mechanical damage if unacceptable materials enter the feed. On-site track-mounted mobile units can be equipped with conveyors and magnets to separate metals for possible recycle. They can be controlled remotely by the excavator operator who provides feed material for the unit. Maintenance requirements include routine filter and lubrication of the drive system and also sharpening (hard-facing) of the cutters. Hard-facing requires about 16 hours per month assuming 40 hours per week operating time. Operational availability is typically 75% for the diesel driven units and about 90% for stationary electric units. Attachment A includes vendor inquiry data for the processors.

Most equipment vendors claim size reduction by up to 80% for C&D debris materials. A manual developed by DOE in 1988 to provide guidance in selection of low-level waste (LLW) VR technologies (DOE 1988) indicates that waste density for a simulated mixture of LLW increased from 13 to 30.8 lb per ft^3 using a standard compaction device which translates to a VR of 58%. When the waste was shredded prior to compaction, the density increased from 13 to 80.3 lb per ft^3, equivalent to an 84% decrease in volume. The increase in density from 30.8 to 80.3 lb per ft^3 indicates about a 60%

decrease in volume realized by shredding alone. An additional study performed at Columbia University (CU 2009) indicated that shredding increases the bulk density of municipal solid waste by two or three times, resulting in reduced transportation costs.

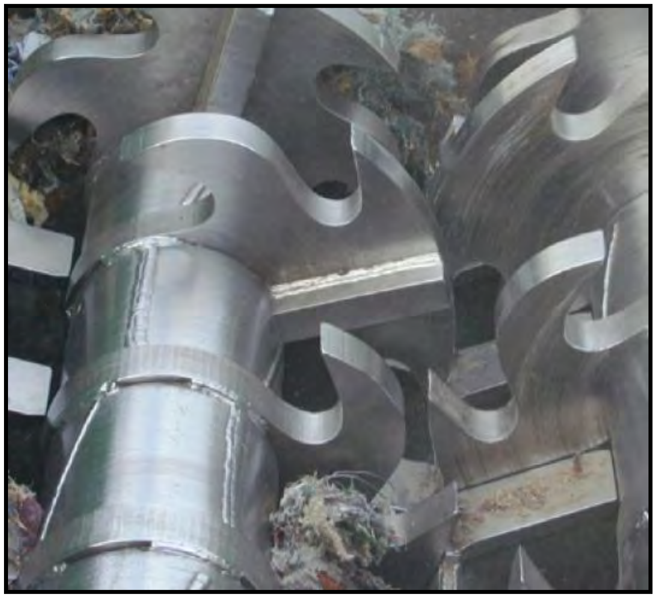

Figure B-2. Shredder Cutter Assembly
(SSI Shredding Systems, Inc.)

5.4.1.2 Crushers

Impact crushers are generally used for concrete and rubble that don't contain large quantities of metals. Two types are commonly used at demolition sites. The first involves a spinning rotor with "blow-bars" that initially impact the material propelling it against one of several rigid impact or "wear" plates (see Figure B-3). The material bounces between the blow bars and wear plates until it reaches a size that allows it to pass through the machine to the conveyor. The second type uses spinning "swing-hammers" that initially impact the material and propel it against breaking plates that direct the material back into the hammers until it reaches a size that can pass through the preset gap between the hammers and the plates.

Mobile crusher units are readily available on road-ready frames that include a fifth wheel for tractor hauling. Once on site, the units include support legs that allow the unit to be leveled and stabilized for immediate operations. The machines can be equipped with conveyors and magnets to separate metals for possible recycle. They can be controlled remotely by the excavator operator who provides feed material for the unit. Maintenance requirements include routine filter and lubrication of the drive system and also maintaining the crusher mechanism. In the case of the spinning rotor impactor, this involves periodic replacement of blow-bars and the stationary wear plates. Eagle Crusher Company machines use wear plates that can be rotated to increase run time and reduce maintenance costs. Blow-bars (about $3,300 per set) usually require replacement after processing about 20,000 tons of material. Wear plates (about $1,500 for a group of six) are rotated or replaced every 80,000 tons of material. Replacement of blow-bars requires about four hours for two operators and replacement of wear plates requires about one hour for two operators. Operational availability is typically 80% for diesel driven units. Attachment A includes equipment manufacturer inquiry data.

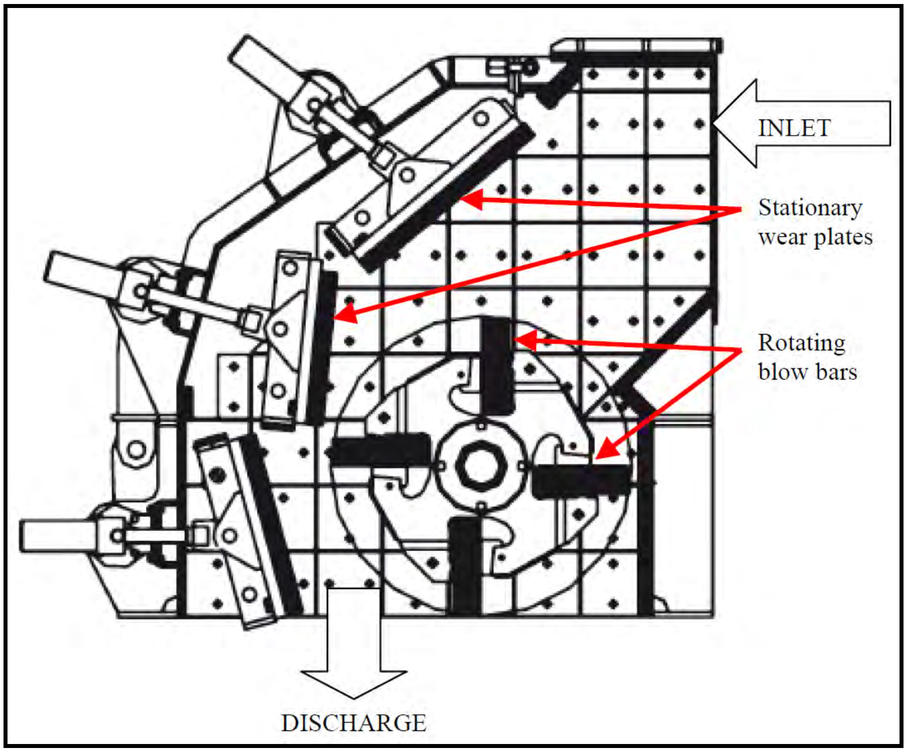

Figure B-3. Rotary Impact Crusher Components
(Striker Crushing and Screening Co.)

5.4.1.3 Compactors

Compactors operate using a hydraulic press to compress materials in a confined area that conforms to a shape and size that is suitable for transportation and disposal. Compactors are typically used for light voluminous materials (wood, paper, plastic, light-gauge metals). Drum compactors are commonly used to crush empty waste drums that were used to store and transport LLW. PPE and dry active waste, such as mop heads and wipes used in decontamination activities, can become a significant fraction of the waste volume unless VR methods are employed. A typical approach involves the use of empty waste drums as containers for PPE and using a compactor to process the PPE-filled drums. The rigid structure of the compacted drum provides a strong envelope to prevent PPE from re-expanding after compaction. Compacted 55-gallon drums can be over packed in 85-gallon drums with very little void space. PPE is typically bagged and placed in B-25 boxes with very little compaction. At EMWMF, B-25 boxes are placed in the landfill in a sealed condition, whereby the void space within the box could not be filled and would replace landfill capacity with air. Using a compactor for PPE in drums would reduce this void space by about 80%, or about 6 ft^3 per drum. Industrial refuse compactors are available that are designed to compact large volumes of light materials into a cubical bale configuration. The shape and size of the resultant compressed form from a compactor could meet landfill size requirements and significant savings in transportation costs would be expected. Void space evaluation would be required to determine the acceptability of the compressed bail waste form.

The size reduction machine deployed at the K-33 building demolition project at ETTP (BNFL 2001) is referred to as a “supercompactor,” but the product is actually heavy gauge steel components that have been sheared into smaller pieces. The compaction component refers to the feed box that bends and molds the heavy steel into a shape that can be indexed into the cutting device. This machine is described in Section 5.4.1.4 as a shearing machine.

5.4.1.4 Shearing Machines

Shearing machines are typically used in shipyards and commercial metal recycling facilities to size reduce heavy steel items. British Nuclear Fuels Limited (BNFL) used a Harris Model BSH 2205-30 Shear (BSH Shear) designed for size reducing scrap metal from shipyards and steel mills to process large equipment removed from the K-33 building at ETTP (BNFL 2001). The size reduced metal was either to be recycled or shipped to Envirocare in Utah (now Energy*Solutions*) or the Nevada Test Site (now the Nevada National Security Site [NNSS]). BNFL reported that the project saved \$100M in disposal costs (Platts 2004). It is presumed that most of the cost savings derived from reduced transportation costs and disposal fees. The K-33 shear was capable of cutting solid metal components up to 10 inches thick. A photo of a BHS Shear by Harris is shown in Figure B-4. The \$13M facility (including the shear and containment facility) was used for approximately three years to process 70,000 tons of material. K-33 equipment was initially disassembled and hand-cut into sections that were small enough to fit into the charge box of the 1,400 horsepower shear. In the charge box, the materials are compressed using a "tuck and roll" device into 26 ft long laminate sections that were indexed lengthwise into the shear for cutting into 10 inch lengths to meet debris dimensional requirements for NNSS. Discussions with former BNFL operations supervisors indicated the typical net weight of the sheared material loaded into a 25 ft^3 intermodal container was 52,500 lb giving a bulk density of 2,100 lb per yd^3. This is triple the bulk density normally experienced for large equipment disposed at the EMWMF (per CARAR density data). The compressed and sheared sections were collected in containers for shipment. The K-33 operation required a crew of 20 to operate, including those conducting primary size reduction operations, radiation protection personnel, equipment operators, and supervision. Assuming total personnel costs of \$8.7M, and maintenance costs of \$150,000, the approximate cost of VR for this operation was about \$330 per yd^3.

Figure B-4. BSH Shear by Harris

5.4.2 Selected Size Reduction Methods

Size reduction processing reduces disposal and transportation costs by increasing the density of the debris, which conserves landfill space and allows more material to be loaded per truckload. With continually rising fuel costs and the inherent risk of waste transportation, reducing the number of transport events is a significant benefit, especially for the distances required in the Off-site Disposal Alternative. For EMDF on-site disposal, the principal benefits of VR are the reduction in the quantity of clean fill material required to fill the void spaces within the material being placed in the disposal cell and the reduction in landfill size. The quantity of clean fill used is based on the volume and type of waste received. Once the waste has been placed in the cell with fill material, the heavy equipment (bull dozers) used to place the material is also used to compact the waste mix by driving over the materials. The capacity of the landfill is defined as the space occupied by the compacted waste and fill.

As defined in the CARAR (DOE 2012a) completed annually for the EMWMF based on the WGF, there are two types of quantitative waste volume estimates used in this RI/FS as described below:

- "As-generated" waste volume:
  - Volume estimate based upon excavated bulk volumes of soils, sediments, and demolished building debris that includes void space.
  - Bulk volume of soils, sediments, and demolished building debris that is roughly equivalent to the volume expected to be shipped (i.e., used for Off-site Disposal Alternative).
  - Includes higher amount of void space and has lower bulk density than debris that has been compacted in a landfill.

The as-generated volume is used in project planning to determine the number of truckloads and associated cost and duration necessary to move wastes from the work site to the disposal facility (on-site or off-site).

- "As-disposed" waste volume:
  - Volume estimate of waste after disposal in the disposal facility, at which point debris wastes, waste (soil) suitable for use as fill, and clean (additional) fill have been mixed and processed to meet compaction, void space, and operational requirements (i.e., used to determine the volume required for an on-site disposal facility).
  - Physically equivalent to survey results taken quarterly to estimate disposal facility airspace utilized.
  - Includes lower amount of void space than as-generated waste volumes because voids have been filled with soil and the material has been compacted in the landfill.

The as-disposed waste volume estimate is used as the basis for determining the required capacity of a new disposal facility for the On-site Disposal Alternative. Chapter 2 of this RI/FS includes additional information regarding as-generated and as-disposed waste volume estimates developed for the RI/FS.

Soil used as fill typically has an as-generated void fraction of about 25% and general construction debris has an as-generated void fraction of about 50%. Landfill capacity is referred to in terms of as-disposed volume, while WGF information is typically reported in terms of as-generated volume. To evaluate VR approaches, it was first necessary to determine the projected amount of as-generated debris that could be processed (see Table B-3). Based on this quantity, VR equipment can be sized and the full impact of processing can be determined.

Fill materials are used to reduce settlement of the waste and to ensure long-term stability of the final cap placed on the landfill. Previous experience gained from operating EMWMF indicates a soil-to-debris ratio greater than 1:1 is required to fill voids in bulky building debris (DOE 2004 and 2011a). Additional clean (uncontaminated) soil fill is required for operational purposes (e.g., to construct dump ramps and the planned clean layer within the middle of the cell) (DOE 2011a). Because of shortfalls in contaminated soils and soil-like waste materials, EMWMF has purchased clean soil from off-site borrow sources to fill void spaces in the landfill (DOE 2011a). Size reduction of certain waste materials, such as bulky building debris, reduces the void space and reduces the volume of fill required for a particular waste stream

(DOE 2003 and 2004). Cost effectiveness is determined by comparing the cost of size reduction processing (capital cost and operating cost) with the cost savings realized through the reduction in fill requirements and reduced landfill size for several waste material types and processing methods.

5.4.2.1 Size Reduction of Equipment and Structural Steel

Since heavy equipment and structural steel debris have relatively large void space and clean fill requirements, an initial evaluation was performed to determine the impact of VR through size reduction of equipment and heavy steel on clean fill requirement and landfill space.

From Table B-3, the volumes of equipment and steel anticipated for VR processing are 63,162 and 211,415 yd^3, respectively, or a total of 131,411 tons. It was assumed that the shearing machine described in Section 5.4.1.4 would be used for this application. The productivity of this machine, based on the K-33 project, is about 15.8 tons per hour, the equivalent of about 4.5 years of operation at 40 hours per week for the quantity given. This production rate is judged to be adequate based on a 15-year duration expected for D&D projects that would produce most of the equipment and heavy steel materials for processing. The density information used to develop the CARAR estimates indicates an as-generated void fraction of over 90% for equipment and metals. It is assumed that shearing operations will reduce the void volume of equipment and heavy steel components by 50%, doubling the bulk density. Fill material would still be necessary to occupy void space in the material, although the fill requirement would be lower. The CARAR provides estimates of the clean fill requirement based on the type of debris and density. In the case of equipment debris, it was assumed that the CARAR clean fill requirement would be reduced from a ratio of 9.58:1 (clean fill volume:equipment volume based on the as-disposed debris volume) to the ratio that would normally be required for construction debris or 2.26:1. In the case of structural steel debris, it was assumed that the clean fill requirement would be reduced from a ratio of 6.63:1 (clean fill volume:steel volume based on the as-disposed debris volume) to 2.26:1.

Table B-6 compares the fill requirements for unprocessed material with the anticipated fill requirements for size reduced equipment and steel. The total quantity of clean fill avoided is 113,455 yd^3 which is approximately 27% of a complete landfill cell. The value of clean fill not used at $6.5/ton is $914K. In addition to clean fill savings, there are reductions in the cost of transporting the debris from the generator site to the EMDF. Since the bulk density is greater by a factor of two, the volume of debris per shipment is doubled and the number of shipments reduced by half. At $220 per transport event, the total savings would be about $3M. Landfill construction costs would not be reduced because the anticipated size of the cell and associated labor and materials would be the same, even if the cell is projected to receive a smaller fraction (73%) of the debris it was designed to accommodate. Landfill operating costs would also be the same because the waste generation schedule and resource levels would not change if the same quantity of waste (smaller volume, but same mass) must be managed. The total estimated cost savings from size reduction of equipment and heavy steel is about $3.92M. From the K-33 operation described in Section 5.4.1.4, the approximate cost of the processing equipment and facility is $13M without operating costs. This is $9.1M greater than the estimated savings associated with size reduction, so it would not be cost effective to implement this process. As discussed previously, this method of VR provided cost savings for the K-33 project because heavy steel debris was shipped off-site for disposal at much greater cost than what would be expected for on-site disposal at the EMDF. The benefits of VR for the Off-site Disposal Alternative are addressed in Section 5.4.3.4.1.

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Table B-6. Disposal Capacity Gained Through Size Reduction of Equipment and Heavy Steel Debris

Debris Type	Description	As-generated Volume for Processing (yd^3)	Weight, Tons	As-disposed Volume (yd^3)	Clean Fill Requirement for Unprocessed Material (yd^3)	Basis	Volume after Size Reducing Material (yd^3)	Volume Reduction	Clean Fill Ratio for Processed Material (Soil: Debris)	Clean Fill Requirement for Processed Material (yd^3)	Basis
Equipment	Thick walled steel, glove boxes, hoods, structural components, heavy-walled equipment, cranes structures	63,162	21,475	3,821	36,607	Clean fill ratio is 9.58 for as-disposed equipment (soil: debris)	31,581	50%	2.26	8,636	Clean fill ratio is reduced to the value required for construction debris, 2.26.
Heavy steel	Large diameter pipe, tanks, structural steel	211,415	109,936	19,561	129,693	Clean fill ratio is 6.63 for as-disposed metals (soil: debris)	105,707	50%	2.26	44,209	Clean fill ratio is reduced to the value required for construction debris, 2.26.
Total Volume (yd^3)		274,576	131,411	23,383	**166,299 (A)**		137,288			**52,845 (B)**	Total clean fill required for processed material
										113,455 (A-B)	Total disposal capacity gained through reduced clean fill requirement (equals volume A minus volume B)

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5.4.2.2 Size Reduction of Concrete and General Demolition Debris

The balance of the debris shown in Table B-3, concrete, masonry rubble, and other demolition debris constitutes about 56% of the total or about 644,964 yd^3. Concrete and masonry rubble make up about 42% of the total debris volume and 14% is comprised of general demolition debris such as siding, sheet metal, and roofing materials. The density information used to develop the CARAR indicates an as-generated void fraction of 25% for concrete and 50% void fraction for general construction debris. By reducing the void fraction, crushing machines and shredders could have a major impact on landfill space requirements.

Crushed concrete would require a lesser quantity of fill due to the reduction in void space, and a significant fraction of the concrete could be pulverized to a soil-like material that may be used in place of fill. Based on the group of facilities analyzed, the quantity of concrete debris is almost half of the total quantity of debris generated. Consequently, crushed concrete could satisfy the fill requirement for a substantial amount of other debris (equipment, heavy structural materials, etc.). For this evaluation, it was assumed that the concrete rubble volume is reduced by 20% and the fill requirement for concrete rubble is reduced by 50% due to the soil-like, self-filling nature of the pulverized fraction of the concrete. In addition, it is assumed that 50% of the crushed concrete could be used in place of fill material for landfill placement of other debris types. For general construction debris, an industrial shredder would be very effective for reducing the volume and clean fill requirement. A 40–50% size reduction would be expected with a similar percentage reduction in clean fill requirement.

Table B-7 compares the fill requirements for unprocessed concrete and general demolition debris with the anticipated fill requirements for size reduced materials and provides an estimate of the landfill capacity that could be gained. The capacity gained from reduced clean fill requirement is 225,991 yd^3 and the amount of crushed concrete that could be used to replace clean fill is 145,994 yd^3. From Appendix A, the anticipated volume of clean fill required for EMDF is 838,993 yd^3, so crushed concrete could reduce the total cost of clean fill by about 17 %, equivalent to a purchased clean fill value of nearly \$1.2M. About 13% of the capacity gain is from shredding of general debris with the balance from concrete crushing operation. The total capacity gain, 371,985 yd^3, approaches the capacity of a full cell. Consequently, additional savings from deducting cell construction costs is possible.

Based on the potential for substantial cost reductions applying VR methods to concrete and general demolition debris, further consideration was warranted. Implementation on a project-by-project basis (VR equipment deployed at the project site, by each D&D contractor) was considered versus a single facility, accessible to all projects. Intuitively, a single facility is more cost effective, therefore a rough order of magnitude (ROM) cost estimate for such a facility, was developed.

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Table B-7. Disposal Capacity Gained Through Size Reduction of Concrete and General Demolition Debris

Debris Type	Description	As-generated Volume for Processing (yd^3)	Weight, Tons	As-disposed Volume (yd^3)	Clean Fill Requirement for Unprocessed Material (yd^3)	Basis	Volume after Size Reducing Material (yd^3)	Volume Reduction	Clean Fill Ratio for Processed Material (Soil: Debris)	Clean Fill Requirement for Processed Material (yd^3)	Basis
Concrete and Masonry	Reinforced concrete, concrete block, brick, shield walls	364,985	474,481	291,988	364,985	Clean fill ratio is 1.25 for as-disposed dense concrete (soil: concrete)	**291,988 (C)**	20%	0.625	175,193	Clean fill ratio is 50% of the CARAR requirement for light concrete, 0.625
Demolition	Small buildings, small cooling towers, structural framing, interior and exterior finishes, flooring, wooden structures	60,605	49,090	30,303	68,484	Clean fill ratio is 2.26 for as-disposed construction debris (soil: debris)	36,363	40%	1.36	40,847	Clean fill ratio is 60% of the CARAR requirement for debris, 1.36
Metal (ferrous, light-guage)	Ventilation duct, light framing, small diameter pipe, siding, small tanks	26,012	13,526	2,407	15,957	Clean fill ratio is 6.63 for as-disposed compactable metal (soil: debris)	13,006	50%	3.31	7,967	Clean fill ratio is 50% of the CARAR requirement for debris, 3.31
Roofing Materials (asphalt)	Asphalt shingles, low-slope built-up roofs, vapor barrier, insulation, roof vents, flashing, felt	30,422	23,121	15,211	0	No clean fill required, self-filling	18,253	40%	0	0	Considered self-filling so no clean fill required.
Legacy Material and NTS	Containers, furniture, trash, wood	1,698	544	849	1,715	Clean fill ratio is 2.26 for as-disposed construction debris (soil: debris)	1,019	40%	1.36	1,145	Clean fill ratio is 60% of the CARAR requirement for debris, 1.36
Total Volume (yd3)		483,723	560,761	340,758	**451,142 (A)**		360,630			**225,151 (B)**	Total clean fill required for processed material
										225,991 (**A**-**B**)	Disposal capacity gained through reduced clean fill requirement from VR
										145,994 (**C***0.5)	50% of crushed concrete used to replace clean fill
										371,985	Total disposal capacity gained (equal to the sum of capacity gained through VR and the quantity of crushed concrete used to replace clean fill.)

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5.4.3 Cost Analysis of Size Reduction Facility

The analysis of crushing and shredding equipment deployment for concrete and general demolition debris indicates the potential for substantial savings in landfill construction costs, and warrants further consideration. Without historical cost data for projects involving this equipment, it was necessary to develop a ROM estimate for a processing facility. It is assumed in this case that the facility would be constructed on the EMDF site in the vicinity of the landfill operation.

The cost of shredding and crushing demolition debris was determined by obtaining budgetary vendor quotes for appropriately-sized equipment and estimating engineering, construction, and operating costs based on manufacturer recommendations and typical DOE project requirements. Demolition projects are typically performed in open air surroundings after selective removal of contaminated building sections and equipment. However, size reduction operations could cause airborne release of contamination that would otherwise remain undisturbed or imbedded in the debris materials. Dust suppression systems could be used, however, the safety of workers and those in areas adjacent to the demolition operations can only be ensured if airborne containment systems are provided. The deployment of size reduction equipment for radioactively contaminated or potentially radioactively contaminated material requires a containment enclosure with ventilation and a high-efficiency particulate air (HEPA) filtered exhaust system. In addition, the operation will require the support of radiation control personnel for monitoring worker exposures, controlling contamination, and managing radioactive materials. Capital costs associated with size reduction would include the following:

- Size reduction equipment (one crusher and one shredder)
- Material handling equipment for feeding processors and containerizing processed material
- A building enclosure with HEPA filtered exhaust
- Staging areas for incoming debris and outgoing processed materials
- Utility connections (electricity, water, communications)
- Fire protection system
- Lighting
- Air handling units for climate control
- Instrumentation for monitoring ventilation air flow and airborne contamination levels

Processing equipment was selected based on debris quantities and expected rate of debris generation. The expected quantity of concrete and rubble is 478,481 tons to be generated over a 21-year time frame or an average of approximately 22,785 tons per year. A crusher with a maximum processing capacity of 150 tons per hour (tph) is selected for this process. Since much of the concrete will contain rebar, the rate is expected to be about 33% of the maximum or about 50 tph. The machine selected could process the average yearly quantity of concrete debris in about three months. The machine is oversized in order to minimize the space needed for staging feed materials for the operation.

The expected quantity of general debris for processing is expected to be about 86,281 tons and consists mainly of light gauge sheet metal, roofing materials, siding, wood framing, ventilation duct, and other materials. The design processing capacity of the shredder selected for this material is 25 tph, with an expected capacity of 10 tph due to expectations of some heavier gauge metals and a fraction of the concrete debris. Like the crusher, the shredder was sized for minimizing the space needed for staging and would be expected to process an average one year quantity of debris in about three months. Operating these machines would require the use of two excavators with appropriate tool attachments for handling the debris. The crusher and shredder would be equipped with conveyors for transferring size reduced materials to a transport container.

The enclosed area of the facility would be approximately 3,000 ft^2 to accommodate the crusher, shredder, one excavator, and two intermodal containers that would receive the size reduced material. Additional staging areas would encompass about 12,000 ft^2.

Planning, engineering design, and construction activities would be significant elements of the capital work scope. Once constructed, commissioning and readiness review activities would be performed prior to process operations. Table B-8 summarizes the capital costs for one facility.

Table B-8. Capital Costs for EMDF Size Reduction Facility

Cost Element	Description	Labor and Materials ($K)
Planning and Acquisition	Includes all planning documents required for DOE capital projects (i.e., Project Execution Plan, alternative analysis, preliminary cost estimate, quality assurance plan, risk management plan, commissioning plan, etc.)	629
Engineering Design	Title I and II design packages including system requirements, specifications, and drawings	382
Construction:		
Mobilization	Contractor plans and mobilization of construction equipment	47.1
Construction Support	Construction Superintendent, Safety Engineer, Field Supervisor, and equipment rental for project duration	269.4
Site Preparation	Geotechnical sampling, excavation, and concrete foundation	204.0
Enclosure	80 ft × 72 ft × 30 ft height pre-engineered building with structural steel, siding with 4" of insulation, roofing, trim, windows, 3 personnel entry doors, (2) 16 ft rollup doors; Price includes installation.	199
Plumbing/Fire Protection	Fire hydrant , piping, and controls; potable water piping	57.8
Electrical and Lighting	Power pole, transformers, disconnect switch, panel boards, receptacles, indoor and outdoor lighting, exit signs, emergency egress signs, cable, conduit, hangers, and racks.	188
HVAC	Air handling unit, chiller and chilled water piping, intake louvers, control room 2-ton package unit, ductwork, fittings, grilles, and diffusers	284
HEPA Exhaust System	HEPA filter housings (2), ductwork, dampers, exhaust monitoring, and controls	482.4
Radiation Control Instrumentation	Rad meters (beta/gamma/alpha), alpha probes, pancake probes, friskers, Model 3030 sample counter, portal monitor	68.7
Processors (2), excavators (4), and support equipment	Crusher, shredder, delivery, setup, and training	1,952
Demobilization	Turnover documentation, equipment removal, office removal	32.9
Commissioning	Component testing, system tests, procedure development, training, management assessment, and readiness assessment	220.6
Subtotal:		**$ 5,017**
Overhead at 8.5%		**$ 426.4**
Construction contingency at 35%*		**$ 1,905**
Total Capital Cost		**$ 7,348**

*Mid-range of DOE contingency for Class 4 estimate per DOE Guide 413.3-21 *Cost Estimate Guide*. (DOE 2011c)

Operating the facility will require utility supply costs, fuel for the processors, maintenance of processors and support equipment, and an operating crew. The operating life of the equipment was investigated to determine if equipment replacement would be necessary at some point in the 22 years of CERCLA waste generation. Based on manufacturer discussions, these systems can be expected to operate for the duration of the 22-year time period of waste generation if maintained properly. The major mechanical components impacting the waste material can be sharpened or replaced, hydraulic pumps can be replaced, and the drive engines can be overhauled if necessary. These maintenance costs are included in the cost estimate; details are provided in Attachment B to this Appendix. The crew would be composed of the personnel listed in Table B-9.

Table B-9. Operations Personnel for Size Reduction Facility

Resource	Full-time Equivalent (FTE)*	Responsibilities
Operations Supervisor	1	The Operations Supervisor would coordinate and supervise all process operations activities and personnel. The Supervisor would ensure that operations are conducted in accordance with procedures and in compliance with applicable permits and regulations.
Equipment Operators	4	Equipment operators would operate the crusher, shredder, and excavators in accordance with procedures and safety protocols.
Truck Driver	1	The driver would be responsible for transporting the size reduced debris to the landfill site.
Radiation Control Technician (RCT)	1	The RCT would monitor the work area for contamination, prepare radiation work permits for equipment operators, and monitor the performance of the containment and HEPA filter system.
Maintenance Technician	0.25	The Maintenance Technician would perform preventative maintenance and repair services for the process equipment.
Environmental Monitoring Technician	0.25	The Environmental Monitoring Technician would monitor and sample for airborne and waterborne contaminants in accordance with environmental permits.
Health and Safety Technician	0.25	The Health and Safety Technician would monitor work conditions, prepare work/rest schedules for equipment operators based on temperature conditions, and ensure compliance with the worker health and safety plan.

* Refer to Table B-10 for operating personnel costs.

Project management would also be necessary to administer essential functions that support the safe and effective execution of facility operations. Management personnel would implement and oversee the following activities:

- Health and Safety (H&S)
- Radiation Protection
- QA and Training Programs
- Environmental Protection Program
- Site Access Control
- Risk Management
- Project and Document Controls
- Contract Administration
- Finance
- Accounting and Payroll
- Procurement
- Data Management

For estimating purposes, it was assumed that project management costs would be 20% of total project costs. Overhead costs (taxes, insurance, office space, security, etc.) are expected to be 8.5% of project costs. For a ROM estimate type, a 35% contingency is added to the capital costs to account for unanticipated cost items and resources. Table B-10 provides a summary of estimated life-cycle costs for the size reduction facility. A lump sum estimate of $500K was included for D&D of the size reduction facility upon completion of operations. It was assumed that the enclosure and equipment would be decontaminated, disassembled, and placed in the EMDF landfill site just prior to landfill capping and closure activities.

Table B-10. Total Life-cycle Costs for Size Reduction Facility (FY 2012 dollars)

Cost Element	Description	Labor and Materials ($K)
Capital costs with contingency	Planning, engineering, construction, and commissioning	7,348
Operating crew	Supervision, equipment operators, truck drivers, RCTs, H&S support, environmental support, sampling costs, personal protective equipment (PPE) for 22-year operating life-cycle*	21,131
Maintenance	Fuel, replacement and reworking of shredder and crusher components, engine overhauls for shredder, crusher, and excavators	2,113
Utilities and supplies	Electricity, water, replacement HEPA filters	2,660
Decontamination, demolition, and disposal at completion	Building and equipment decontamination, demolition, and disposal. Assumes disposal at EMDF.	500
Project management	20% of total project costs**	6,235
Overhead costs	8.5%	2,774
Total Life-cycle Cost	Capital, operating, and D&D costs (Unescalated)	**42,761**
Present Worth (discount rate = 1.5%)	Life-cycle (FY 2016)	**$39.70M**

* Refer to Table B-9 for operating personnel responsibilities.

**Project management costs are 20% of capital and operating costs, before tax, overhead, and contingency. These costs include management of all aspects associated with capital design/construction and operation. Functions include: safety management, engineering support, quality assurance, environmental compliance, performance assurance, project controls, document control, and administrative support over the 22 year operating life-cycle.

Attachment B provides supporting cost details for the capital and operating cost estimate. The total life-cycle cost from Table B-10 is about $42.8M, or about $88.40 per yd^3 of material processed.

5.4.3.1 Cost Effectiveness of Size Reduction

Cost savings as a consequence of size reduction for concrete and general demolition debris include reduced cost of clean fill for the landfill, reduced landfill construction costs, and reduced post-closure costs. For shredding and crushing operations, the total capacity gained is 371,985 yd^3 including reduced clean fill requirements and the use of crushed concrete as fill material. This volume is comparable to the volume of a complete disposal cell for the landfill. The cost estimate summary data from Appendix I for the EBCV Site Option, Table I-5 was used to estimate the cost savings associated with reducing the size of EMDF by the equivalent of one cell (Cell 6). Table B-11 provides a summary of avoided costs associated with EMDF construction and operations. The reduced costs of construction, construction support, capping, and closure are about $30.1M. The total avoided cost of clean fill in this case is approximately $3M based on a value of $6.50/ton of clean fill. Post-closure maintenance and monitoring is reduced by about $0.79M which is the incremental 100-year savings associated with maintaining the cap of smaller area. Long-term ground water monitoring costs (the bulk of long-term monitoring/maintenance costs) would not change with the removal of one cell from the EMDF. The total avoided costs for Cell 6 would be about $33.9M. The life cycle costs for size reduction are higher than the EMDF avoided costs by about $8.87M, indicating that deployment of a size reduction facility is not cost effective. In terms of Present Worth, this difference increases to ($39.7M - $28.23M) or $11.48M. Similar results would be expected for other siting Options.

Table B-11. Avoided EMDF Construction Costs Through Size Reduction

Cost Element	$M
Capital Cost of Cell 6	30.1
Avoided cost of clean fill	3
Long-Term Monitoring and Maintenance (Reduced surveillance and maintenance costs)	0.79
Total Cost Avoided if Cell 6 is not constructed	**33.89**
Present Worth Cost Avoided (discount rate = 1.5%)	**28.23**

5.4.3.2 Evaluation of Alternative Locations for Size Reduction Facility

Since deploying a size reduction facility on the EMDF site is not cost effective, alternative location options were evaluated to determine if cost effectiveness could be improved. Two options were evaluated:

- Installing two facilities adjacent to demolition sites at ORNL and Y-12 using existing buildings for containment enclosures.
- Installing a facility adjacent to the EMDF disposal cell area and within the leachate collection zone.

Deploying size reduction systems within existing buildings at ORNL or Y-12 near the demolition areas would reduce construction and transportation costs. Construction costs would be reduced by utilizing existing buildings to enclose the size reduction facility and provide ventilation containment. Transportation costs for moving waste materials from the demolition site to the EMDF would be reduced through increasing the bulk density of the debris and allowing more material to be transported per truckload.

The advantages of installing the size reduction facility within the EMDF disposal cell area include utilization of the leachate collection system for water management and containment, and utilization of the heavy equipment used for landfill placement to move the processed materials to the designated landfill placement location, thus eliminating the handling step associated with transporting the processed materials from size reduction facility to the placement location.

5.4.3.2.1 Deployment Using Existing Facilities at ORNL and Y-12 Demolition Sites

Increasing the bulk density of the debris reduces transportation costs by decreasing the number of transportation events necessary to move the debris from the demolition site to the EMDF. Transporting a 10 yd^3 truckload of debris costs an average of $220 per load. As shown in Table B-7, the total volume of the debris prior to size reduction is 645,534 yd^3 and 481,264 yd^3 after processing for a difference of 164,270 yd^3, which is equivalent to the volume that would not require transportation from the demolition site to EMDF. At $220 per 10 yd^3 load, the avoided cost of transportation would be $3.6M.

If two suitably sized existing inactive facilities at ORNL and Y-12 could be used to house and contain the two size reduction equipment at both sites, the capital costs associated with containment enclosures and associated support systems would be significantly reduced. However additional processing equipment and labor would be needed to operate at both sites. Table B-12 provides a comparison of size reduction facility costs for the two deployment approaches. Though capital costs, transportation, and D&D costs are reduced, combined operating costs are higher for the two facilities. Total life-cycle costs increase for deployment of size reduction processing at two sites by approximately $2.4M indicating that the cost benefit of using existing facilities to house the equipment is negated by the additional operating costs.

5.4.3.2.2 Deployment within the EMDF Cell Boundary

The EMDF design layout for the EBCV site was reviewed to evaluate the feasibility of installing the size reduction facility within the footprint of the landfill site, with expected similar conclusions for the other possible Bear Creek locations. The advantages to this approach include utilization of the existing leachate collection system for water management and containment, and the ability to use existing heavy equipment to move the processed materials to the landfill placement location. This differs from deployment outside the cell boundary by allowing processing and placement of waste materials in the same general location. This eliminates the handling step associated with transporting the processed materials from the size reduction facility to the placement location.

To minimize the distance between the size reduction facility and the landfill cells, the facility should be placed in a central location in close proximity to the cells. The first option examined involved placement of the facility within a constructed cell where waste placement activities had not begun. Since utility infrastructure is needed to support the processing, the facility must be constructed at a static location. The last anticipated cell (Cell 5) would be the optimum construction site to allow maximum use of the facility before the cell was needed for waste placement. However, there are several issues associated with this approach including:

- The facility would have to be removed or relocated before all of the waste for EMDF could be processed.
- The facility would need to be placed in the last anticipated cell for maximum utilization. This would negate the phased approach to construction and potentially the sizing of the leachate collection system.
- In the event of heavy rainfall, catchment areas within the cells are expected to accumulate standing water, which could potentially flood the size reduction facility.
- Vibration of the processing equipment could apply additional stress on the components of the liner and leachate collection system.

Table B-12. Cost Comparison for Size Reduction Facility Deployment at EMDF and at Two Facilities in Existing Buildings at ORNL and Y-12

Cost Element	Description	Labor and Materials for Single Facility at EMDF ($K)	Explanation of Change for Deployment at two Demolition Sites	Labor and Materials for two Facilities at ORNL and Y-12 ($K)
Capital costs	Planning, construction, and commissioning	7,348	Enclosure costs eliminated; processor costs increased for deployment at two sites	4,537
Operating crew	Supervision, equipment operators, drivers, RCTs, H&S support, environmental support, sampling costs, PPE	21,131	Operating crew costs increase for deployment at two sites	25,640
Transportation	Transportation of debris to EMDF	14,202	Transportation costs are reduced by increasing debris bulk density	10,588
Maintenance	Fuel, replacement and reworking of shredder and crusher components, engine overhauls for shredder, crusher, and excavators	2,113	No change (maintenance costs are based on processing quantity)	2,113
Utilities and supplies	Electricity, water, replacement HEPA filters	2,660	Increased utility requirements for two enclosures	5,273
Decontamination, demolition, and disposal at completion	Building and equipment decontamination, demolition, and disposal. Assumes disposal at EMDF.	500	D&D cost applies to equipment only	200
Project management	20% of total project costs*	6,235	No change (same percentage)	7,513
Overhead costs	8.5% of total project costs	2,774	No change in overhead rate	3,533
Total Project Cost	Capital, operating, and D&D costs (not escalated for inflation)	**56,963**		**59,397**

*Project management costs are 20% of capital and operating costs, before tax, overhead, and contingency.

Due to these issues, it was decided to evaluate the placement of the facility at the northern edge of the landfill in an elevated location better suited for moving the processed materials to the active cells and avoiding the potential impact of accumulated storm water (see Figure B-5). The designed topography of the EMDF site indicates a suitable area at the north side of Cell 4 that was deemed optimum for the processing facility. Using this location for the size reduction facility would nevertheless require a significant amount of earthwork to develop the area identified for the facility. Consequently, the phased approach to EMDF construction would have to be modified to allow Phase I to include development of the area north of Cell 4 and construction of the size reduction facility. Also, though the proximity of the size reduction facility would be closer to most areas of the landfill, it would still be necessary to move the processed material from the facility to the placement location. The longest haul distance for transport would be approximately 2,300 ft with an elevation change of 150 ft. Using the heavy equipment required for spreading and compacting the waste to move the processed materials this distance to the placement site may cause a significant loss in productivity and higher fuel costs as compared to using additional dump trucks to move the processed material to the placement site.

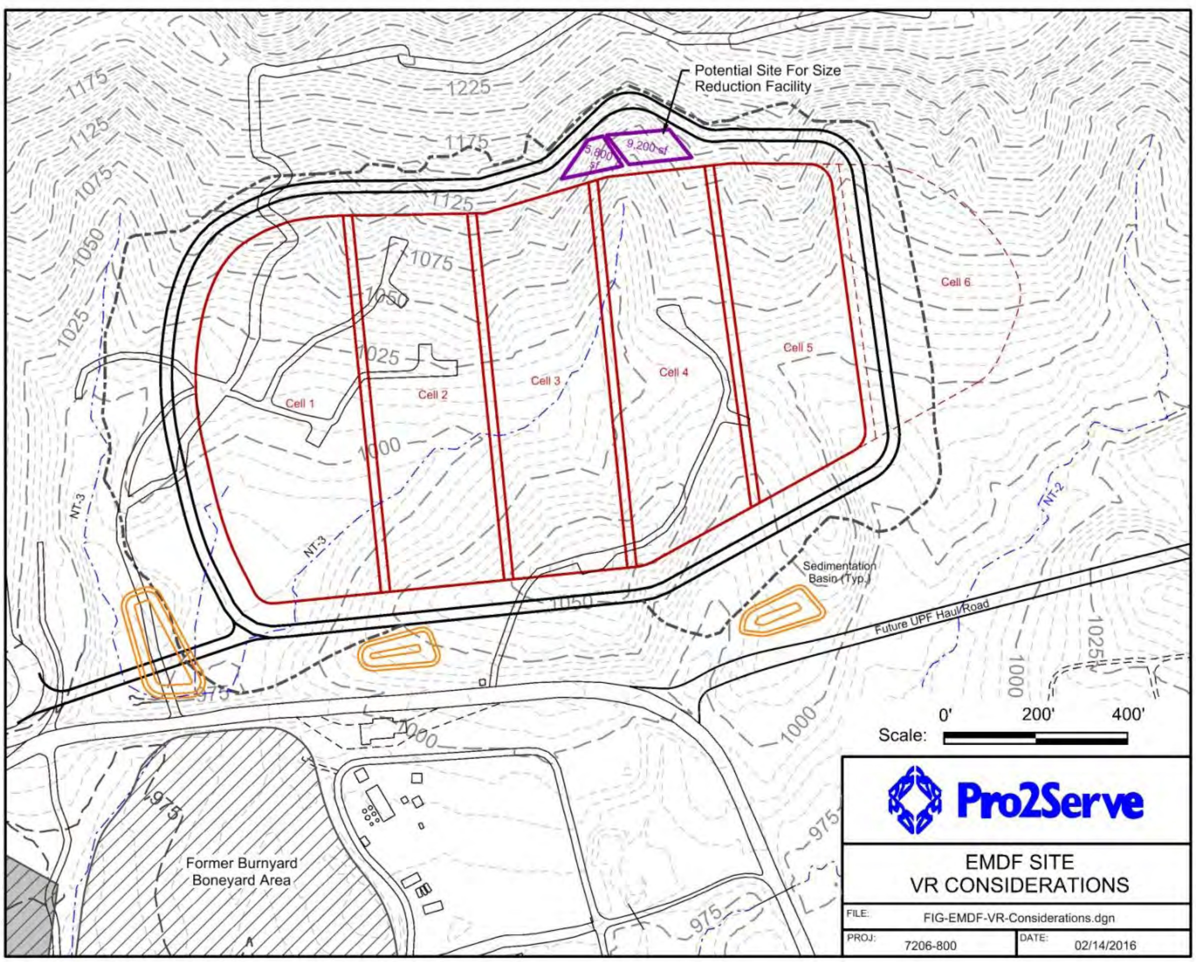

Figure B-5. EMDF EBCV Site Plan with Potential Location for Size Reduction Facility

The location for the size reduction facility is relatively level and provides an adequate footprint for the processing area; however, this site is on the perimeter of the landfill and could not take advantage of the landfill liner and leachate collection system for containment. To extend the landfill liner under the facility would require approximately 25,000 ft^2 of additional liner coverage. Roughly calculating the liner cost per ft^2, based on the estimate performed for EMDF, yields $27.14/$ft^2$ or $678,500 for the extended area. Constructing a concrete pad with containment for the facility could be performed at a lower cost than extending the liner system and it would accomplish the same purpose of collecting potentially contaminated runoff from the facility. The foundation could be designed to allow runoff from the facility to flow by gravity to the leachate collection system. The facility construction costs include the concrete pad with containment instead of extending the landfill liner and leachate collection system.

For evaluating the potential cost savings associated with constructing the size reduction facility within the landfill footprint, the cost data in Table B-10 for the facility constructed outside the landfill site was used to compare costs with those anticipated for the facility within the landfill footprint. Table B-13 shows the comparative costs for each work element. As shown, the capital costs, maintenance, utilities, and D&D costs would be the same. The difference in operating cost reflects the best possible case where the cost of transporting the processed material from the facility to the placement site is completely avoided by assuming the landfill heavy equipment would be used for that purpose.

As indicated in Table B-13, the cost of size reduction operations is reduced by $3.8M with elimination of truck transporting the processed material from the size reduction facility to the EMDF cells. However, when compared to the cost benefits in Table B-11, the cost of size reduction remains $5.05M greater than the cost of EMDF disposal without size reduction processing.

5.4.3.3 Size Reduction Summary for On-site Disposal Alternative

Several size reduction technologies and deployment options were explored for size reduction processing of demolition debris of several different types prior to disposal at EMDF. Potential cost benefits were identified and evaluated against the estimated cost of constructing and operating a size reduction facility both at the EMDF EBCV site and at the Y-12 and ORNL sites where demolition activities will take place. The results clearly indicate that the cost of implementing size reduction processing is higher than the cost benefits from reduced landfill size, reduced transportation costs, and from reduced quantities of clean fill. Table B-14 provides a summary of the cost/benefit study results. As demonstrated previously (see Section 5.4.3.1) in terms of Present Worth, these net cost differences will be somewhat larger (more negative).

Table B-13. Cost Comparison between Size Reduction Facility Installations at EMDF and within the EMDF Landfill Site*

Cost Element	Description	Labor and Materials for Single Facility at EMDF Outside Landfill Site ($K)	Explanation of Change for Deployment at two Demolition Sites	Labor and Materials for Single Facility at EMDF within Landfill Site ($K)
Capital costs	Planning, construction, and commissioning	7,348	Increased site preparation costs	8,395
Operating crew	Supervision, equipment operators, drivers, RCTs, H&S support, environmental support, sampling costs, PPE	21,131	Cost decreased by reduced cost for moving waste from facility to waste placement site	16,808
Maintenance	Fuel, replacement and reworking of shredder and crusher components, engine overhauls for shredder, crusher, and excavators	2,113	No change (same processing quantity)	2,113
Utilities and supplies	Electricity, water, replacement HEPA filters	2,660	No change	2,660
Decontamination, demolition, and disposal at completion	Building and equipment decontamination, demolition, and disposal. Assumes disposal at EMDF.	500	No change	500
Project management	20% of total project costs**	6,235	No change in percentage	5,585
Overhead rate	8.5% of total project costs	2,774	No change in rate	2,877
Total Project Cost	Capital, operating, and D&D costs (not escalated for inflation)	**$ 42,761**		**$ 38,938**

*Costs are those associated with building the EMDF at the EBCV site. Other site locations would be expected to have similar costs.

**Project management costs are 20% of capital and operating costs, before tax, overhead, and contingency.

Table B-14. Summary of Size Reduction Cost/Benefit Study Results for the On-site Disposal Alternative*

Deployment Approach	Avoided Costs	Size Reduction Cost (Capital and Operating)	Net Cost
Size reduction of equipment and heavy structural steel	$5.22M	$13M (K-33 project capital cost only)	(-$7.78M)
Size reduction facility for concrete and general debris deployed at the EMDF	$33.89M	$42.76M	(-$8.87M)
Size reduction facility for concrete and general debris deployed in existing facilities at the Y-12 and ORNL sites	$37.5M	$48.8M	(-$11.3M)
Size reduction facility for concrete and general debris deployed within EMDF landfill site	$33.89M	$38.94	(-$5.05M)

*Based on estimated costs for the EMDF EBCV Site Option.

5.4.3.4 Volume Reduction for Off-Site Disposal Alternative

The Off-site Disposal Alternative would provide for the transportation of future CERCLA candidate waste streams to one or more approved off-site disposal facilities and placement of the wastes in those facilities. Volume reduction efforts would have a significant impact on off-site disposal by reducing the number of waste shipments with associated high transportation costs and the disposal fees.

5.4.3.4.1 Size Reduction for Off-site Disposal

The use of VR equipment to size reduce and increase the bulk density of demolition debris would, in some cases, increase the quantity of material per shipment and reduce the total number of off-site shipments. The Off-site Disposal Alternative is described in Chapter 6 and costs are provided in Appendix I, Table I-9. This information was used as a basis for determining the economic benefit of various VR approaches.

In the Off-site Disposal Alternative, all non-classified LLW and LLW/TSCA waste (comprising the majority of the total waste volume evaluated under the Off-site Disposal Alternative as described in Chapter 2) would be shipped to either NNSS in Nye County, Nevada, (Option 1) or Energy*Solutions* in Clive, Utah, (Option 2). It is required by DOE that all classified waste be shipped to NNSS. The remaining 3% of LLW/RCRA mixed waste would be shipped to Energy*Solutions* in Clive, Utah, or Waste Control Specialists in Andrews, Texas.

Intermodal containers with 25 yd^3 capacity are practical for shipment of debris to NNSS due to the lack of rail transport capability to the disposal site. Additional NNSS requirements limit intermodal loading to 18 ft^3 to avoid difficulties associated with unloading during waste placement actions. As a consequence of the container limitations, shipment of debris with low bulk density is inefficient because the volume capacity of the container is reached before approaching weight limits of the container for roadway transport. Such shipments are considered "volume limited". To improve transportation efficiency, size reduction may be used to increase the bulk density of the debris to increase the weight of material loaded per container. For shipment to Energy*Solutions* (Option 2), railway transport may be used which allows for much larger containers such as gondolas that can hold up to 148 yd^3. Debris with low bulk density is shipped more efficiently by railway because the quantity per railcar is not limited by volume, but rather by the weight capacity of the railcar. These shipments are considered "weight limited". Therefore, the use of size reduction to increase the bulk density is not necessary for railcar shipments to Energy*Solutions*. For the purpose of VR evaluation, shipment of LLW debris to NNSS (Option 1) is assumed and analyzed, because increasing the bulk density of the debris is beneficial in this case.

Transportation for the off-site disposal estimate assumes that LLW debris would be transported by intermodal containers to a truck-to-rail transfer facility at ETTP for rail shipment to Kingman, Arizona, where transloading of intermodals from railcar to trucks would be performed for transport to NNSS. A single articulated bulk container railcar (ABC railcar) is assumed to carry eight intermodal containers. Transportation cost for one railcar from the ETTP to Kingman, Arizona, would be \$25,440 in 2012 dollars (or \$3,180 per intermodal container). The cost of unloading the intermodal containers from the railcar and transporting by truck from Kingman to NNSS would be about \$1,370 per intermodal container. The intermodal containers would be taken into the appropriate disposal cell and emptied per approved procedures. Empty containers would be surveyed at the disposal facility for release and returned to ORR for reuse. Intermodal containers would be purchased and replaced after 10 years of use.

The cost effectiveness of size reduction would depend upon the type and quantity of material to be shipped off site. Table B-15 summarizes an analysis performed to determine those materials that would benefit from VR processing. The materials and quantities to be processed by VR (Table B-3) were evaluated to estimate the additional quantities that could be loaded per intermodal container. NNSS acceptance criteria limits the maximum volume per intermodal to 18 yd^3 and maximum net weight of 36,000 lb. The 18 yd^3 maximum is used for intermodals that are to be emptied and returned to the generator to avoid debris jams while dumping the intermodal contents through the hinged door at the end of the container. After determining the total additional weight of material that could be shipped per intermodal, bulk density information was used to determine the equivalent volume in terms of as-generated material, which is the volume that would not require shipment if size reduction processing is performed. As-generated materials that have a relatively high bulk density such as concrete and masonry would not be as cost effective to crush further because the intermodal and truckload quantity would be limited by weight rather than volume. However, materials with a high void fraction and low density could be size reduced to increase the bulk density and increase the quantity and weight shipped per truckload. These materials include equipment, large diameter ductwork and pipe, structural steel, light framing, siding, small tanks, asphalt shingles and other roofing materials, containers, furniture, trash, and wood. The results show that size reduction processing would be beneficial for all materials except for concrete and masonry.

The materials that benefit from size reduction are generally bulky with high void fraction. Most include metallic debris and would require a shearing machine for processing heavy gauge metal and a shredder for thin gauge metals and light debris. It was assumed that a centrally located size reduction facility at ETTP would be provided to process debris as received by dump truck from the demolitions site. To estimate the facility cost, the data for the EMDF on-site size reduction facility for concrete and general construction debris (see Table B-8), was adjusted by substituting the concrete crusher with a shearing machine. Operating costs were adjusted for the additional labor and energy for operating the shear. In addition, the duration of operations was extended by five years to compensate for the higher costs of off-site shipments and annual budget limitations. Table B-16 provides a summary of the life-cycle costs for the facility.

Table B-15. Volume Reduction Analysis for the Off-Site Disposal Alternative

Description	As-generated Bulk Density (lb/yd^3)	As-generated Volume for Processing (yd^3)	Total Intermodals without VR	Intermodal net Weight without VR (lb)	Bulk Density after VR (lb/yd^3)	Size Reduction Basis	Volume after VR (yd^3)	Intermodal Net Weight when Full (lb)	Total Intermodals with VR	Net Intermodal Shipments Avoided	Equivalent As-generated Waste Volume (yd^3)
Thick walled steel, glove boxes, hoods, heavy-walled equipment, cranes	680	63,162	3,509	12,240	1,360	50% size reduction	31,581	24,480	1,754	1,754	31,581
Pipe, tanks, structural steel	1,040	211,415	11,745	18,720	2,080	50% size reduction	105,707	36,000	5,638	5,638	101,479
Reinforced concrete, concrete block, brick, shield walls	2,600	364,985	26,360	36,000	3,250	20% size reduction **	291,988	36,000	26,360	0	0
Small buildings, small cooling towers, structural framing, interior and exterior finishes, flooring, wooden structures	1,620	60,605	3,367	29,160	2,700	40% size reduction	36,363	36,000	2,727	640	11,515
Ventilation duct, light framing, small diameter pipe, siding, small tanks	1,040	26,012	1,445	18,720	1,733	40% size reduction	15,607	31,200	867	578	10,405
Asphalt shingles, low-slope built-up roofs, vapor barrier, insulation, roof vents, flashing, felt	1,520	30,422	1,690	27,360	2,533	40% size reduction	18,253	36,000	1,284	406	7,301
Containers, furniture, trash, wood	640	1,698	94	11,520	1,067	40% size reduction	1,109	19,200	57	38	679
TOTALS		**758,300**	**48,211**				**500,519**		**39,157**	**9,053**	**162,960**

** Not included as a waste amenable to VR.

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Table B-16. Total Life-cycle Costs for Off-Site Disposal Alternative Size Reduction Facility

Cost Element	Description	Labor and Materials ($K)
Planning and Acquisition	Includes all planning documents required for DOE capital projects (i.e., Project Execution Plan, alternative analysis, preliminary cost estimate, quality assurance plan, risk management plan, commissioning plan, etc.)	629
Engineering Design	Title I and II design packages including system requirements, specifications, and drawings	382
Construction		
Mobilization	Contractor plans and mobilization of construction equipment	47
Construction Support	Construction Superintendent, Safety Engineer, Field Supervisor, and equipment rental for project duration	269
Site Preparation	Geotechnical sampling, excavation, water supply, and concrete foundation; 80 ft × 80 ft × 30 ft height pre-engineered building.	416
Mechanical Systems	Heating, ventilation, air conditioning, exhaust filtration, plumbing, and fire protection	810
Electrical and Lighting	Power pole, transformers, disconnect switch, panel boards, receptacles, indoor and outdoor lighting, exit signs, emergency egress signs, cable, conduit, hangers, and racks.	188
Radiation Control Instrumentation	Rad meters (beta/gamma/alpha), alpha probes, pancake probes, friskers, Model 3030 sample counter, portal monitor	69
Processing Equipment	Shear machine, shredder, excavators (3), and containers	9,416
Demobilization	Turnover documentation, equipment removal, office removal	33
Commissioning	Component testing, system tests, procedure development, training, management assessment, and readiness assessment	221
Total Capital Cost	Planning, design, construction, and commissioning	**12,480**

Table B-16. Total Life-cycle Costs for Off-Site Alternative Size Reduction Facility (Continued)

Cost Element	Description	Labor and Materials ($K)
Operations		
Operating crew	Supervision, operators, drivers, RCTs, H&S support, environmental support, maintenance technicians, sampling costs, PPE for 27-year project life cycle.*	41,564
Maintenance	Rotating or replacing knife blades, greasing, replacing hydraulic fluid, fuel, oil changes, engine overhauls	2,215
Utilities and supplies	Electricity, water, replacement HEPA filters	4,318
Total Operating Cost	Operating crew, maintenance, and utilities	**48,097**
D&D	Building and equipment decontamination, demolition, and disposal. Assumes disposal at EMDF.	1,500
Project management	20% of total project costs**	12,241
Overhead	8.5% of total project costs	6,317
Contingency	35% of total construction costs	3,942
Total Life-cycle Cost	Capital, operating, and D&D costs (unescalated)	**84,577**

*Due to DOE annual budget limitations, disposal operations are expected to require an additional 5 years to complete.

**Project management costs are 20% of capital and operating costs, before tax, overhead, and contingency.

The cost of size reduction, $84.6M, must be compared to the avoided cost of off-site disposal to determine cost effectiveness. The avoided cost for off-site disposal was calculated based on a unit rate for off-site disposal of $1,013 per yd^3 in 2012 dollars with contingency for disposal Option 1. This value is determined from Appendix I data for the off-site alternative (prior to VR). In Table B-17, the rate was applied to the avoided shipment volume from Table B-15 to determine the avoided cost. Compared to the cost of size reduction, cost benefit for the Off-site Disposal Alternative Option 1 is a savings of $80.5M.

Table B-17. Cost Benefit of Size Reduction for Off-site Disposal Alternative (Option 1)

Material	Avoided Shipping Volume (yd^3)	Avoided Shipping Cost at $1,013 per yd^3 ($K)
Thick walled steel, glove boxes, hoods, heavy-walled equipment, cranes	31,581	31,991
Pipe, tanks, structural steel	101,479	102,798
Small buildings, small cooling towers, structural framing, interior and exterior finishes, flooring, wooden structures	11,515	11,665
Ventilation duct, light framing, small diameter piping, siding, small tanks	10,405	10,540
Asphalt shingles, low-slope built-up roofs, vapor barrier, insulation, roof vents, flashing, felt	7,301	7,396
Containers, furniture, trash, wood	679	688
TOTAL	162,960	165,078
Life-cycle Size Reduction Facility Cost, $K		**84,577**
Avoided Cost of Off-site Disposal in Option 1, $K		**80,501**

The avoided cost of \$80.5M is applied to the Appendix I off-site disposal estimate for Option 1, resulting in a cost of \$960 per yd^3 (see Appendix I). To determine how this unit rate compares to on-site disposal, it is necessary to determine unit rates for the same materials if disposed at EMDF. The overall unit rate for on-site disposal was determined by dividing the total cost of the EMDF (2012 dollars with 22% contingency) at \$777.1 M (from Appendix I, Table I-2 for five cells) by the total as-generated volume of debris and soil 1,948,558 yd^3 from Appendix A, Table A-3, resulting in a unit cost of about \$399 per yd^3. However, this constitutes an average rate and some materials are more costly to dispose of than others. To determine the cost of disposal for a particular waste type, the unit cost of EMDF air space must be determined and applied to the as-disposed waste volume along with the required clean fill volume. The unit cost of air space is given by the total EMDF cost divided by the total as-disposed air space of 2.2M yd^3 giving \$353.22 per yd^3. Table B-18 applies this unit cost to the as-disposed volume of waste types with fill requirements. Unit costs range from \$107 to \$636 per yd^3 and are higher for materials with higher ratios of as-disposed to as-generated volumes and significant fill requirements. All of the unit rates, however, are much lower than the rate for off-site disposal with or without the use of size reduction.

5.4.3.4.2 Recycling, Segregation, and Sequencing for Off-site Disposal

The benefits of waste recycle and segregation are significant for the Off-site Disposal Alternative. For every yd^3 of material recycled or segregated for disposal at the ORR Landfill, the cost avoided is \$960 based on the unit rate for off-site disposal, less the cost of recycling or segregation. From Section 5.1.2, the cost of recycling would be about \$54 per yd^3 and from Section 5.3, the cost of segregation is about \$54 per yd^3 plus the cost of disposal in the ORR Landfill, which would be far less than the cost of off-site disposal.

Project sequencing would also be beneficial for off-site disposal if waste soil could be made available to mix with low density debris and increase the mass of waste per intermodal for shipments. The challenge for this approach would be the logistics associated with loading intermodal containers with a mixture of soil and debris generated from different CERCLA actions and locations. Additional space for soil stockpiling and costly double-handling of soil would be required for it to be available for mixing with debris. Mixing of waste types would require additional planning and certification effort to obtain approval from the disposal facility for mixing wastes with different profiles.

Table B-18. Unit Cost Determination for On-site Disposal Cost by Waste Type without Volume Reduction

Description	As-generated Volume (yd^3)	As-disposed Volume (yd^3)	Clean Fill Required (yd^3)	Clean Fill Ratio (soil:debris) from CARAR	As-disposed Volume for Waste and Clean Fill (yd^3)	Cost of EMDF Airspace at $353.22/$yd^3$ ($K)	Cost per yd^3 of As-generated Material ($/$yd^3$)
Thick walled steel, large machine tools, large electric motors, process vessels	210,539	12,737	122,023	9.58	134,760	$47,600	$226.09
Large diameter pipe, structural steel, crane structures	281,886	26,082	172,924	6.63	199,006	$70,293	$249.37
Reinforced concrete, concrete block, brick, shield walls	486,647	389,317	486,647	1.25	875,964	$309,408	$635.80
Small buildings, small cooling towers, structural framing, interior and exterior finishes, flooring, wooden structures	80,807	40,404	91,312	2.26	131,716	$46,525	$575.75
Ventilation duct, light framing, small diameter pipe, siding, small tanks	34,683	3,209	7,253	2.26	10,462	$3,695	$106.54
Asphalt shingles, low-slope built-up roofs, vapor barrier, insulation, roof vents, flashing, felt	40,562	20,281	0	0	20,281	$7,164	$176.61
Containers, furniture, trash, wood	2,265	1,132	2,559	2.26	3,691	$1,304	$575.75
TOTALS	**1,137,389**	**493,163**	**882,717**		**1,375,880**		

5.4.4 CERCLA Evaluation of Debris Size Reduction

Size reduction of debris is a process option for consideration in implementing on-site and off-site disposal remedies in this RI/FS. Under the CERCLA process, alternatives are evaluated against seven of the nine criteria to facilitate comparison of the alternatives. The CERCLA evaluation process is applied to the debris size reduction option separately to simplify the full alternatives analysis presented in Chapter 7 of the main document. This analysis compares each alternative with and without implementation of mechanical size reduction. The Off-site Disposal Alternative, Option 1 (disposal at NNSS) is used for comparison due to the beneficial impact of size reduction (Section 5.4.3.4.1). The two CERCLA alternative evaluations for debris size reduction are summarized as:

On-site Disposal (site independent)		Off-site Disposal (Option 1 only)	
With mechanical size reduction	Without mechanical size reduction	With mechanical size reduction	Without mechanical size reduction

The option not using mechanical size reduction becomes the baseline from a CERCLA perspective, against which the action, size reduction, is compared. Tables B-19 and B-20, for the on-site and off-site disposal alternatives respectively, summarize the CERCLA evaluation for implementing mechanical size reduction.

Results indicate that mechanical size reduction at the demolition site is not advantageous for the On-site Disposal Alternative. The most significant disadvantages of mechanical size reduction at an on-site facility include an increased risk to workers due to significant handling of contaminated material and operation of heavy equipment, secondary waste generation, and additional net cost. These disadvantages outweigh the advantage of reducing the landfill footprint (without benefit of reducing the source toxicity or mobility).

A review of VR as proposed in the NRC draft and final Environmental Impact Statement documents NUREG-0782 and NUREG-0945 (NRC 1981, 1982) written in support of the implementation of 10 CFR 61 (Licensing Requirements for Land Disposal of Radioactive Waste) indicates that the NRC did not consider VR to be part of the disposal process. Generators were assigned the burden of reducing their volume, and encouraged to do so for compactable, non-stable waste (this includes PPE and compactable trash) to provide more stability upon disposal. VR of debris is not discussed. In fact, the disposal alternatives proposed in these documents point out the increased stability of waste forms and disposal facilities themselves, decreased leachability and decreased contact of water with waste, and increased protectiveness to inadvertent intruders afforded by cementitious waste forms and increased use of grouting. Crushing concrete debris to the point that it can be used as void fill reduces the use of soil as fill and would result in a decreased disposal capacity need, but soil would typically would provide a better matrix to reduce leaching of radioactive contaminants than would pulverized concrete, and no reduction in toxicity is afforded by the process.

In the case of off-site disposal, mechanical size reduction benefits outweigh the disadvantages, and it is recommended to retain size reduction for the Option 1 Off-site Disposal Alternative in the full CERCLA evaluation. The most significant advantage is the reduction in risk of injuries and fatalities realized by the reduction in volume transported off-site (results in an estimated 2.0 fewer total injuries/fatalities). Additionally a net cost savings is achieved with the reduction in transportation costs. Disadvantages of mechanical size reduction are similar to those discussed above for implementation with on-site disposal.

Table B-19. Comparative Analysis of Off-site Disposal with Mechanical Size Reduction to Off-site Disposal without Mechanical Size Reduction

Evaluation Criterion	**On-site Disposal Alternative with Mechanical Size Reduction** **key:** + = Advantages compared to not implementing Mechanical Size Reduction = Disadvantages compared to not implementing Mechanical Size Reduction *N* = Neutral (no change) over not implementing Mechanical Size Reduction	
Overall protection of human health and the environment	*N* + –	• No reduction in contaminant source mass, so overall protection of the environment for on-site disposal is not impacted. • Allows for a reduced permanent footprint. • Presents higher risk to workers with additional construction activities, double-handling of waste, more contact with waste during operations, operation of heavy equipment, and D&D activities for the size reduction facility.
Compliance with ARARs	*N*	• Fully complies with applicable or relevant and appropriate requirements (ARARs).
Long-term effectiveness and permanence	+ *N* –	• Reduces footprint of landfill permanently. • No reduction in contaminant source mass, so provides no long-term increased protection. • Results in a waste form more likely to be unrecognizable to an intruder as waste or something to be avoided. Intruder more likely to receive a dose from intrusion.
Short-term effectiveness	+ – – –	• Less construction required to build landfill because footprint is smaller, and less fill required. • Results in secondary waste generation through control of contamination (use of dust suppression and decontamination in which contact waste water is generated) and personal protective equipment (clothing, filter materials). • Double handling of waste is necessary, increasing risk to workers in terms of contaminant contact as well as equipment operation. Waste is transported to disposal/VR facility, unloaded and staged, VR implemented, staged/reloaded, and then disposed. • Upon completion, facility will require demolition and disposal.
Reduction of toxicity, mobility, or volume through treatment	+ – –	• Reduces waste volume disposed. • Potentially increases mobility of contaminants by increasing surface area available to leaching. Potentially increases mobility of contaminants by decreasing soil usage that provides attenuation of contaminants. • May affect toxicity by increasing leaching of contaminants over a given time period long-term.
Implementability	*N*	• Technically feasible; new construction is required. Administrative requirements are considered achievable. Services and materials required for design, construction, and operation are readily available, as are qualified personnel, specialists, and vendors. Construction would involve the use of standard construction equipment, trades, and materials; no new technology development is required.
Cost	–	• Overall net increase in cost of disposal to implement mechanical size reduction compared with savings realized by reducing landfill footprint.

Table B-20. Comparative Analysis of Off-site Disposal with Mechanical Size Reduction to Off-site Disposal without Mechanical Size Reduction

Evaluation Criterion		**Off-site Disposal Alternative with Mechanical Size Reduction** **key:** + = Advantages compared to not implementing Mechanical Size Reduction – = Disadvantages compared to not implementing Mechanical Size Reduction *N* = Neutral (no change) compared to not implementing Mechanical Size Reduction
Overall protection of human health and the environment	*N* + –	• No reduction in contaminant source mass, so overall protection of the environment for on-site disposal is not impacted. • Reduces number of waste loads by increasing bulk density. Reduction in loads transported results in reduced short term risk to public, estimated as 2.2 total injuries and fatalities avoided. • Presents higher risk to workers with additional construction activities, double-handling of waste, more contact with waste during operations, operation of heavy equipment, and D&D activities for the size reduction facility.
Compliance with ARARs	*N*	• Fully complies with ARARs.
Long-term effectiveness and permanence	+ *N* –	• Reduces off-site capacity required for permanent disposal. • No reduction in contaminant source mass, so provides no long-term increased protection. • Results in a waste form more likely to be unrecognizable to an intruder as waste or something to be avoided. Intruder more likely to receive a dose from intrusion.
Short-term effectiveness	+ – – –	• Reduction in loads transported results in reduced short term risk to public; estimated as 2.2 total injuries and fatalities avoided. • Results in secondary waste generation through control of contamination (use of dust suppression and decontamination in which contact waste water is generated) and personal protective equipment (clothing, filter materials). • Double handling of waste is necessary, increasing risk to workers in terms of contaminant contact as well as equipment operation. Waste is staged/unloaded, VR is implemented, and waste reloaded for transport. • Upon completion, facility will require demolition and disposal.
Reduction of toxicity, mobility, or volume through treatment	+ – –	• Reduces waste volume disposed, and reduces number of shipments required. • Potentially increases mobility of contaminants by increasing surface area available to leaching. Potentially increases mobility of contaminants by decreasing soil usage that provides attenuation of contaminants. • May affect toxicity by increasing leaching of contaminants over a given time period long-term.
Implementability	*N*	• Technically feasible; new construction is required. Administrative requirements are considered achievable. Services and materials required for design, construction, and operation are readily available, as are qualified personnel, specialists, and vendors. Construction would involve the use of standard construction equipment, trades, and materials; no new technology development is required.
Cost	+	• Overall reduction in cost of disposal through reducing waste transport costs.

6. PREVIOUS VOLUME REDUCTION EVALUATIONS

In August 2001, DOE published the *Waste Management Program Plan for Oak Ridge Reservation Comprehensive Environmental Response, Compensation, and Liability Act – Generated Waste* (WMPP, DOE 2001a). At the time the WMPP was written, it was believed that current and future expansion capacity of the EMWMF would accommodate forecasted disposal volumes. However, the WMPP indicated that further emphasis to reduce the volume of debris waste may be necessary to achieve an appropriate operating soil-to-debris ratio. Specifically, the WMPP recommended physical size reduction treatment and segregation of clean materials to the ORR Landfill be considered. As a best management practice, it was recommended that clean debris not be disposed at EMWMF because it takes up expensive disposal space and would require additional clean fill to achieve an appropriate soil-to-debris ratio. Also, the contaminated soil disposed at EMWMF should be utilized as fill to reduce the demand for clean soil fill. Both of these recommendations have been implemented as discussed in Sections 5.2 and 5.3.

Subsequent to the first load of waste being disposed at EMWMF during May 2002, DOE published the *Comprehensive Waste Disposition Plan for the DOE Oak Ridge Reservation* in March 2003 (DOE 2003). By this time, it was realized that EMWMF did not have adequate capacity to accommodate the projected CERCLA waste volumes and EMWMF has since been expanded. The goal of the plan was to assist DOE, TDEC, and EPA with ongoing efforts to assure that solid wastes managed by DOE Oak Ridge Environmental Management programs have access to cost-effective and environmentally sound disposal facilities. The plan includes a commitment by DOE to evaluate volume reduction methods as a means of reducing CERCLA waste volumes and conserving the disposal capacity of EMWMF.

In 2004, BJC conducted a VR study focused on the approximately 350,000 yd^3 ("as-generated volume" basis) of metal and demolition debris waste streams generated from decontamination and decommissioning of the eight largest buildings at ETTP and from the ETTP Scrap Metal Project (BJC 2004). It also evaluated the current baseline to see if there were additional opportunities for waste segregation. Two size reduction technologies were evaluated, including shredding and compacting. It was concluded that, at best, 100,000 yd^3 of capacity could be gained by applying size reduction technologies to the targeted waste streams. The cost of size reduction was evaluated against a potential cost savings of \$37 per yd^3 for transportation and \$20 per yd^3 associated with EMWMF expansion costs. At the time the study was performed, it was believed that 100,000 yd^3 would reduce the landfill height and would not affect the landfill footprint; hence, the cost savings were operations related with no benefit from lower construction costs. The cost range for size reduction processing was estimated at \$68 to \$78 per yd^3 which is higher than the anticipated cost savings of \$57 per yd^3. The study concluded that it was not cost-effective to size reduce the waste or perform additional characterization sampling required to further segregate the waste based on contamination level.

7. LESSONS LEARNED

Discussions were held with former employees from the Weldon Spring Site RA Project (WSSRAP) and the Fernald Environmental Management Project (FEMP) sites who were involved with the design and operations of the disposal facilities at each site. Each site constructed on-site disposal facilities for disposal of the vast majority of remediation waste and demolition debris generated by the closure of the sites. While VR was not the primary focus of either site, actions were taken which contributed to tangible reductions in the size of the final disposal facility.

At WSSRAP, a 1.48M yd^3 capacity disposal facility was constructed and operated. The facility was used to dispose of demolition rubble from the on-site buildings, contaminated soils, and other wastes originally generated from site operations. Operations of the facility were based on strategic waste placement in the cell. Wastes were transported to the landfill by dump truck and then placed in pre-determined positions.

Prior to loading in the transport vehicles, all debris had to meet size restrictions, so shearing attachments for excavators were used to cut the material to proper size. This was primarily performed to maximize transport efficiency but had the additional benefit of size reduction for the cell, minimizing void spaces that would need to be filled. Flowable grout was used to fill those void spaces that remained. Additionally, some pulverization of the foundation concrete was performed to improve transport efficiency and reduce the volume of waste placed in the cell. This approach is routinely used in Oak Ridge demolition projects. Shearing attachments are routinely used on excavators to reduce transportation costs, meet EMWMF waste acceptance criteria, and maximize waste placement efficiency.

The FEMP constructed an on-site disposal facility with a capacity of over 2.9 M yd^3 for disposal of remediation waste, including demolition debris, generated by the closure of the former Feed Materials Production Center. The WAC for the disposal facility included size limitations for the debris being placed in the cell. As at WSSRAP, operations of the facility were based on strategic waste placement. The need for clean fill was minimized by balancing soil and debris placement with sequencing of D&D and soil remediation projects to maintain this balance. Early stages of the remedial action focused almost exclusively on soil remediation which resulted in most of the first cell being filled with waste soil since D&D had not yet begun. Upon realization of this disparity, improved project sequencing was initiated to assure waste soil was available during debris placement. Additionally, Fernald implemented concrete crushing actions, especially on building foundation slabs. Crushed concrete was used in lieu of soil as filler material. A recommendation from FEMP site personnel was to size reduce debris at the demolition site prior to transport and placement in the disposal cell. This was accomplished with mechanical VR equipment at the demolition site location. The major lesson learned was that balancing soil and debris to minimize clean fill is the best opportunity to conserve landfill capacity. As discussed in Section 5.2, DOE Oak Ridge implements project sequencing to maximize the use of waste soil as fill material for demolition debris.

At ETTP, excavators with crusher and shearing attachments are routinely used to size reduce materials to meet the EMWMF acceptance criteria and to reduce transportation costs. Excavator attachments for sizereduction are used routinely for D&D projects; however, the primary purpose of the excavators is for building demolition and the low productivity of excavator attachments for VR processing alone is not cost effective. As described previously, excavators would be required to support VR operations by minimal size reducing as necessary for placement in VR equipment feed hoppers.

8. SUMMARY

The results of this study indicate that volume reduction methods must be evaluated on a case by case basis and are not always cost effective or advantageous for disposal of CERCLA waste. Recycling, waste segregation, project sequencing, and size reduction can all be beneficial under certain conditions. However, some methods include technical and administrative challenges that introduce unacceptable costs and risks.

Waste segregation and project sequencing are integral to CERCLA waste management activities. These methods are beneficial to both the On-site and Off-site Disposal Alternatives. Waste segregation requires evaluation to determine if a more rigorous characterization effort would be cost effective under the specific work conditions encountered. Poor waste segregation could result in challenging the EMDF design capacity by disposing of excessive quantities of clean materials in the EMDF. If project sequencing is efficiently executed and the majority of waste soil is used as fill material, EMDF landfill space is conserved. Alternatively, if project sequencing is poor and waste soil is not used to replace clean fill, the additional landfill space occupied by the waste soil would approach the volume of an additional disposal cell. Both segregation and sequencing would benefit off-site disposal by reducing the number of waste shipments and associated costs.

Recycling is potentially beneficial for both On-site and Off-site Disposal Alternatives, but would depend on characterization requirements that are currently uncertain. Once NRC and DOE have established a sound technical basis for survey and release for solid materials associated with radiological activity, recycling efforts should focus on recovery and recycle of metals. Recycling materials in public commerce, however, would not be allowed unless the current DOE ban on the recycle of potentially contaminated materials is lifted.

Mechanical size reduction processing can be an expensive endeavor that must be evaluated carefully to determine cost effectiveness. The potential for airborne release during processing of potentially contaminated materials is a significant risk, therefore expensive containment systems and operational controls must be provided. These systems increase size reduction facility costs beyond the bounds of cost effectiveness for the On-site Disposal Alternative. Additionally, secondary waste generation, double handling of waste and worker exposure outweigh the advantage of reduced footprint under the analysis. This analysis does not preclude the possibility of mechanical VR being advantageous at the project level, which if implemented would reduce transportation to the on-site disposal facility. Current practices at demolition sites do conduct size reduction using shearing attachments on excavators to reduce transportation costs, meet EMWMF waste acceptance criteria, and maximize waste placement efficiency. Further project level mechanical VR should be considered on a case-by-case basis, and is outside the scope of this RI/FS.

A size reduction facility for the Off-site Disposal Alternative that transports the bulk of material to NNSS for disposal would be cost effective due to the high cost of transporting the waste off-site. Most importantly, a significant reduction in transportation risk (2 injuries/fatalities) is estimated based on the ability to reduce transportation shipments for this Off-site Disposal Alternative Option 1.

Volume reduction efforts are essential for preserving the design capacity of the EMDF On-site Disposal Alternative and would substantially reduce the cost of the Off-site Disposal Alternative. Regardless of the disposal method, implementation of waste sequencing, segregation, and recycling efforts to decrease disposal costs are best management practices. Evaluation of further volume reduction approaches will continue to be an integral part of the CERCLA waste disposal strategy at both the program and project level.

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APPENDIX B - ATTACHMENT A:
VENDOR INFORMATION

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Vendor:	SSI Shredding Systems, Wilsonville, Oregon (www.ssiworld.com)
Equipment Model:	PRI-MAX 6000 Primary Reducer and the PRI-MAX 770
Application:	Demolition debris including wood, siding, thin gauge metal (up to ¼-inch), roofing, shingles, flashing, conduit, sheet metal, ductwork, with a small fraction of concrete materials

Material preparation requirements:	Limited by size of hopper only; 224" L × 94" W × 43" H; 13.1 yd^3.
Processing capacity:	60 – 150 tons per hr (10-40 tons per hr for the PRI-MAX 770).
Power	700 HP diesel mobile unit (250 HP for PRI-MAX 770). 500 HP electric stationary unit.
Maintenance requirements:	Stationary electric units cost about $1 per ton to maintain, including routine maintenance, checkouts, hard-facing of cutters, and periodic shaft and cross member replacements. Hard-facing is usually performed once per month and requires two maintenance operators for two days (32 hrs).
Number of operators:	The operator who loads the feed can operate the machine remotely, plus whatever support is needed to move processed materials away from the machine; estimate 1.25 operators.
Climate limitations:	None
Support equipment:	Excavator dedicated to loading the shredder; conveyor and magnet for separating metals: $150K.
Budgetary cost of equipment:	$1.2M for complete system (shredder, drive, conveyor, and magnet) on tracks that move the equipment along with the progress of the demolition. Recommend having a spare shaft/cutter assembly on hand at $80,000 and 10 sets of cross members (cutter table) at $12,000 (for 10). **For a smaller model, the PRI-MAX 770, the cost would be $325,000. The cost of cutters and cross members would be 50% lower than those used for the 6000 model.**
Cost of major overhaul:	Replacement or rework of shaft; $80K, plus replacement of cross members $12K; required every 2 years if routine hard-facing is performed. Assume shaft replacement takes two operators two days (same as hard-facing).
Typical downtime %:	Stationary electrically driven units are less maintenance intensive and experience about 10% downtime. Mobile diesel powered unit's experiences about 25% downtime.
Space required:	Feed hopper 224" L × 94" W × 43" H, plus conveyor and drive engine.
Fuel consumption and electrical requirements:	$16/hr electric at 7 cents per kW-hr. 18 gal/hr diesel fuel or $72/hr at $4/gal diesel.
Other:	Recommends using a concrete crusher instead of (or in addition to) the PRI-MAX if the total fraction of concrete and masonry is over 10% of the total. Recommended ***Eagle*** crusher manufacturer.

Vendor:	Shred-Tech Corporation, Cambridge Ontario, Canada (www.shred-tech.com)
Equipment Model:	Shred Tech ST500 Transportable Shredder
Application:	Truck tires, magnesium castings, municipal/industrial waste, pallets, wood waste, copper and steel wire and cable, scrap aluminum, etc.

Material preparation requirements:	Limited by size of hopper only; 115” L × 69” W × 40” D.
Processing capacity:	6-20 tons per hr depending on material.
Power	500 HP diesel mobile unit.
Maintenance requirements:	Routine cutter maintenance is usually performed once per month and requires two maintenance operators for two days (32 hrs).
Number of operators:	Estimate 1.25 operators.
Climate limitations:	None
Support equipment:	Conveyor included in price. Separate excavator would be used to load feed.
Budgetary cost of equipment:	$1,032,640 for shredder, drive, and conveyor.
Cost of major overhaul:	Replacement or rework of shaft; assume $40K,
Typical downtime %:	Mobile diesel powered unit’s experiences about 25% downtime.
Space required:	60 ft × 8.5 ft for feed hopper plus conveyor and drive engine.
Fuel consumption and electrical requirements:	Estimate 12 gal/hr diesel fuel or $48/hr at $4/gal diesel.

Vendor:	Eagle Crusher, Galion, Ohio
Equipment Model:	UltraMax 1000-15CV
Application:	Demolition concrete and brick with reinforcement steel

Material preparation requirements:	Reduce to 24" cube using excavator.
Processing capacity:	Up to 160 tons/hr.
Power	375 HP with power upgrade to allow the addition of conveyor and screens.
Maintenance requirements:	Routine oil and filter change-outs for drive engine; rotation of wear plates.
Number of operators:	0.5 FTE operator (same operator who feeds with excavator).
Climate limitations:	None
Support equipment:	Conveyor, screens (if needed to produce a specific size material).
Budgetary cost of equipment:	$456,400 (mobile unit including conveyor, magnetic separator, and 175 HP auxiliary generator).
Lease option	$25,000 per month plus conveyor for $2000 per month.
Cost of major overhaul:	Blow bars and wear plates require rotation or replacement periodically. Blow bars typically require replacement after every 20,000 tons of processed material. Blow bars cost $3,300 per set. Wear plates may require rotation or replacement every 80,000 tons of material processed. Wear plates cost between $100 and $400 each. There are many wear plates, but only about 6 require replacement. Takes about 4 hrs to replace blow bars, and about 1 hr to replace or rotate wear plates.
Typical downtime %:	80% availability.
Space required:	620 ft^2 with conveyor.
Fuel consumption and electrical requirements:	About 10 gal/hr diesel fuel.
Operating cost:	$1.85 per ton if operated at high production rate (240,000 tons per year); $4 per ton when operated by feeding with an excavator. (Includes fuel, maintenance, periodic replacement of blow bars and wear plates, and cost of capital).
Other:	Open-circuit allows for production of material that does not have to meet a particular specification, allows for 90% within a particular size range. Closed-circuit operation produces material within a specified size range using screens. Unique feature by Eagle includes uniformly designed wear plates that can be rotated to provide uniform wearing and extended life.

Vendor:	Rubble Master
Equipment Model:	RM100 (Crusher)
Application:	Demolition concrete rubble with rebar

Material preparation requirements:	Reduce size of concrete to 12 – 16 inches to reduce bridging and downtime for repositioning. Reduce rebar length to 6 ft of less.
Cost of repairs:	Major overhauls start after 1000 hrs; you can add \$ 0.15 per ton thereafter. For example : 100 tons per hr × \$ 0.15 per ton × 800 hrs per year = \$12,000.00.
Number of operators:	1 FTE Operator and a Mechanic one day per week
Climate limitations:	None
Support equipment:	Includes conveyor.
Budgetary cost of equipment:	\$500,000 for new machine, used machine at 300 hrs for \$460,000.
Maintenance requirements:	Lubrication, grease, minor; air filters; periodic oil change; etc.
Typical downtime %:	8% (2 out of 12 hrs); possibly 500 – 1000 hrs operations before major overhaul needed.
Space required:	30 ft × 8 ft.
Cost of operating:	Operating cost for an RM60 is \$ 0.20, RM70 is \$ 0.30, RM80 is \$ 0.40 and a RM100 is \$ 0.50 per ton, this includes fuel, wear, oil, filters and grease.
Fuel consumption and electrical requirements:	5-6 gal/hr diesel, no electrical requirements.
Other:	U.S. distributer: HMI.

Vendor:	Harris (equipment company)
Equipment Model:	BSH-30-2225-B Shear
Application:	K-33 Project Supercompactor; size reducing heavy gauge metal and equipment

Feed preparation requirements:	Used hand-held plasma cutters and air-arc (arc gouge) cutters to prepare materials for 26' feed box. This was the slow step of the process. The shear operators spent a lot of time in stand-by waiting for material to process. Air-arc cutters were much faster than the plasma cutters, but were much louder due to the use of compressed air, and also emitted a large shower of sparks during operation. This was acceptable for cutting converter vessels because sparks were contained within the vessel. Feed box was 26 ft long and throat width was 5 ft, allowing cut width of 2-5 ft. Longer boxes are available, up to 40 ft.
Maintenance requirements:	Rotating and replacing knife blades and greasing the equipment and support systems occupied 6 personnel in two 12-hr shifts, once per month. There are three blades with four cutting edges each. Each blade is about 6 inches thick and weighs 900 lb. Three sets of blades are replaced per year at about \$10K per set (total \$30K/yr). The largest maintenance cost was in replacing hydraulic fluid pumps due in part to the use of a low flash point fluid (Quinter Lubric 822 by Quaker State). There are seven pumps total and they had to be replaced twice during the operation at about \$15K each (total \$210K). The fluid cost was \$20/gal + \$6/gal for disposal of contaminated fluid. The fluid has to be replaced twice (5,000 gal ea. total cost \$130K). The type of pump used (piston pump) was used in order to provide a slightly increased cutting power for the unit. For a slightly lower power requirement, vane pumps could have been used and would have been less expensive to operate. The normally used fluid AW46 hydraulic fluid costs about \$5/gal. Fluid replacement is usually no more frequent than once every 2 years. It can be filtered and re-used in the unit for up to 10 years.
Number of operators:	To operate the shear requires on person at the controls, one person to provide feed, and 3 persons to manage the product which involves moving the intermodals into place, distributing the product in the intermodal, and managing the filled intermodal. Intermodals were frequently punctured during loading due to the size, weight, and shape of the metal pieces. The intermodals were placed on a stand after filling and patched as necessary. Placing flat sheets of metal (waste material) in the bottom of the intermodals prior to loading helped reduce punctures.
Installation:	About 6 months required to assemble the shear (with a lot of down time due to DOE work process). Total weight of all components was about 550-600 tons with several components weighing 100 to 125 tons, others from 35 to 95 tons each; about 7 or 8 main components. Unit was assembled by C. Reed Davis.
Support equipment:	Track hoes used to rake/distribute material within intermodals. Intermodals did not have full-open lids, making it difficult to distribute material in the container. System included 4 air-cooled oil coolers mounted on roof about 85 ft above the shear.

Budgetary cost of equipment:	$6,800,000
Typical downtime %:	25%
Fuel consumption and electrical requirements:	Electricity costs equivalent to about 1,660 horsepower (7) 200 HP main motors; (1) 100 HP pilot motor, (4) 25 HP cooler pump motors, (4) 15 HP cooler fan motors.
Other:	Mobile units are now available, manufactured overseas called Eco Techna. Available in diesel or electric powered. Energy*Solutions* has a machine at their facility in Kingston. Cutting power is about 500 to 700 tons compared to 2225 tons for the K-33 unit. Would not be capable of handling the materials processes in the K-33 project. Mobile units are not powerful enough to handle the materials processed at K-33. Mobile units have a 2 ft throat that would limit ability to fold material. Not enough power to fold to get through throat. Much more prep work to feed the cutter. Length limit for feed box is 22 ft. long, some smaller, 15-22 ft range. Probably could not fold machining equipment such as drill presses, lathes, mills, etc. Cast iron for these machines would break and not cut. Mobile units typically weigh 80,000 lb or more and are limited to thickness of 1.5 to 2 inches (without folding). Ton per hr rating should be considered a very high end maximum as it is typically limited by the speed required to prepare materials for the feed box. For adequate power, recommend 1,100 lb stationary machines are available that can be moved, but would probably require 60 days to move in the DOE environment. They require a solid concrete foundation, but no piers. Most are diesel powered. Had trouble using these machines for cutting aluminum and copper. Aluminum would gall and foul machine moving parts and cause them to stick.

APPENDIX B - ATTACHMENT B:
VOLUME REDUCTION PROCESSING COST ESTIMATE

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Table B-21. Basis for Size Reduction Cost Estimate

Basis for Estimate		
Volume (yd^3)	**Weight (tons)**	**Description**
483,723	560,761	Total concrete and demolition debris for processing, yd^3
118,738	86,281	Total for shredding
364,985	474,480	Total for crushing

Table B-22. Cost Data for Shredder Operation

Shredder Summary Information		
Parameter	**Data**	**Basis**
Manufacturer	SSI Shredders	
Model	PRI-MAX 770	
Capacity	25 Tons/hr max	Based on vendor estimated capacity for C&D waste.
Capital Cost	$325,000	E-mail quote from SSI, June 2011.
Transportation and Setup	$10,500	Assume $5K to transport; SSI tech support for 40 hours at $100/hr plus airfare and per diem of $1,500.
Operating hours	8,628	10 tons per hr.
Fuel	$224,330	6.5 gal/hr diesel fuel or $26/hr at $4/gal diesel (based on direct scaling from 700 HP to 250 HP diesel).
Maintenance: Hard-facing of cutters and routine checkout.	$121,872	Hard-facing is usually performed once per month and requires two maintenance operators for two days (32 hrs); oil/filter change requiring 2 operators for 2 hrs every 200 hrs + 1/2 hr/day checkout.
Major overhaul	$179,600	At full-time operations (2000 hr/yr), replacement or rework of shaft; $40K, plus replacement of cross members $5K; required every 2 years if routine hard-facing is performed. At 4884 hrs total, assume overhauled three times during the life of the equipment. Assume labor is the same as hard-facing requirement. This also includes $35,000 for a major engine overhaul.

Table B-23. Cost Data for Crusher Operation

Crusher Summary Information		
Parameter	**Data**	**Basis**
Manufacturer	Eagle Crusher	
Model	UltraMax 1000-15CV	
Capacity	150 tons per hr	Product particle size would be 85-90% < 2 inch. Capacity would be 125 tons/hr for product size < 1 inch.
Capital Cost (2 units)	$456,400	Quote from Eagle Crusher.
Transportation and Setup	$10,500	Assume $5K to transport; Eagle Crusher tech support for 40 hours at $100/hr with airfare and per diem ($1,500).
Operating hours	9,490	50 tons per hr.
Fuel	$379,584	10 gal/hr diesel fuel or $40/hr at $4/gal diesel.
Maintenance: Changing oil and filters; rotation of wear plates.	$41,145	Rotation of wear plates every 80,000 tons of material processed, requires two maintenance operators for 4 hrs (8 hrs) + oil/filter change requiring 2 operators for 2 hrs every 200 hrs + 1/2 hr/day checkout.
Major overhaul	$132,862	Blow bars typically require replacement after every 20,000 tons of processed material. Blow bars cost $3,300 per set. Wear plates may require rotation or replacement every 80,000 tons of material processed. Wear plates cost between $100 and $400 each. There are many wear plates, but only about 6 require replacement. Takes about 4 hrs to replace blow bars, and about 1 hr to replace or rotate wear plates. Also includes $35,000 for a major engine overhaul.

Table B-24. Cost Data for Excavator Operation

Excavator Summary Information		
Parameter	**Data**	**Basis**
Manufacturer	Volvo	
Model	2010 VOLVO ECR235C	
Capacity	7.5 ton	
Capital Cost (4 units)	$814,000	Source of cost information: McAllister Equipment Company,. Anticipate needing five excavators at $203,500 each over the course of the operation; priced June 2011.
Transportation and Setup	$31,200	Assume $5K to transport; Volvo tech support for one week at $100/hr with airfare and per diem ($1,500) for two units.
Operating hours	36,235	Combined hrs for shredder and crusher.
Fuel	$724,708	5 gal/hr diesel fuel or $20/hr at $4/gal diesel for 150 HP diesel engine.
Maintenance: Changing oil and filters; inspections	$149,471	Oil/filter change requiring 2 operators for 2 hrs every 200 hrs + 1/2 hr/day checkout.
Major overhauls	$160,000	Five major engine overhauls.

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APPENDIX C:
TREATMENT AND DISPOSAL OPTIONS FOR MERCURY-CONTAMINATED WASTE

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CONTENT

TABLES

FIGURES

ACRONYMS

ARARs	Applicable or Relevant and Appropriate Requirements
CAMU	Corrective Action Management Unit
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
D&D	deactivation and decommissioning
DOE	U.S. Department of Energy
EMDF	Environmental Management Disposal Facility
EMWMF	Environmental Management Waste Management Facility
EPA	U.S. Environmental Protection Agency
FY	fiscal year
IMERC	incineration of mercury waste
LDR	land disposal restriction
ORR	Oak Ridge Reservation
PW	process waste
RCRA	Resource Conservation and Recovery Act of 1976
RI/FS	Remedial Investigation/Feasibility Study
RMERC	retort of mercury waste
S/S	solidification/stabilization
TCLP	Toxicity Characteristic Leaching Procedure
U.S.	United States
WCS	Waste Control Specialists
WEMA	West End Mercury Area
Y-12	Y-12 National Security Complex

1. INTRODUCTION

The purpose of this Appendix is to describe options for treatment and disposition of mercury-contaminated mixed waste debris to be generated by Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) response actions on the Oak Ridge Reservation (ORR). Mercury is a major contaminant of concern for wastes that will be generated in the cleanup of Y-12 National Security Complex (Y-12). These wastes will include debris from demolition of four mercury process facility complexes at Y-12 and contaminated soils and sediment generated by the corresponding remediation projects.

Debris and soil/sediment waste having levels of mercury contamination below 40 CFR 268 regulatory limits for land disposal (i.e., upon characterization, result in less than the maximum Toxicity Characteristic Leaching Procedure [TCLP] waste extract concentration for mercury, 0.2 mg/L) are not considered hazardous and do not require treatment for disposal; however, there may be a measureable amount of mercury in this waste. Among wastes that *do* require treatment for the mercury toxicity characteristic prior to disposal, this evaluation considers only demolition debris because disposal of this waste stream will require special consideration in terms of its future management and disposition (see Sections 5.1.4 of this Remedial Investigation/Feasibility Study [RI/FS]). However, as a basis and assumption for the alternatives considered in this RI/FS, mercury debris treatment is assumed to be managed by the demolition contractor (Project scope), and therefore the On-site Disposal Alternative "receives" this waste in a form that meets land disposal restrictions (LDRs). For the Off-site Disposal Alternative, mercury-contaminated debris is assumed to be transported to the disposal facility (either Energy*Solutions* in Clive, Utah or Waste Control Specialists (WCS) in Andrews County, Texas). Either of those facilities are capable of performing treatment for mercury, but again the assumption is that the demolition contractor is responsible for the treatment in terms of cost and location. Thus the off-site costs for this waste stream only incorporate transportation and disposal costs (e.g., waste may or may not meet LDRs when it is transported), regardless of where or how the waste is treated. Hybrid disposal is a combination of the on- and off-site alternatives.

For mercury-contaminated soils requiring treatment, the On-site Disposal Alternative assumes that treatment to remove or immobilize mercury is the responsibility of the project that generates the waste. For off-site disposal, the assumption applies as for debris, that the soil treatment is the responsibility of the waste generator/remediation contractor, and is therefore not considered further in the alternative (e.g., only transport and disposal is covered by the cost estimate). Additional information regarding treatment standards and techniques applicable to mercury-contaminated soils is provided in Section 2 of this appendix.

Based upon available characterization data and waste volume estimates (see RI/FS Chapter 2, and Appendix A), approximately 381,000 yd^3 of debris are anticipated to be generated from demolition of mercury-process facilities at Y-12. As much as 150,000 yd^3 of this debris (including uncertainty) have been estimated to potentially meet the definition of hazardous or mixed waste based on the mercury toxicity characteristic and would require treatment for land disposal. Current planning for mercury facility demolition includes extensive decontamination efforts to minimize the volume of debris requiring treatment (DOE 2014). In terms of volume, mixed waste soils were not differentiated from low level waste soils under the assumption that treatment would be provided and funded by the generator/remediation contractor, and in any case, treatment of soils would not be accomplished at any disposal site, on- or off-site.

The following sections address the regulatory treatment standards for mercury-contaminated wastes, as well as discusses methods for treatment and treatment combined with disposal for debris.

2. TREATMENT STANDARDS AND TECHNOLOGIES FOR MERCURY-CONTAMINATED WASTE

The Resource Conservation and Recovery Act of 1976 (RCRA) identifies hazardous wastes that are restricted from land disposal unless contaminant-specific treatment standards are met. These LDRs (40 CFR 268) specify the limits (treatment standards) for hazardous constituents in treated wastes or waste extracts, or specify a Technology-Based Standard for treatment.

The LDR treatment standards for non-wastewaters that exhibit or are expected to exhibit the toxicity characteristic for mercury depend on the total mercury concentration in the waste and the types of waste materials present. The threshold for mercury toxicity specified in 40 CFR 261.24 is a TCLP waste extract concentration of 0.20 mg/L (EPA SW-846, Method 1311). The 40 CFR 268.40 treatment standards for high mercury content wastes (≥ 260 mg/kg total mercury) are technology-based and include incineration (IMERC) for waste including organic constituents, and retorting or roasting (RMERC) in a thermal processing unit for inorganic wastes (including RMERC residues). For low mercury content wastes (<260 mg/kg total mercury, including IMERC residues) the treatment standard is a maximum TCLP waste extract concentration of 0.025 mg/L (or 0.20 mg/L for RMERC residues). These treatment standards apply to both soil and debris waste forms, unless alternative treatment standards for hazardous debris at 40 CFR 268.40 are used as the basis for LDR compliance (EPA 2003). For liquid (elemental) mercury with or without radionuclide contamination, the technology-based treatment standard is amalgamation, an immobilization process that creates a more physically stable solid or semi-solid mercury amalgam.

Contaminant immobilization by chemical formation of an insoluble compound (stabilization), coupled with solidification provided by a binding agent (e.g., Portland cement) can be an effective means of meeting treatment standards for hazardous metals. Formation of highly insoluble mercuric sulfide (HgS) is desirable for geochemical stabilization of mercury. However, due to the relatively high solubility of some other mercury compounds, effective stabilization and solidification (S/S) of mercury-contaminated wastes using traditional methods has proven to be challenging (SAIC 1998). Mixed low-level wastes containing mercury can present additional technical challenges related to radioactive constituents.

Since the 1990s, there has been substantial research and technology development for treatment of mercury-mixed wastes, primarily focused on radioactive elemental mercury and mercury-contaminated sludges, soils, and soil-like waste forms (Klasson et al. 1997; Mattus 2001; Morris and Hulet 2003; Perona and Brown 1993, EPA 2007). Several technology demonstration campaigns involving the United States (U.S.) Department of Energy (DOE) National Laboratories (e.g., Adams et al. 2001; Gates et al. 1995; Kalb et al. 2001; Mattus and Mattus 1994; Mattus 2001; Osborne-Lee et al. 1999) and private industry (e.g., ATG 1998, 2000, 2001; DOE 1999a, 1999b, 1999c, 1999d; NFS 2001; UCOR 2012) have identified S/S techniques that can successfully meet mercury TCLP standards for land disposal of treated waste. For Y-12 soils that require mercury treatment for disposal, the RI/FS assumes that individual remedial action projects/contractors will utilize one of these proven technologies (e.g., immobilization with sulfur-based polymers) prior to sending the waste for disposal, and therefore a particular treatment process for soils is not specified as an element of the alternatives examined.

For debris-type waste, effective S/S to immobilize mercury can be more difficult than for soil-type wastes that are easier to mix with the stabilizing and binding agents. In 1992, the U.S. Environmental Protection Agency (EPA) issued technology-based alternative treatment methods and standards for hazardous and mixed waste debris in recognition of the technical challenges of treating debris-like materials (EPA 2003). These treatment alternatives for hazardous debris offer flexibility and potential cost savings as compared to the original LDR treatment processes and standards. The alternative treatment standards for debris, 40 CFR 268.45, include three technology groups: (1) extraction (physical and chemical), (2) destruction (biological and chemical), and (3) immobilization (macroencapsulation, microencapsulation, and sealing). Destruction technologies are not applicable to hazardous metals such as mercury.

3. TREATMENT TECHNOLOGIES FOR MERCURY-CONTAMINATED DEBRIS

For mercury-contaminated debris that is considered hazardous (D009) according to the TCLP toxicity threshold of the LDRs, potentially effective treatment technologies include thermal extraction and recovery (including RMERC and thermal desorption), liquid-phase chemical extraction, and immobilization methods. For mixed low-level radioactive debris that requires treatment for mercury, thermal and chemical extraction methods typically generate secondary radioactive waste streams (both liquid and gaseous), are costly due to the pre-treatment requirements and high energy usage, and generally applied only to smaller volumes of waste. Immobilization methods such as macroencapsulation, which may incorporate mercury S/S as part of the treatment process, are arguably the most practically applicable treatment technology for large volumes of mercury-contaminated demolition debris.

Of these possible treatment technologies, the only feasible option for treatment of D009 debris directly at a disposal facility would be immobilization by macroencapsulation. Macroencapsulation can be accomplished outside of the landfill footprint and the stabilized form moved into the landfill footprint for final disposal, or it can be accomplished “in-cell” as an integral part of the disposal. As well, macroencapsulation could be accomplished at the project/demolition site prior to the waste being disposed, requiring transport of the macroencapsulated waste to the disposal facility.

Other treatment options, including thermal extraction and chemical extraction processes are viable options for treatment of mercury-contaminated waste, but are not practical options to implement at an on-site disposal facility due to the much more involved processing required. These options are best accomplished prior to delivery of the treated debris to a disposal facility due to the complicated unit operations required, secondary waste generation, and validation required to meet regulatory requirements. While all these options are viable treatment methods for mercury-contaminated waste, the decision on which treatment to apply for a particular debris waste stream (e.g., equipment, walls, tiles, etc.) will depend on several factors such as material characteristics, levels of contamination, consideration of worker exposure, etc. and will be the responsibility of the generating contractor (i.e., the demolition contractor). Selecting any of the options for treatment, with the exception of macroencapsulation at the disposal facility, necessarily means the waste is treated prior to transporting it for disposal for the reasons stated above. Therefore, only immobilization by macroencapsulation is considered as a treatment process that may be combined with disposal.

Liquid mercury that is recovered during pre-demolition and demolition operations at the project site is considered elemental mercury, and must be treated by amalgamation (per 40 CFR 268.40). This type of treatment is provided by commercial vendors, and the waste would be managed off-site.

Figure C-1 is a flowchart illustrating the management of mercury-contaminated debris, which demonstrates that decisions regarding proposed treatment reside on the demolition project side. As indicated in Figure C-1, only macroencapsulation is an option that can be incorporated as part of disposal of this waste. As the only viable treatment that may be combined with, and performed by, a disposal facility, further discussion and information on this process is given in the following sections.

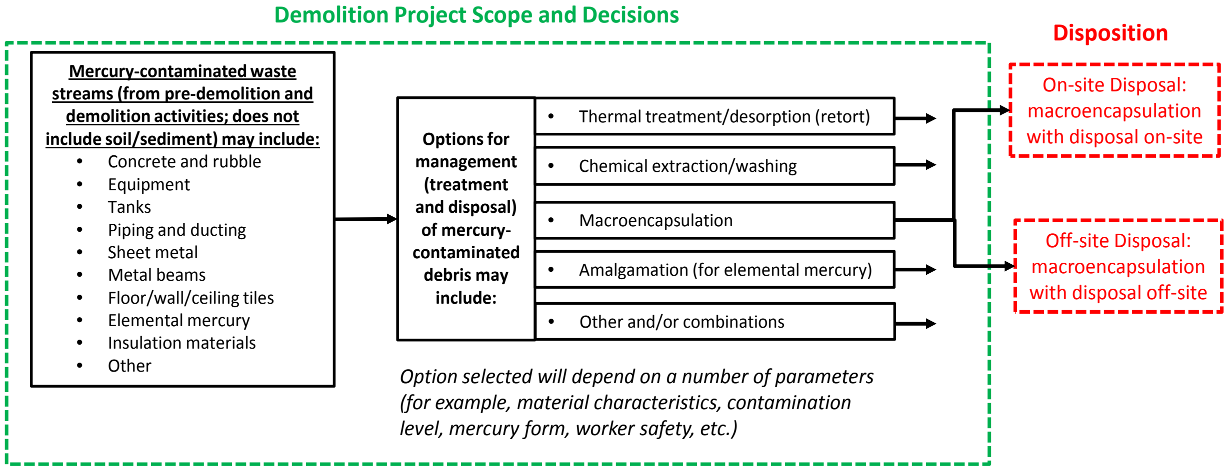

Figure C-1. Management of Mercury-Contaminated Debris; Integrated Treatment and Disposal

3.1 ENCAPSULATION

Encapsulation is a general technique for physical immobilization of hazardous constituents by enveloping a waste in a low-permeability material to limit exposure to leaching agents and reduce leachability of treated waste. For soil-like wastes, encapsulation by mixing with a binding agent to produce a relatively homogeneous solid in which the waste is well dispersed throughout the encapsulation matrix is termed *microencapsulation*. Microencapsulation is a form of contaminant stabilization that typically employs cementitious binders (Portland cement or pozzolan-lime mixtures) to solidify and stabilize waste. This type of treatment may include various additives to improve compressive strength or enhance set/cure time, or chemical stabilization agents to reduce the leachability of contaminants. Although microencapsulation has been applied to mercury-bearing wastes, the effectiveness of traditional cementitious binders for stabilization of elemental mercury or highly soluble mercury compounds may be limited (SAIC 1998).

Encapsulation of hazardous *debris* with cementitious binders qualifies as microencapsulation under the treatment standards for hazardous debris at 40 CFR 268.45, although some sources refer to all techniques that encase (without mixing) bulk waste materials within a solid, stabilizing matrix as *macroencapsulation* (e.g., SAIC 1998). In general, macroencapsulation refers to the enclosure or encasement of a bulk mass of waste within an impermeable solid barrier. The treatment standards for hazardous debris define macroencapsulation as "*Application of surface coating materials such as polymeric organics (e.g., resins and plastics) or use of a jacket of inert inorganic materials to substantially reduce surface exposure to potential leaching media*". The corresponding performance standard for macroencapsulation is "*the encapsulating material must completely encapsulate debris and be resistant to degradation by the debris and its contaminants and materials into which it may come into contact after placement (leachate, other waste, microbes)*" 40 CFR 268.45, Table 1.

3.2 MACROENCAPSULATION TECHNIQUES

Treatment by macroencapsulation typically involves enclosing waste in a reinforced bag or rigid container made of inert, low-permeability materials or encapsulation by pouring an encasing material (e.g., flowable fill) over and around the waste to reduce exposure to leaching media. In practice, containers are often used in combination with encasement to macroencapsulate hazardous debris. Containers may provide the macroencapsulation barrier, or simply serve to hold waste for encasement.

Encasement materials fill void space within the debris, and usually serve to immobilize contaminants as well. For mercury-contaminated wastes, encasement methods using materials and additives specifically chosen to chemically stabilize mercury (e.g., sulfur polymer cement) have been developed and tested (Mattus and Mattus 1994, SAIC 1998, DOE 1999d, Kalb et al 2001, Chattopadhyay 2004, Randall and Chattopadhyay 2004, EPA 2007).

Macroencapsulation Containers and Bags

Simply containerizing waste material is not equivalent to macroencapsulation, and the description of technology-based standards at 40 CFR 268.42 states that *"Macroencapsulation specifically does not include any material that would be classified as a tank or container according to 40 CFR 260.10."* However, stainless steel containers with welded closures have been approved for macroencapsulation of mixed waste debris in some cases (Siry 2007), and several commercial vendors offer macroencapsulation products and services that utilize rigid polyethylene containers to meet the performance standard for macroencapsulation (e.g., UltraTech Inc., Chemical Waste Management Inc). These containers are loaded with waste and sealed to prevent contact with leaching media in the disposal environment. Void spaces inside the containers are filled with a suitable material prior to final closure. Reinforced concrete containers, appropriately sealed, have also been used for macroencapsulation.

There are a few vendors that manufacture soft-sided, reinforced bags of various sizes that have been used to meet the definition of macroencapsulation. These reinforced bags, referred to as macro-bags, use inert polymeric material to reduce surface exposure to potential leachate, and are resistant to degradation from waste contaminants. PacTec manufactures a macro-bag that has been approved by Nevada National Security Site as meeting the definition of macroencapsulation for mixed-waste debris and was approved by the Tennessee Department of Environment and Conservation for use at the Environmental Management Waste Management Facility (EMWMF) (DOE 2011). The macro-bag can be placed on the inside of a rigid container and filled with waste, or placed on the outside of a rigid container already filled with waste. Treatment of debris by direct placement in macro-bags (without a container) is not recommended, due to the potential for damaging the bag and compromising the macro-barrier.

Encasement and In-Cell Macroencapsulation

There are existing companies and facilities that can macroencapsulate waste by pouring an encasing material over and around the waste, sometimes within the land disposal facility itself (in-cell macroencapsulation, which is performed at the Energy*Solutions* disposal facility in Clive, Utah and WCS in Andrews County, Texas, which performs the macroencapsulation prior to disposing of the forms in the landfill). The waste is placed in a container and/or other encasement form for encapsulation and then a flowable, cementitious grout is added to fill void spaces and solidify the waste mass. For this type of treatment process, the containers may include intermodal transport containers, standard waste containers of various sizes, or specially constructed reinforced concrete vaults. Depending on the type of container and method of grouting, the container, the encasing material, or the two in combination may constitute the macroencapsulating barrier per 40 CFR 286.45.

In some cases, standard metal containers are fitted with interior forms ("standoffs") to ensure that the encasing material completely encapsulates the waste, providing a continuous external barrier. With this technique, the encapsulating grout rather than the container provides the encapsulation barrier. This approach decreases the waste capacity of any given size container, and so potentially increases the number of containers required for treatment and disposal. With regulatory approval, this type of macroencapsulation could be completed in-cell, eliminating the need to relocate the heavy waste forms for disposal.

Containerized or uncontainerized hazardous debris may be placed into an in-cell encasement form or reinforced concrete containers and then grouted in place to accomplish in-cell macroencapsulation. Concrete containers may be smaller pre-fabricated units or larger vaults constructed in-cell. The vault or encasement form is loaded with waste and flood grouted to fill voids and stabilize contamination. Interior seams and exterior surfaces of concrete containers or vaults can be coated with sealants to ensure effective isolation of waste from leaching agents. Complete encapsulation is achieved by sealing containers or vaults with concrete covers, or by ensuring that a sufficient thickness of grout covers the upper surface of the waste. Removable vault covers may be employed to limit exposure of untreated debris, and can facilitate loading and grouting of larger vaults over extended time periods.

In-cell macroencapsulation is also possible with macro-bag and container combinations or with containers made of stainless steel or high density polyethylene where the macro-bag or container itself fulfills the macroencapsulation standard. In either of these cases, flowable fill could be used to stabilize contaminants and fill voids. A similar approach to in-cell grouting of containerized waste for stabilization purposes only (e.g., not to meet regulatory treatment standards) has been performed at the EMWMF for selected waste streams.

Chemical Stabilization and Encapsulation Materials

Materials used for waste encasement or microencapsulation can be formulated to chemically stabilize mercury contamination, reducing the leachability of mercury compounds and providing an added measure of contaminant immobilization to a macroencapsulation treatment process. Various combinations of stabilizing agents (typically sulfur compounds), binding agents (cementitious and polymeric) and encapsulation processes have been developed to improve immobilization of mercury and other contaminants in hazardous and mixed wastes (Morris et al. 2002, EPA 2007). Binding/solidifying materials tested have included polyester and epoxy resins, polyethylene, sulfur polymer cement, chemically bonded phosphate ceramics, asphalt, ceramic silicon foam, rubber, sol-gels, and traditional cementitious binders augmented with activated carbon or other proprietary agents or processes (refer to Randall and Chattopadhyay, 2004 for a review).

For mercury wastes in general, the effectiveness of chemical stabilization will depend on the chemical forms (speciation) of mercury present, the types of waste materials and other contaminants present, and the geochemical nature of the final disposal environment (moisture, pH, redox potential, etc). Developmental testing of encapsulation materials for debris have typically been small scale laboratory exercises, with limited evaluation of mercury leachability in the final waste forms (e.g., Mattus 1998). However, evaluations of encapsulated mercury-contaminated soils and sludge suggest that several different materials can be effective in meeting the RCRA treatment standard (TCLP $\leq$ 0.025 mg/L). Although the long-term performance of these mercury stabilization processes has not been systematically evaluated, it is likely that some formulation of encasement material for chemical stabilization of mercury can provide an additional, cost-effective measure of protection for macroencapsulation of Y-12 demolition debris.

Debris Macroencapsulation Summary

The most practical and effective set of macroencapsulation technologies for hazardous debris depends on the waste material characteristics and types of contamination present, in part because those characteristics impact operational and worker safety practices in waste generation, packaging, and transport. For example, very large debris/equipment items may be most easily coated with a polyurethane spray as a sealant/macroencapsulant. For process equipment that is highly contaminated with mercury, decontamination prior to treatment would be necessary to permit safe and compliant waste packaging, transport, and treatment. Thus, for mercury-contaminated debris from Y-12, a single technical approach to macroencapsulation or other treatment would not be applicable to all waste streams, and adopting an appropriate set of techniques is likely to be required.

Some treatments may be employed at the demolition site (e.g., decontamination as an example, another example would be thermal treatment to remove mercury) including some types of macroencapsulation; however, only macroencapsulation would be an option for deployment at the disposal facility. Ultimately, decisions on how best to manage the various debris waste streams will be made by the contractor performing the demolition.

Development and testing of specific materials that might be employed and specific macroencapsulation techniques used at an on-site disposal facility would be a necessary step in implementing this process. Once material and technique development is satisfactorily advanced, detailed plans for waste acceptance and operations will be required for macroencapsulation to be carried out at an on-site disposal facility. Additionally, detailed design work for an on-site disposal facility will have to incorporate the method to be employed for macroencapsulation, whether that method is to complete the treatment at a location adjacent to the disposal facility (in which case the design will have to accommodate such an operation) or provisions made (detailed calculations) to complete treatment within the footprint of the landfill via in-cell macroencapsulation. Information defining the acceptance of waste to be macro-encapsulated will necessarily need to be developed and provided to demolition contractors to aid in their decision making regarding management of mercury debris.

4. COST COMPARISON OF TREATMENT OPTIONS FOR MERCURY CONTAMINATED DEBRIS

As outlined in previous sections, macroencapsulation is a viable treatment method for mercury-contaminated debris, and is likely the most cost effective method for large scale operations in which large volumes of debris are treated. As the only method that is offered at existing off-site disposal facilities, and the only method that is feasible for incorporation into an on-site disposal facility's operations, a cost comparison of these scenarios is made here.

<u>On-site Macroencapsulation of Mercury-Contaminated Debris</u>

There are two general methods for deploying macroencapsulation on-site: (1) macroencapsulation at the disposal site, either (A) in-cell or (B) at an adjacent treatment area, and (2) macroencapsulation at the waste-generator site (demolition site). Treatment at the Environmental Management Disposal Facility (EMDF) would involve transport of untreated hazardous waste to the facility, but also permits a range of more cost-effective technical approaches compared to macroencapsulation of waste at the generator site.

Treatment methods for macroencapsulation at the EMDF might encompass all of the techniques described in Section 3.2; however, many of those technical details/techniques (e.g., materials to be used) would be determined during development work on macroencapsulation and need not be specified here. The use of macro-bags is not considered further here because of the expense involved and the possibility of breaching the bags (tearing during movement of waste); however, in some instances macro-bags may be suitable.

Development of macroencapsulation methods at the on-site facility centers on the location in which the macroencapsulation treatment is applied. In the case of in-cell macroencapsulation, containerized or uncontainerized debris would be placed into the final (in-situ) disposal location, on the cell floor prior to treatment. Possible options to implement in-cell macroencapsulation have been identified as

1. Macroencapsulation at the disposal site, either (A) in-cell or (B) at an adjacent treatment area
2. Macroencapsulation at the waste-generator site (demolition site)

Below is a summary of each of the above scenarios. Cost estimates, compared with off-site treatment and disposal, follow.

1.A. Macroencapsulation of debris within relatively large (approximately 20,000 cubic yards) concrete vaults constructed inside the disposal cell. Macroencapsulation standard would be met by the preconstructed concrete vaults and addition of controlled low strength material (CLSM) or grout added to fill voids.

This option involves constructing a large (550-ft-long, 100-ft-wide, 10-ft-high walls), open-ended, concrete vault on top of a new disposal facility liner system. Demolition debris would be placed into the vault in lifts and compacted using a dozer. After waste placement the vault would be filled periodically with CLSM to eliminate void spaces. Water collected within the vault during waste placement would be removed and treated appropriately. Ten to eleven vaults would be required to accommodate the anticipated 150,000 yd^3 of debris requiring treatment. A graphic depiction of this method is shown in Figure C-2.

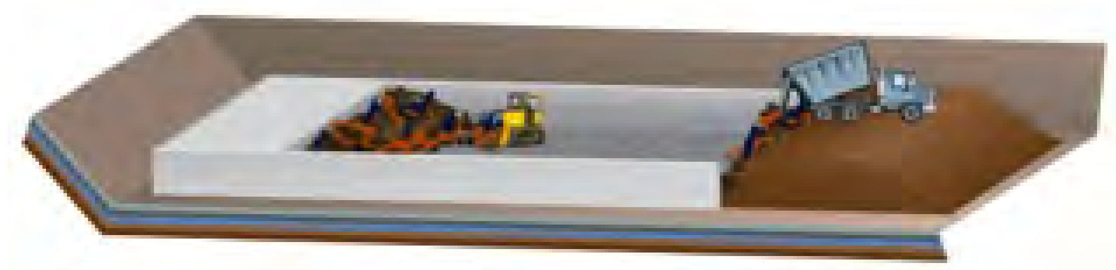

Figure C-2. Large-scale In-cell Macroencapsulation

With this option, debris would be loaded at the generator site, transported to the on-site disposal facility, and dumped at the open of the large concrete vault. A dozer would be used to place and compact the waste within the vault. This method (in-cell macroencapsulation) offers minimal requirements for size reduction at the generator site and the most compaction within the disposal facility. If vaults or forms are constructed that are smaller in size, the cost would be somewhat higher (as was assumed in the previous version of this RI/FS).

1.B. **Encasement of debris within Sealands at a location adjacent to cell, but out-of-cell.** In this method, the macroencapsulation standard is met by either macro-bags external to the sealand providing encapsulation, or pallets within sealand providing space for flowable grout to encapsulate debris. This method involves loading debris into top loaded Sealand containers at the generator site. These Sealands would be modified with plastic pallets around the edge prior to loading to allow the CLSM to flow around the debris. Conversely, macro-bags could provide the macroencapsulation standard.

The debris-loaded containers would be shipped to the disposal facility and filled with CLSM outside of the disposal cell. Lining the Sealands with plastic pallets would allow the CLSM to completely encapsulate the debris and eliminates the need for macro-bags. The addition of the plastic pallets reduces the usable volume of the Sealand. After the CLSM has cured, the containers would be placed in the disposal facility cell. This option would require the purchase of approximately 12,165 Sealand containers.

2. **Macroencapsulation at the waste-generator site**. This method would include size-reduction of debris at the generator site to fit into a B-25 container. The container is filled with CLSM and enclosed with a macro-bag at the generator site. Once the CLSM has cured the container is transported to the disposal facility and placed in the disposal cell.

Significant waste handling and size reduction would be required at the generator site. The generator site would also need to be equipped with a batch plant to produce the CLSM and a staging area for the B-25s while curing. This option significantly increases the waste disposal volume due to the size reduction required for the debris to fit into the B-25 and the lack of compaction. This scenario would require the purchase of approximately 121,200 B-25 boxes.

Small containers filled with CLSM and placed in macro-bags at the generator site is estimated at $333 M. The cost estimate for this option only includes costs for the containers, macro-bags, and CLSM. Costs associated with the additional size-reduction equipment and personnel that would be required, as well as transportation of the containers to the disposal facility would substantially increase this estimate.

Either location approach in (1) above for performing macroencapsulation at the EMDF will require a regulatory strategy allowing relief from the 40 CFR 268 Subpart C placement prohibitions on land disposal for mercury toxicity characteristic hazardous waste. Details on the possible regulatory approach are given in Section 5, *Regulatory Approach for Macroencapsulation.* The approach outlined in (2) above will require designation of an Area of Contamination to proceed with the treatment at the disposal site.

Final determination of the appropriate materials and specific operations for on-site macroencapsulation of specific waste streams is beyond the scope of this analysis, and is subject to regulatory approval according to the *Federal Facility Agreement for the Oak Ridge Reservation* (DOE 1992). Selection of appropriate macroencapsulation methods and materials will require consideration of worker health and safety factors, short- and long-term risks to the environment, efficiency in utilizing available disposal capacity (ratio of as disposed waste volume to as-generated volume), and requirements for mercury vapor suppression, secondary waste management (e.g., contact water), and decontamination of equipment.

Off-site Macroencapsulation of Mercury-Contaminated Debris

In terms of off-site disposal, mixed wastes including mercury-contaminated debris could be treated at off-site disposal sites using methods and technologies approved at those sites, including macroencapsulation. Treatment and disposal of mixed waste at Energy*Solutions* in Clive, Utah and WCS in Andrews County, Texas is currently performed. Both facilities have the necessary permits and have been approved to provide mixed waste treatment and disposal for CERCLA waste. Vendor quotes for the treatment and disposal of those wastes were obtained, and were averaged to result in a single cost for comparison with on-site estimated costs. The following assumptions were utilized in determining a final estimate for off-site treatment and disposal of mercury-contaminated debris:

- Macroencapsulation is the assumed waste treatment for mercury-contaminated debris disposed at Energy*Solutions* or WCS.
- Waste treatment/disposal fees for Energy*Solutions* or WCS are based on the actual volume shipped in the container and not on the total container volume.
- Energy*Solutions* and WCS provided vendor estimates for the treatment and disposal of mercury-contaminated debris. Those quotes were for 100,000 yd^3 of waste. The quotes were adjusted to account for the higher volume in this RI/FS (that volume is ~ 150,000 yd^3).
- The WCS quote did not include packaging. This was added into their quote. Both quotes included transportation.
- The two quotes were averaged for a final estimated cost to package, transport, treat, and dispose of 150,000 yd^3 of mercury-contaminated waste. The quotes were given in fiscal year (FY) 2014 dollars. The quotes were de-escalated to obtain FY 2012 dollars. A value of $216,740,474 was calculated as an average of the two quotes.

Table C-1 contains the cost estimates for on- and off-site treatment and disposal of mercury-contaminated debris.

Table C-1. Cost Comparison of On-site Treatment/Disposal Methods and Off-site Treatment/Disposal for 150,000 yd^3 of Mercury-contaminated Debris (FY 2012 dollars)

Cost Element	On-site Macroencapsulation Treatment & Disposal Methods [a]			Off-site Treatment and Disposal Estimate
	In-cell (at Disposal Site)	Out-of-Cell (at Disposal Site)	Demolition Contractor	
Project Management and Other Costs	$ 2,958,628	$ 2,407,084		
Capital Cost	$ 590,190	$ 1,353,905		
Operations Cost	$ 34,514,583	$ 187,085,482	$ 273,369,683	
Subtotal	$ 38,063,401	$ 273,369,683	$ 273,369,683	$ 216,740,474
Contingency [b]	$ 8,373,948	$ 41,986,224	$ 60,141,330	$ 58,519,928
Total	**$ 46,437,349**	**$ 232,832,695**	**$ 333,511,013**	**$ 275,260,402**

[a] In the D3 RI/FS, an ~$80 M on-site estimated cost was given for medium-scale in-cell macroencapsulation of mercury-contaminated debris. Here, the in-cell macroencapsulation is performed in large vaults.

[b] Contingency assumption, 22% for on-site methods and 27% for off-site treatment/disposal. See Appendix I of the RI/FS for an explanation of contingencies applied.

In addition to cost, many considerations must be made in selecting a method to apply to treat mercury-contaminated debris. A few considerations are noted here.

- **Feasibility and Performance of Macroencapsulation Techniques**: Including the specific products, materials and processes utilized for waste encasement/stabilization and macroencapsulation, as well as the relative risk of macro-barrier failure or damage prior to disposal, consistency of performance (quality control), and anticipated long-term performance of the macro-barrier.
- **Potential for Release of Mercury or Other Contaminants Prior to Waste Treatment**: Including potential air and surface water pathways during transport and/or prior to treatment, as determined by factors such as waste container specifications, frequency of applying vapor suppression agents and/or soil cover prior to treatment, and the duration of exposure of untreated waste (batch volume and frequency of debris macroencapsulation).
- **Interim management of waste**: Including possible storage of waste required.
- **Worker Health and Safety Requirements**: Including personal protective equipment (e.g., respirators) and requirements for medical surveillance of personnel. Protectiveness to worker considering method of treatment and operations required.
- **Requirements for Size-reduction of Debris by the Waste-generator.**
- **Requirements for Management of Secondary Waste**: Primarily liquids, including elemental mercury recovery, decontamination effluents and contact water resulting from precipitation on exposed, untreated debris.

- Environmental Monitoring Requirements.
- **Efficiency of Disposal Cell Volume Utilization** ("waste loading," or the ratio of waste volume as-disposed to as-generated volume).

Each of these general considerations have potential impacts on project risks and costs for the waste generator and/or waste disposal facility risks and costs, and these impacts depend on the particular macroencapsulation techniques used and risk mitigation measures employed. In selecting a debris treatment method, a primary consideration of this type is the tradeoff between risk and cost related to the need for and size of waste containers. In-cell macroencapsulation by large-scale, in-situ encasement of bulk debris transported to the disposal facility in trucks eliminates the cost of waste containers, reduces the need for debris size-reduction at the demolition site, does not require difficult movement of extremely heavy stabilized waste forms, and permits more efficient use of disposal cell volume all at a much lower cost. This cost advantage would be partially offset by the cost of mercury vapor suppression or other measures to mitigate risks of contaminant release during transport or unacceptable worker exposure during waste treatment, prior to completion of macroencapsulation.

5. REGULATORY APPROACH FOR MACROENCAPSULATION AT AN ON-SITE FACILITY

An on-site disposal facility as proposed in this RI/FS is subject to RCRA. LDR regulations at 40 CFR 268 require that hazardous wastes, including those that are hazardous by characteristic, be treated prior to placement in a land disposal unit. Macroencapsulation could be performed within the EMDF cells or locally near the cells to enhance operational control, staging, and safety, and to reduce treatment costs. This approach constitutes "placement" prior to LDR treatment standards for the debris having been met. This on-site CERCLA remedial response action must comply with the substantive requirements of RCRA when they are determined to be applicable or relevant and appropriate requirements. As stated, RCRA LDRs do not allow placement of a RCRA hazardous waste (e.g., mercury-contaminated debris as is expected to result from the demolition of Y-12 mercury-use facilities) in a disposal facility (on the land) until the applicable treatment standard has been met.

Designation of the disposal area (or treatment area, if treatment is not performed in the disposal area footprint) as a Corrective Action Management Unit (CAMU) is the preferred regulatory path to allow macroencapsulation at a future on-site disposal facility (40 CFR 264.440 et seq.). To be designated as a CAMU, several substantive requirements must be met. First and foremost, the waste to be managed must be considered CAMU-eligible. Per 40 CFR 264.552(a)(1)(i) all solid and hazardous wastes, and all media (soils, ground & surface water, sediments) and debris that are managed for implementing clean-up may be considered as CAMU-eligible waste. As a CERLCA cleanup waste, mercury-contaminated debris that will result from the demolition of Y-12 facilities is CAMU-eligible.

As noted in the CAMU regulations, placement of CAMU-eligible wastes into or within a CAMU does not constitute land disposal of hazardous wastes [40 CFR 264.552(a)(4)]. Upon completion of macroencapsulation, however, the debris would meet all LDR requirements.

Upon meeting the substantive requirements stated in the CAMU regulations, a CAMU designation would be granted for a CERCLA remedy in a Record of Decision or other such decision document.

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APPENDIX D:
ON-SITE DISPOSAL ALTERNATIVE SITE SCREENING

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CONTENTS

FIGURES

TABLES

ACRONYMS

BCBG	Bear Creek Burial Ground
BCV	Bear Creek Valley
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CCE	Country Club Estates
DOE	U.S. Department of Energy
EBCV	East Bear Creek Valley
EMDF	Environmental Management Disposal Facility
EMWMF	Environmental Management Waste Management Facility
GPC	Groves Park Commons
KC	Knox County
M yd^3	million cubic yards
NT	Northern Tributary (to Bear Creek)
ORR	Oak Ridge Reservation
RI/FS	Remedial Investigation/Feasibility Study
RO	Rarity Oaks
ROD	Record of Decision
SR	State Route
T	Tuskegee
SWSA	Solid Waste Storage Area
UEFPC	Upper East Fork Poplar Creek
WBCV	West Bear Creek Valley
WWSY	White Wing Scrap Yard
Y-12	Y-12 National Security Complex

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1. CANDIDATE SITE SCREENING

Review and screening of potential sites for the Environmental Management Disposal Facility (EMDF), a low-level radioactive and mixed waste landfill, was conducted as part of the Remedial Investigation/Feasibility Study (RI/FS) alternatives screening process. The United States Department of Energy (DOE) Oak Ridge Reservation (ORR) encompasses approximately 33,500 contiguous acres, and thus offers numerous potential sites for consideration. A previous site-screening study identified and evaluated 35 sites on the ORR for a potential on-site disposal facility (DOE 1996).

The RI/FS (DOE 1998) for the existing Environmental Management Waste Management Facility (EMWMF) pared the original 35 candidate sites considered in the 1996 study down to three sites that were further evaluated, and the current EMWMF site was selected among those. This RI/FS re-evaluated 16 candidate sites, including sites identified in the 1996 siting study, the three sites identified in the EMWMF RI/FS, as well as other possible favorable locations. Specifically, those 16 sites include multiple locations in East Bear Creek Valley (EBCV), West Bear Creek Valley (WBCV), and Chestnut Ridge; the White Wing Scrap Yard (WWSY); a single Melton Valley location; and two other ORR locations.

1.1 METHODOLOGY

The screening process consisted of candidate site identification, data review, and application of a two-stage screening evaluation based on available data and information. The methodology was designed to eliminate sites obviously not meeting project requirements early in the process in order to focus more detailed evaluation on only the more viable sites. Screening was conducted as an iterative process by applying criteria developed on the basis of facility design assumptions, available area, topography, regulatory drivers, and other siting considerations, including projected land use. Primary and secondary screening focuses on implementability. Sites that met aspects of implementability in the second screening were then examined fully in this RI/FS as possible siting options for the On-site Disposal Alternative.. The 2008 ORR planning document (DOE 2008a) helped identify potential conflicts in land-use priorities among various DOE mission goals and objectives, including long term research and protected land areas.

1.2 IN-SITU SITING OPTIONS

Regulators expressed concerns that disposal of Y-12 National Security Complex (Y-12) mercury-contaminated wastes in Bear Creek Valley (BCV) would lead to a second watershed being impaired by mercury, and requested that the RI/FS consider burial of these wastes within the Upper East Fork Poplar Creek (UEFPC) Watershed as an alternative.

One conceptual approach examined is disposal of contaminated building debris in engineered facilities at, or near, the remediation sites in the Y-12 industrial area. These brownfield disposal sites could be used post-remediation for such low-impact purposes as parking lots, or vegetated open spaces; however, these areas would generally not be available for other forms of development. This conceptual approach could potentially align with the vision for modernizing the Y-12 industrial area described in *Final Site-Wide Environmental Impact Statement for the Y-12 National Security Complex* (DOE 2011). Figure D-1 shows the current and envisioned future plan for Y-12. The long-range vision is for excess Y-12 facilities to be demolished leaving room for several new facilities surrounded by significantly more open space.

The primary benefit of this approach is that mercury-contaminated materials would remain in the watershed that has already been significantly impacted by the contaminant, and thus avoid spreading it to a watershed with relatively little mercury contamination. Further, the disposal sites would remain in an area that will be controlled by DOE or successor agencies for any reasonable foreseeable future. An additional benefit would be gained in a small decrease in transportation costs for moving debris from the demolition site to the disposal site.

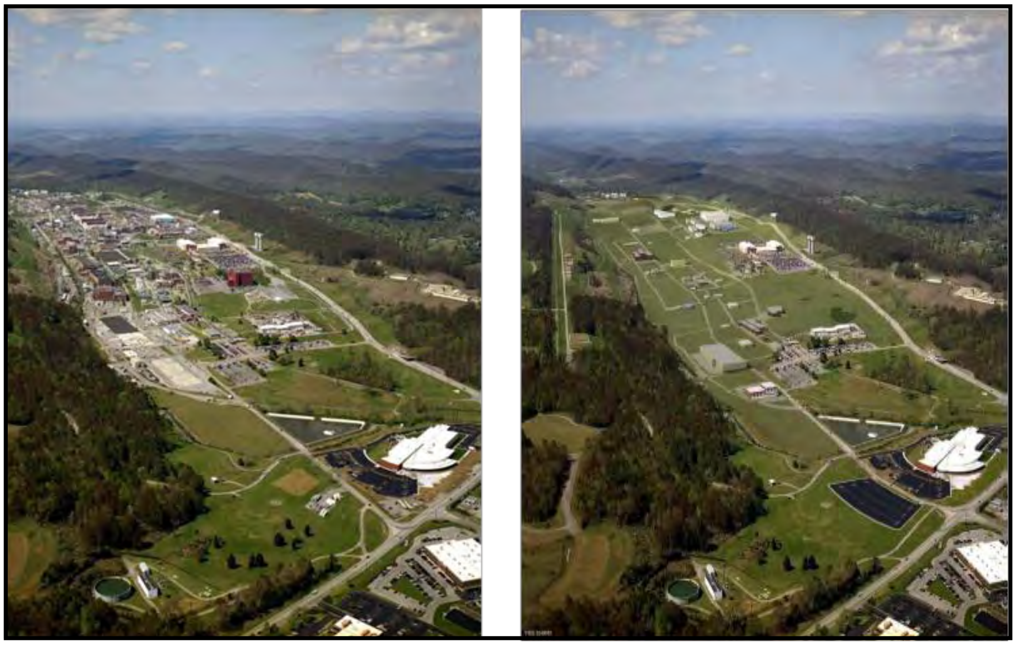

Figure D-1. Current and Future Y-12 Plan

Offsetting the benefits are several major disadvantages. First and foremost is increased risk and cost associated with in-place disposal. Risk is increased relative to a single large disposal cell because there would be a need for multiple new disposal cells, each of which has the potential to release contaminants. Second, it would be extremely difficult to sequence the complex operational, demolition, and disposal activities for both soil and debris such that disposal need meets disposal capacity. This also greatly increases overall costs as a result of utilities re-routing and security system changes. Costs would also be increased by the need to design and construct several facilities, instead of one; by the increase in infrastructure needed to serve several facilities; and by the additional monitoring and maintenance required to ensure that each of the several disposal cells performs as designed. Post-remediation operational flexibility would be reduced because the areas devoted to waste disposal would be unusable for any purpose that would require foundations or buried utilities. Additionally, the current Records of Decision (RODs) addressing cleanup in the UEFPC watershed are considered interim RODs (BJC 2002, BJC 2006), and leave open-ended the possibility of needing to address further soil cleanup in the area depending on final ground water and surface water decisions. Disposing of debris and soil in-place would make any further cleanup impractical.

Finally, even under the assumption that the volume of waste to be disposed is the same under the single facility and multiple facility approaches, the effective footprint (waste plus containment system) of multiple facilities after closure would be significantly greater than for a single large facility.

Additionally, there are several impediments to implementation of this potential remedy. First, the Y-12 industrial area contains a dense network of buried and overhead utilities that would have to be re-routed to accommodate any burial site(s) large enough to accommodate expected waste volumes. Second, the Perimeter Intrusion Detection and Assessment System would have to be realigned to accommodate disposal sites. Third, the in-place disposal sites would either require early soil clean-up, or if buildings were disposed of in their own footprints, could mask mercury-contaminated soils from further remediation.

The disadvantages of in-place waste burial far out-weigh any benefits realized, and this alternative is therefore not considered further in this document. However, this decision does not preclude future pursuit of alternative disposition of mercury-contaminated debris and/or soil within UEFPC watershed area.

2. PRELIMINARY SCREENING

The 16 candidate sites screened for this RI/FS were selected utilizing data and information presented in the 1996 DOE site screening study (DOE 1996), the EMWMF RI/FS (DOE 1998), and a 2008 ORR planning document (DOE 2008a). Table D-1 lists the 16 candidate sites and indicates the basis for their consideration. The site locations are identified by number on Figure D-2. Screening was conducted as an iterative process by applying criteria developed on the basis of facility design assumptions, available area, topography, regulatory drivers, and other siting considerations, including land use.

Table D-2 identifies and briefly describes the preliminary siting criteria the candidate sites were screened against. These include available area, topography, surface water, and karst:

- Area: Use of projected waste volumes in conjunction with design requirements and assumptions resulted in a minimum threshold requirement for a landfill footprint area of 60-70 acres.
- Topography: Topographic constraints on siting were reviewed to determine the suitability of candidate sites for disposal facility development. Considered in this evaluation were degree of slope and geomorphologic indications of site stability, and soil thickness.
- Surface Water: The presence of surface water features, such as streams and wetlands, were a consideration. Consideration was given to whether streams were ephemeral (wet weather conveyances), intermittent, or perennial, whether springs and seeps were present, whether wetlands, if present, are natural or artifacts of construction, and whether the water features represented unique habitats or contained status species.
- Karst: The presence of karst surface features, such as sinkholes, or indications that significant voids may exist beneath the landfill footprint, were considered in relation to structural stability, ground water monitoring, and contaminant migration.

Candidate sites that presented critical construction/engineering obstacles were eliminated from further consideration in the preliminary screening phase. The “discussion” column in Table D-2 identifies those candidate sites retained, identifies the option designs that are derived from an updated or modified design of another listed option, and why six of the candidate sites were eliminated from further consideration. The preliminary screening phase reduced the original 16 candidate sites to ten for further evaluation.

Table D-1. Candidate Sites Identified for the RI/FS Screening Evaluation

Candidate Site*	Basis for Consideration
(1) EBCV-Option 1	Adjacent to EMWMF
(2) EBCV-Option 2	Adjacent to EMWMF, combines Bear Creek Burial Ground (BCBG) remedy component with landfill siting
(3) EBCV-Option 3	Adjacent to EMWMF
(4) EBCV-Option 4	Adjacent to EMWMF
(5) EBCV-Option 5	Adjacent to EMWMF
(6) EBCV-Option 6	Two separate disposal cells (6a & b), adjacent to EMWMF on west and east
(7) EBCV-Option 7	Two separate disposal cells (7a & b)
(8) WBCV-Option 8	Previous waste disposal facility siting study
(9) WWSY	Previous waste disposal facility siting study; adjacent to Waste Area Grouping 11
(10) Chestnut Ridge	East of Spallation Neutron Source
(11) West-Central Chestnut Ridge	Previous waste disposal facility siting study area
(12) East Chestnut Ridge	Previous waste disposal facility siting study area
(13) Former Breeder Reactor area	Possible favorable location
(14) Modified WBCV Option	Revised footprint from Option (8)
(15) Solid Waste Storage Area (SWSA) 7	Former proposed landfill site within Melton Valley, east of legacy waste management areas
(16) Advanced Nuclear Site	Former proposed construction site east end of Melton Valley adjacent to Bearden Creek

*Numbers in parentheses correspond to the areas shown on Figure D-2.

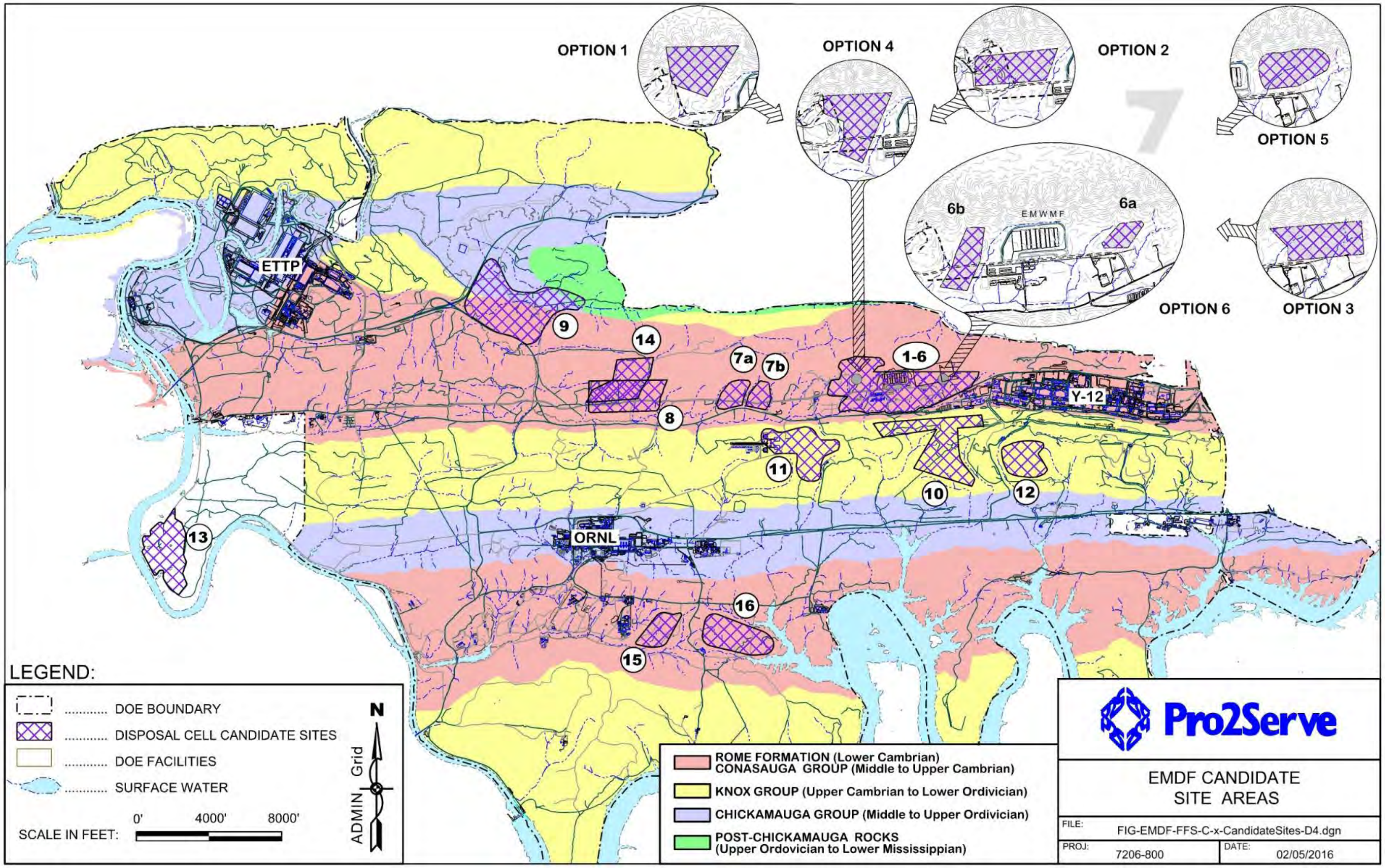

Figure D-2. EMDF Candidate Site Locations

Table D-2. Preliminary Screening of Candidate Sites

Candidate Site	Preliminary Screening Criteria				Discussion
	Insufficient Area	Unfavorable Topography	Surface Water Impacts	Karst Features	
(1) EBCV-Option 1	X	X			Site eliminated due to lack of suitable area for development and unfavorable topography.
(2) EBCV-Option 2			X		**Carried forward to secondary screening, see Table D-3.**
(3) EBCV-Option 3			X		**Carried forward to secondary screening, see Table D-3**.
(4) EBCV-Option 4			X		**Carried forward to secondary screening, see Table D-3**.
(5) EBCV-Option 5			X		Modified version of Option 3 design (crosses NT-3 but avoids direct impacts to NT-2). **Carried forward to secondary screening, see Table D-3.**
(6) EBCV-Option 6					A modified version of Option 4 design with an additional separate cell to the east. **Carried forward to secondary screening, see Table D-3.**
(7) EBCV-Option 7					**Carried forward to secondary screening, see Table D-3.**
(8) WBCV-Option 8			X		**Carried forward to secondary screening, see Table D-3.**
(9) WWSY				?	**Carried forward to secondary screening, see Table D-3.**
(10) Chestnut Ridge		X		X	Site eliminated on basis of steep terrain and karst.
(11) West-Central Chestnut Ridge	X			X	Site eliminated. Lack of suitable area for development due to proximity of Spallation Neutron Source. Karst features are present.
(12) East Chestnut Ridge	X	X	X	X	Site eliminated due to lack of suitable area for development, presence of karst, and unfavorable topography.
(13) Former Breeder Reactor Area			X	X	Site eliminated on basis of proximity to the Clinch River and presence of karst. Site is on TVA-owned land.
(14) Modified WBCV Option					Modified version of Option 8 design; avoids Haul Rd and power line. **Carried forward to secondary screening, see Table D-3.**
(15) Proposed SWSA 7			X		**Carried forward to secondary screening, see Table D-3.**
(16) Proposed Advanced Nuclear Site			X		Site eliminated. Site is directly adjacent to the Bearden Creek embayment of Melton Lake. A high power transmission line runs through the site.

3. SECONDARY SCREENING

Ten candidate sites were examined in the second phase of screening of which six were eliminated from further consideration. The modifying criteria used for the secondary screening phase were location and access, proximity to public areas, site contamination, buffer zones, land use, and disposal capacity. Modifying criteria were designed to eliminate sites from further consideration only when either multiple criteria combined to render a site unfavorable for development or there were particularly significant issues associated with a single criterion.

3.1 PROXIMITY TO THE PUBLIC

Proximity to the public was a consideration for all sites forwarded to secondary screening. Proximity to the public is defined three ways and summarized in Table D-3:

- Occasional use areas include roads (State Route [SR]-95 [abbreviated 95 in table] or Tuskegee Dr.[T]) and commercial/industrial areas that private citizens may use on a short-term basis.
- Residential areas are those areas occupied by existing single and multi-family structures. Roads in residential areas are not counted as occasional use land.
- Distance to DOE boundary.

All the candidate sites in secondary screening are less than one mile from the DOE boundary, as shown in Table D-3, and a few are less than one mile from existing residential areas (Country Club Estates, Rarity Oaks, Groves Park Commons, or lake front homes in Knox County). Two sites are less than 0.5 mile from a public road.

Table D-3. Distance to Public Areas

Candidate Site	Approximate Distance from Candidate Site (Miles)		
	Occasional Use	Existing Residential	DOE Boundary
(2) EBCV-Option 2	1.3 (T)	1.1(CCE)	0.75
(3) EBCV-Option 3	0.8 (T)	1.1 (GPC)	0.4
(4) EBCV-Option 4	1.4 (T)	1.1 (CCE)	0.75
(5) EBCV-Option 5	0.8 (T)	0.8 (GPC)	0.4
(6) EBCV-Option 6a EBCV-Option 6b	1.1 (T) 0.8 (T)	1.1 (CCE) 0.8 (GPC)	0.75
(7) EBCV-Option 7a EBCV-Option 7b	1.9 (95) 2.0 (T)	0.7 (CCE) 0.8 (CCE)	0.75
(8) WBCV-Option 8	0.5 (95)	1.1 (CCE)	0.75
(9) WWSY	<0.1 (95)	1.2 (RO)	0.6
(14) Modified WBCV Option	0.5 (95)	1.0 (CCE)	0.75
(15) Proposed SWSA 7	1.3	1.65 (KC)	1.3
Other areas of interest, included for comparison purposes			
EMWMF	1.1 (T)	1.3 (GPC)	0.75
Y-12 Alpha 5 Complex	0.8 (T)	0.5 (GPC)	0.4

CCE Country Club Estates
GPC Groves Park Commons
KC Knox County
RO Rarity Oaks

By way of comparison, the distance from the center of the Y-12 main plant area (near the Alpha 5 complex) to the nearest residential area is approximately 0.5 mile. All ten sites included in secondary screening are within 0.8–1.2 miles of residential areas, and all are within 0.75 mile of the DOE boundary. Distance to public is therefore not a strong discriminator, except for the WWSY site, as discussed below.

3.2 SECONDARY SCREENING EVALUATIONS

The rationale for elimination of six of the ten sites is briefly discussed below and summarized in Table D-4.

3.2.1 EBCV Option 2

EBCV Option 2 was eliminated because it included a portion of the Bear Creek Burial Grounds (BCBG) and crosses Northern Tributary (NT)-6. EBCV Option 2, shown on Figure D-2, combines a BCBG remedy component with siting of the proposed landfill. Construction of a new landfill under Candidate Site 2 would require excavation of buried waste and residual contaminated soils from several BCBG units including A-North, A-17, and ORP-2 (see Figure D-3) and would impact a portion of NT-6. Note that a Resource Conservation and Recovery Act cap has been installed on areas A-North and ORP-2, and would need to be removed prior to excavation. Excavated waste would be placed in the new landfill and/or disposed off-site. As shown in Table D-4, EBCV Option 2 was eliminated from further consideration because the presence of buried waste and site contamination present significant challenges to landfill construction. The challenges include concerns about worker health and safety, remote excavation techniques, remote-handling of wastes, waste treatment and disposal, and transportation of BCBG buried wastes. These factors would result in extremely high implementation costs and potential risks to human health and the environment.

Further, EBCV Option 2 would be inconsistent with the preferred alternative of hydrologic isolation identified in the Proposed Plan for the BCBG (DOE 2008b). The preferred alternative includes construction of multilayer engineered caps for all previously uncapped BCBG disposal units plus one previously capped unit (BCBG D-West), construction of upgradient storm-flow trenches to intercept and divert shallow ground water and surface water run-on, and construction of downgradient collection trenches. Remedial alternatives considered in the BCBG Proposed Plan included partial excavation and excavation of the BCBG. Following a Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) criteria evaluation, these alternatives were not identified as the preferred alternative. While approval and implementation of a BCBG ROD has been deferred, potential interim actions that could be implemented to reduce migration of contaminants from BCBG are being considered, such as enhanced leachate collection, a component of the preferred alternative presented in the BCBG Proposed Plan.

3.2.2 EBCV Option 3

EBCV Option 3 was eliminated because it covers two tributary streams, NT-2 and NT-3. The eastern part of the footprint which crosses NT-2 represents a major impediment to construction as this segment of NT-2 conveys runoff from a significant watershed area above the site. The EBCV Option 5, which is a modification of Option 3, avoids this major impediment and is considered a more viable option that precludes the need for Option 3.

3.2.3 EBCV Option 4

EBCV Option 4 consists of an irregular polygon lying between EMWMF and BCBG. The site was eliminated based on several drawbacks. Portions of this site were formerly used as a borrow area. In order to provide sufficient volume for the expected wastes, the footprint would need to extend north from near Bear Creek, across the Haul Road and power line right of way and onto the flank of Pine Ridge. Other

Table D-4. Secondary Screening of Candidate Sites

Candidate Site	Secondary Screening Criteria					Discussion
	Location and Access	Site Contamination	Buffer Zones	Land Use	Disposal Capacity	
(2) EBCV-Option 2		X	X			Site eliminated. Presence of buried waste and site contamination present significant challenges to facility construction.
(3) E BCV-Option 3			X			Site eliminated. Covers two tributaries to Bear Creek.
(4) EBCV-Option 4		?	X		X	Site eliminated. Concern about adequate disposal capacity and shallow ground water table south of the Haul Road. Adjacent to legacy burial ground.
(5) EBCV-Option 5			X			**Potential Site.** See further discussion in Section 4.
(6) EBCV-Option 6a			X	X	X	Site eliminated. Insufficient disposal capacity even if combined with a second separate cell. Site may not be adequate to avoid impinging on stream buffer
(6) EBCV-Option 6b						**Potential Site.** Adequate disposal capacity if combined with a second separate cell, but combination would impact a larger overall land area. See further discussion in Section 4.
(7) EBCV-Option 7a			X	X	X	**Potential Site.** Adequate disposal capacity if combined with a second separate cell, but combination would impact a larger overall land area. See further discussion in Section 4.
(7) EBCV-Option 7b						Site eliminated. Site is redundant with Option 7a and 6b combination.
(8) WBCV-Option 8			X	X		Site eliminated. Site is redundant with and includes major site disadvantages relative to Option 14: footprint spans lower reaches of intermittent/perennial flow on NT-14 and NT-15 and is much closer to Maynardville karst
(9) WWSY	X	?	X	X		Site eliminated. Primary concerns related to proximity to public access areas, sensitive habitats, and legacy waste disposal.
(14) Modified WBCV Option				X		**Potential Site.** See further discussion in Section 4.
(15) Proposed SWSA 7 Site	X			X		Site eliminated. Site is adjacent to the High Flux Isotope Reactor. Access from Y-12 would require more than 2 miles new Haul Road to be constructed. One stream would be eliminated.

Note: an X in each column indicates that the site has issues with that criterion. A question mark indicates a potential concern.

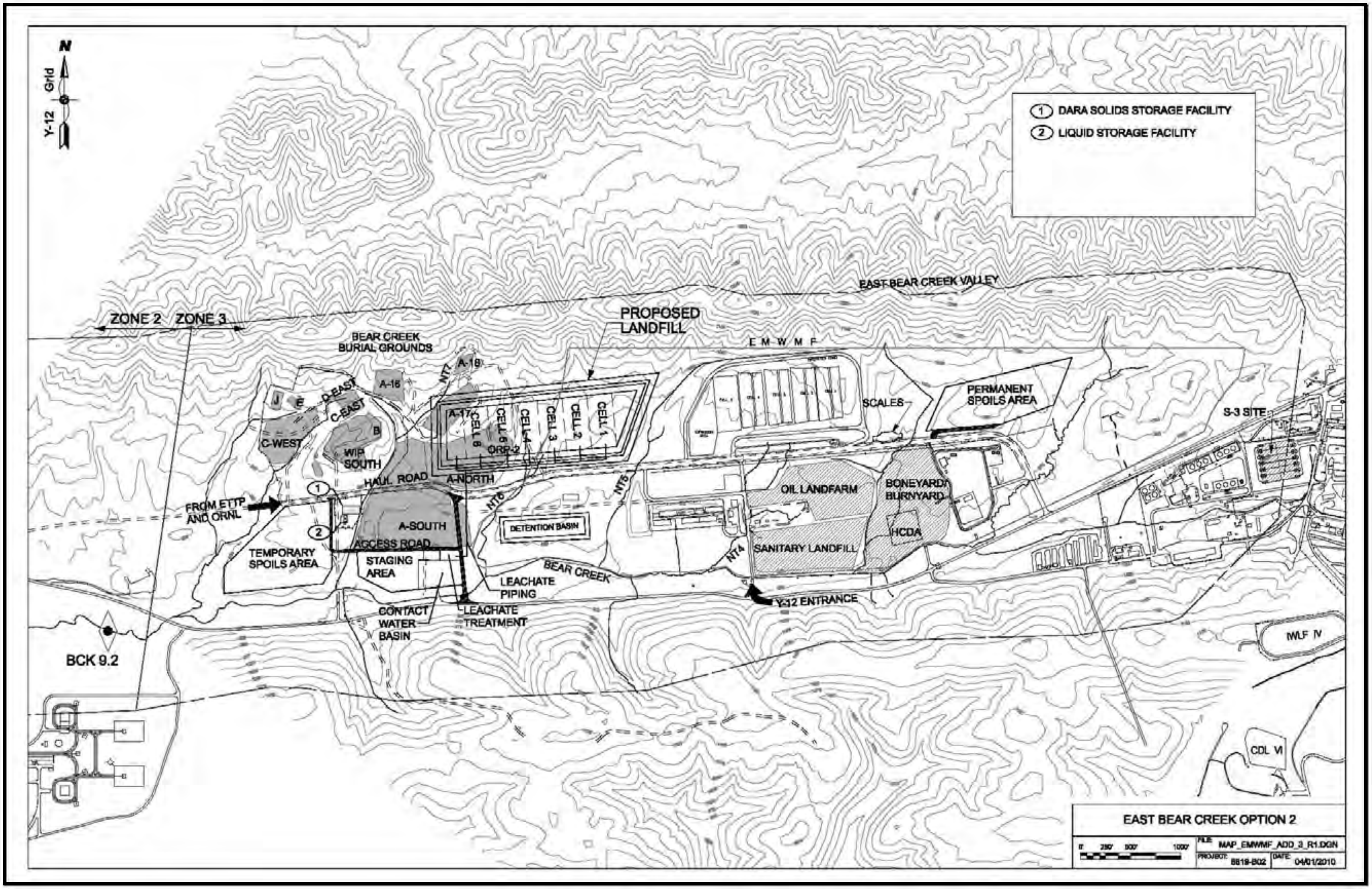

Figure D-3. Possible Footprint for EBCV Option 2

significant negative aspects of this option include: the south end of the landfill is likely to be within the 100-year floodplain of Bear Creek, is relatively close to karst features of the Maynardville Limestone just south of the footprint, and the water table would likely be close to the land surface.

3.2.4 EBCV Options 6a/6b and 7a/7b – Multiple Small Landfills

One suggestion for avoiding construction over surface water features is use of two or more landfills such as candidate Sites 6a, 6b, 7a, and 7b, with relatively small footprints that avoid covering portions of adjacent NT valleys with intermittent stream flow. Each of the smaller landfills has a much smaller total volume (airspace) capacity to total area ratio (e.g., the landfill boundaries/sides take up a much larger portion of the landfill). The height of waste allowable with a smaller landfill is much lower, thus decreasing the volume available for wastes, which requires a larger aggregate land area surrounding the waste. Additionally, some requirements are the same for a small or large landfill, but proportionally for a small landfill may reduce the percentage of the volume available for waste; for example the requirement that the 12 ft top layer of waste cannot contain debris (must be soil).

However, the use of multiple landfills may not totally avoid surface water impacts or maintain adequate buffers between the landfill and streams, because springs and seeps are common and widespread in BCV. Based on a conceptual design analysis among these four smaller footprints, the combination of Sites 6b and 7a were determined to have a total volume capacity sufficient for the estimated wastes (i.e – total combined volume of at least 2 million cubic yards [M yd^3]), and to have other adequate site conditions to warrant retaining these sites for further screening and evaluation.

Site 6a was eliminated based on a relatively small footprint and relatively low volume that would not provide sufficient capacity in combination with any of the other small sites. In contrast, Site 6b offers several advantages over the other small footprint sites. It is located immediately west of the EMWMF within the current industrialized Brownfield area of Zone 3, includes sufficient volume in combination with Site 7a (or 7b), and allows for shared infrastructure with the existing EMWMF. Sites 7a and 7b are roughly comparable in terms of volume, both are located in land use Zone 2 (designated for short-term recreational use and long-term unrestricted use in the BCV Phase I ROD), and are similar in general layout and site features. Thus Site 6b would be the leading choice among the initial small footprint sites used in a dual capacity with Site 7a (or 7b) to provide the needed potential capacity of greater than 2 Myd^3. Site 7a was selected in the screening process to be carried forward for a multi-footprint option, but is representative of either Site 7a or 7b due to their proximity and similarities. Should the Dual Site Option be selected, a more detailed analysis of Sites 7a and 7b would be made to select the most appropriate of the two locations.

3.2.5 WBCV Option 8

Site options 8 and 14 occur in WBCV and have partially overlapping footprints. While both options include suitable disposal capacity, the Option 8 footprint is located further south relative to Site 14 resulting in features that make it less desirable than the Site 14 footprint. The negative features of Site 8 include: 1) Site 8 is much closer to the karst features known to occur within the Maynardville Limestone; 2) the existing Haul Road and power line right of way occur across the center of the Site 8 footprint and would require extensive rerouting work; and 3) the footprint is located much closer to surface water along Bear Creek. The southern boundary of Site 8 is located in close proximity to the contact between the Nolichucky Shale and the Maynardville Limestone south of which karst features begin to develop. The karst features of the Maynardville pose a risk of structural failure from sinkhole development and collapse for support facilities (sediment basins, holding ponds, above ground tanks, support buildings, etc.) that might be located in the relatively flat areas south of Site 8. The closer proximity to the Maynardville karst also reduces the potential for greater subsurface contaminant attenuation that is offered at footprints located within the outcrop belts of the fractured predominantly clastic rocks in areas north of the

Maynardville/Nolichucky contact that do not include karst features. Ground water (and contaminant) flow rates in the Maynardville karst tend to be orders of magnitude greater than those in the fractured clastic rocks to the north. The closer proximity to Bear Creek surface water and to karst flow conditions in the Maynardville could result in a greater risk of off-site contaminant transport in the event of a future site release(s). Based on these differences between the Site 8 and 14 footprint locations, Site 8 was eliminated from further consideration in deference to better fundamental site conditions at Site 14.

3.2.6 WWSY

The WWSY is located outside of BCV just north of the water gap where SR95 cuts through Pine Ridge. The site is located adjacent to SR95 and relative to the sites proposed in BCV is in closer proximity to public access, including roads and trails on DOE property that are open for public use to the north and northwest of the site. The southwestern edge of the waste footprint is only about 300 ft from SR95, a public highway with active daily traffic flow. Among the prospective EMDF sites, the WWSY is located north of Pine Ridge and is one of the farthest sites from Y-12 and ORNL where the bulk of remaining CERCLA waste sites and legacy facilities remain. Transportation pathways for waste disposal would therefore increase in complexity, distance, risk, and cost relative to other proposed EMDF locations.

The surface trace of four imbricate faults of the White Oak Mountain thrust fault occur near the northern and southern margins of the WWSY footprint. One of those fault traces is directly along the northern edge of the footprint. While these ancient faults are not seismically active, deformational features associated with these faults (intense shear fracturing, folding, and localized faults) could enhance subsurface fracture and solution pathways for ground water migration and contaminant transport. Several limestone formations conducive to dissolution and karst development also occur just north of the footprint.

Based on the close proximity to SR95 and nearby public use areas, waste transportation issues, and the relatively more complex hydrogeological setting with very little supporting characterization, the WWSY was eliminated from further consideration.

3.2.7 Proposed SWSA 7 Site

The Solid Waste Storage Area (SWSA) 7 site in Melton Valley, immediately east of the High Flux Isotope Reactor, was extensively evaluated as a potential disposal site in the 1980s. There is adequate area for the expected disposal volume. The SWSA 7 site was earlier investigated as a potential new low-level radioactive waste disposal area (Lomenick, et al. 1983; Rothschild, et al 1984), but was rejected. The site is a hilly area lying between two tributaries to Melton Branch and incorporating a third tributary. Cunningham and Pounds (1991) indicate that wetland vegetation occurs in an artificial pond and possibly at two small sites adjacent to a gravel road. Geologically, the SWSA 7 site is very similar to the WBCV and EBCV sites. The underlying bedrock is composed of Conasauga Group shales, siltstones, and mudstones with lesser amounts of shaley limestone. Groundwater occurs in fractures, and drainage is radial, making monitoring more difficult. There is no karst at this site.

Site topography presents some construction challenges and site preparation would require removal of a larger quantity of soil and rock than at other sites. A short first-order stream (or wet weather conveyance) would be eliminated, as would any wetlands in the area. Approximately two miles of new Haul Road would have to be constructed in order for Y-12 wastes to transit Bethel Valley. This new segment of Haul Road would likely have to cross a portion of the Walker Branch watershed, which is an essentially pristine monitored research area. There are no accessible support facilities at the site, and power, water, leachate containment and treatment systems, and storm water control systems would need to be installed.

The site, as noted above, is adjacent to the High Flux Isotope Reactor, an active facility conducting sensitive work. It is likely that construction and operation of a large landfill would adversely impact High

Flux Isotope Reactor operations. Landfill operations may increase risks for workers at the High Flux Isotope Reactor, as well.

Given the proximity to an active reactor facility, need for additional road construction in a research watershed, construction challenges, and the lack of available support facilities, SWSA 7 was eliminated from further consideration.

3.3 REMAINING SITES

The four candidate sites passing the secondary screening evaluation include:

- the EBCV site (Option 5)
- the Dual Site (Options 6b/7a), and
- the WBCV site (Option 14)

Appendix E provides detailed descriptions of the environmental setting for each of these sites within the overall setting of BCV. The conceptual design features for each of the sites are presented in Chapter 6 of the RI/FS, while detailed and comparative analyses of the proposed site options are presented in Chapter 7.

4. REFERENCES

BJC 2002. *Record of Decision for Phase I Interim Source Control Actions in the Upper East Fork Poplar Creek Characterization Area, Oak Ridge, Tennessee*, DOE/OR/01-1951&D3, Bechtel Jacobs Company LLC, May 2002, Oak Ridge, TN.

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APPENDIX E:
DESCRIPTION OF BEAR CREEK VALLEY AND PROPOSED EMDF SITES

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CONTENTS

FIGURES

TABLES

ACRONYMS

ANA	Aquatic Natural Area
AWQC	ambient water quality criteria
BCBG	Bear Creek Burial Grounds
BCK	Bear Creek Kilometer
BCV	Bear Creek Valley
BNI	Bechtel National, Inc.
BY/BY	Boneyard/Burnyard
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
DOE	U.S. Department of Energy
EBCV	East Bear Creek Valley
EMDF	Environmental Management Disposal Facility
EMWMF	Environmental Management Waste Management Facility
EPA	U.S. Environmental Protection Agency
ETSZ	East Tennessee Seismic Zone
ETTP	East Tennessee Technology Park
FS	Feasibility Study
K	hydraulic conductivity
LLWDDD	Low-Level Waste Disposal Development and Demonstration (program)
MSL	mean sea level
NAAQS	National Ambient Air Quality Standards
ORERP	Oak Ridge Environmental Research Park
NT	Northern Tributary (to Bear Creek)
ORNL	Oak Ridge National Laboratory
ORO	Oak Ridge Office
ORR	Oak Ridge Reservation
PCB	polychlorinated biphenyl
PreWAC	preliminary Waste Acceptance Criteria
RA	Reference Area
RI	Remedial Investigation
ROD	Record of Decision
SU	standard unit
SR	State Route
TCE	trichloroethene
TDEC	Tennessee Department of Environment and Conservation
U.S.	United States

UPF	Uranium Processing Facility
USGS	U.S. Geological Survey
UEFPC	Upper East Fork Poplar Creek
VOC	volatile organic compound
WAC	waste acceptance criteria
WAG	Waste Area Grouping
WBCV	West Bear Creek Valley
Y-12	Y-12 National Security Complex

1. INTRODUCTION

Appendix E to the Remedial Investigation (RI)/Feasibility Study (FS) describes the environmental setting of four potential sites for a new disposal facility for waste generated by Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) actions on the United States (U.S.) Department of Energy (DOE) Oak Ridge Reservation (ORR). The four sites, all within Bear Creek Valley (BCV) were identified in Appendix D as those meeting basic requirements suitable for on-site disposal and culled from a larger list of potential disposal site locations across the ORR. The four sites are categorized under three disposal alternatives – two individual site alternatives and one dual site alternative. From east to west, the three alternatives and four sites include (Figure E-1):

- East BCV (EBCV) Site (Option 5), adjacent to the existing Environmental Management Waste Management Facility (EMWMF), and hereafter addressed as Site 5,
- Dual Site (Options 6b/7a) – two separate footprint areas one near the center of the valley (Site 7a) and the other other from EBCV (Site 6b) adjacent to the EMWMF on the west, and
- West BCV (WBCV) Site (Option 14)

The RI/FS evaluates alternatives for disposing of most future CERCLA waste expected to be generated during environmental restoration of the ORR after the existing EMWMF reaches capacity. The new disposal facility has been named the Environmental Management Disposal Facility (EMDF).

The individual detailed site descriptions in Sections 3 through 6 are preceded by overview sections that include aspects of the BCV watershed shared among each of the proposed sites such as physiography, land use and demographics, transportation, climate and air quality, and broader elements of the environmental setting such as surface water hydrology, and geology/hydrogeology. More detailed treatment of site-specific physical conditions, ecological and cultural resources, and site-specific data from previous investigations are addressed individually for the three sites in subsequent sections. The purpose of this Appendix is to provide detailed information supporting the site screening and selection process for the sites in BCV deemed most suitable for on-site disposal of CERCLA waste.

2. ENVIRONMENTAL SETTING OF BEAR CREEK VALLEY

Many of the natural features of BCV are applicable to each of the proposed sites both in terms of the areas occupied by the site footprints and the areas surrounding and downgradient of the sites. Section 2 addresses environmental characteristics that are generally common among the sites and associated with potential surface and subsurface pathways for contaminant migration downgradient of the sites. Hydrogeological site conceptual models are presented in Section 2.8 for both BCV as a whole and for the individual sites. Section 2.9 reviews the important changes to the natural dynamics of surface water and and ground water flow following landfill construction and capping. Characteristics of surface water and hydrogeological conditions in BCV that are common to the proposed sites are presented in Sections2.10 through 2.13. A detailed summary of tracer test results is presented in Secton 2.13.5, as the findings from those tests provide important clues for understanding and estimating ground water contaminant flow paths and migration rates applicable to the proposed sites. Results of ecological and cultural resource surveys are reviewed in Secton 2.16 through 2.18 as they relate to potential impacts from construction among the site options.

2.1 PREVIOUS INVESTIGATIONS AND WATERSHED MONITORING

A considerable amount of information is available documenting the environmental conditions of BCV and for similar sites elsewhere on the ORR. Much of it is based on surface and subsurface investigations and reports of contaminant source areas and ground water plumes, including the drilling and installation of hundreds of monitoring wells and sampling and analysis of soils, sediment, ground water, and surface

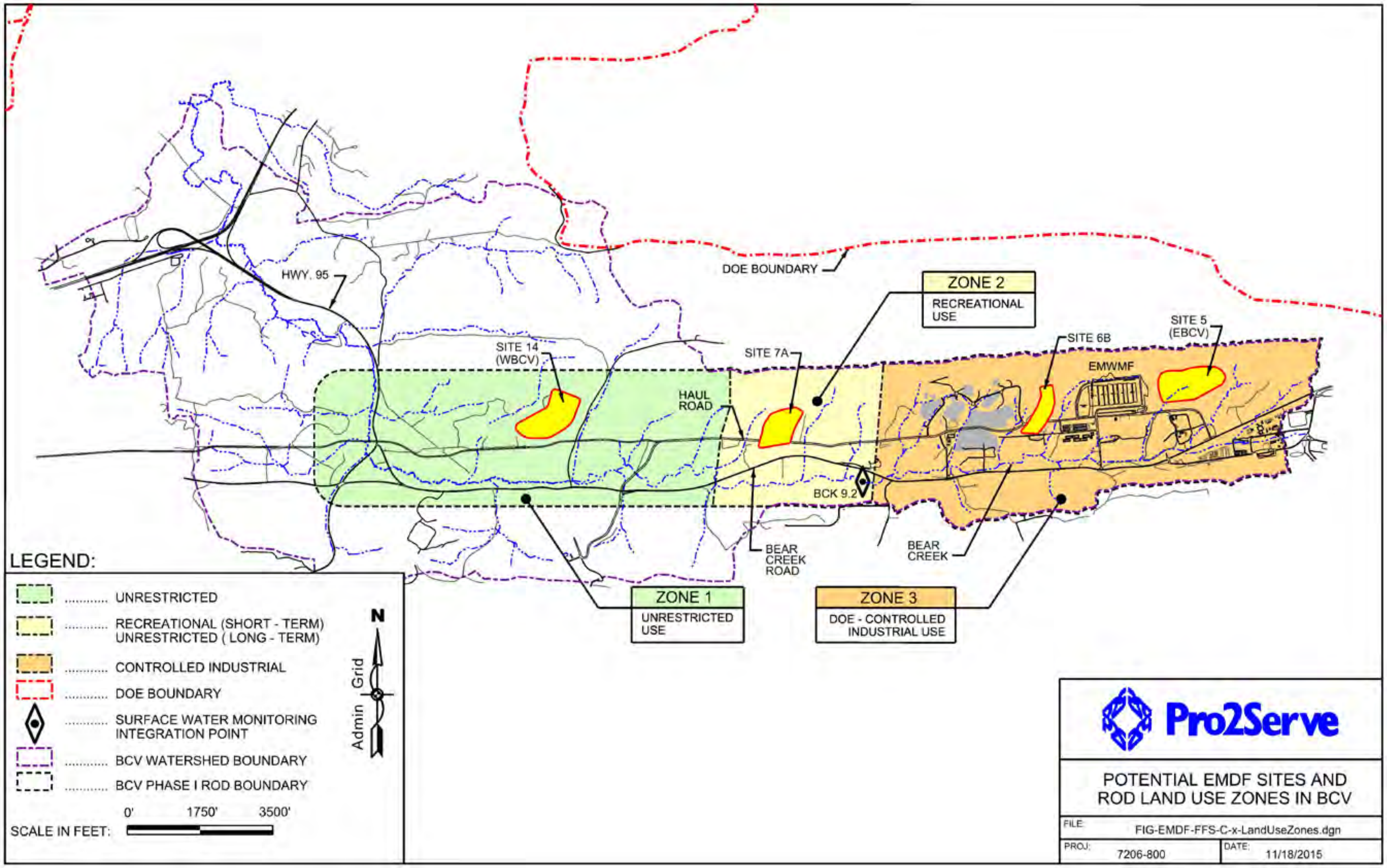

Figure E-1. BCV Phase I ROD land use zones with respect to Sites 14, 7a/6b, and 5

water. In addition, technical reports and applied research papers have been prepared to supplement the findings from hazardous waste site investigation data and reports. Geotechnical investigations and reports, and engineering design documents have been developed for proposed waste management sites such as the Low-Level Waste Disposal Development and Demonstration (LLWDDD) site in WBCV and Sites B and C in EBCV (former Site C is now occupied by the EMWMF site). The results of over three decades of investigations and reports, and the partial remediation of sites in Zone 3, and ongoing monitoring of surface and ground water are all available to support development and planning for the proposed EMDF site in BCV.

Findings from available reports have been incorporated into Appendix E, but reviewers are encouraged to review the multitude of original source documents for additional details. The attached list of references provides many of the key documents that are commonly available through internet searches, through local DOE information centers, or directly from DOE.

2.2 EXISTING CONTAMINANT SOURCES AND PLUMES IN BEAR CREEK VALLEY

Figure E-2 (from the 2015 Remediation Effectiveness Report for the ORR, DOE 2015a) illustrates the existing contaminant source areas, extent of ground water contaminant plumes, and current monitoring locations within the BCV watershed. The existing ground water plumes include radionuclides, volatile organic compounds (VOCs), and nitrates that commingle from the various sources located within the eastern half (Zone 3) of BCV. As shown in the figure, each of the proposed EMDF sites is located well beyond the northern margin of the ground water plumes and areas of periodic extension, and in topographically higher areas outside of the downgradient flow paths of the existing sources.

The BCV RI Report (DOE 1997), the annual Remediation Effectiveness Reports and 5-year CERCLA review reports for the ORR, and reports prepared by UCOR (2013a) and by Elvado (2013) provide greater details on the nature and extent of contamination in BCV, results of BCV remedial actions completed to date, and ongoing monitoring of surface water, ground water, and biota. In particular, Appendix B of the ORR Ground Water Strategy Report (UCOR 2013a) includes detailed contaminant plume maps and cross sections to examine relationships between the proposed EMDF site locations and the nearest plumes. The BCV Phase I Record of Decision (ROD) does not identify remediation levels to be attained in Zone 3, but states that source area remedial actions are expected to improve ground water quality.

The configuration of the ground water VOC plume emanating from the Bear Creek Burial Grounds (BCBG) is notable as the northern parts of this source area footprint occur partially along geologic strike with parts of the proposed EMDF site footprints in BCV (within the outcrop belts of the Maryville/Dismal Gap formation and Nolichucky Shale). The VOC plume indicates southerly contaminant migration downgradient toward Bear Creek where the plume then commingles with the plume following strike dominant flow in the karst of the Maynardville Limestone and surface water flow along Bear Creek toward the southwest. The configuration of existing plumes provides an approximation of plume configurations that could occur in the event of future subsurface releases at the proposed sites.The figure also illustrates the relationships between each of the proposed EMDF sites and existing source areas in Zone 3 versus the absence of existing contaminant sources in Zones 1 and 2.

2.3 PHYSIOGRAPHY AND GEOLOGIC SETTING

The ORR is located in the western portion of the Valley and Ridge physiographic province, which is characterized by a series of parallel narrow, elongated ridges and valleys that follow a northeast-to-southwest trend (Hatcher et al. 1992). The Valley and Ridge physiographic province developed on thick, folded and thrust-faulted beds of sedimentary rock deposited during the Paleozoic era. Thrust fault patterns and the strike and dip of the beds control the shapes and orientations of a series of long, narrow

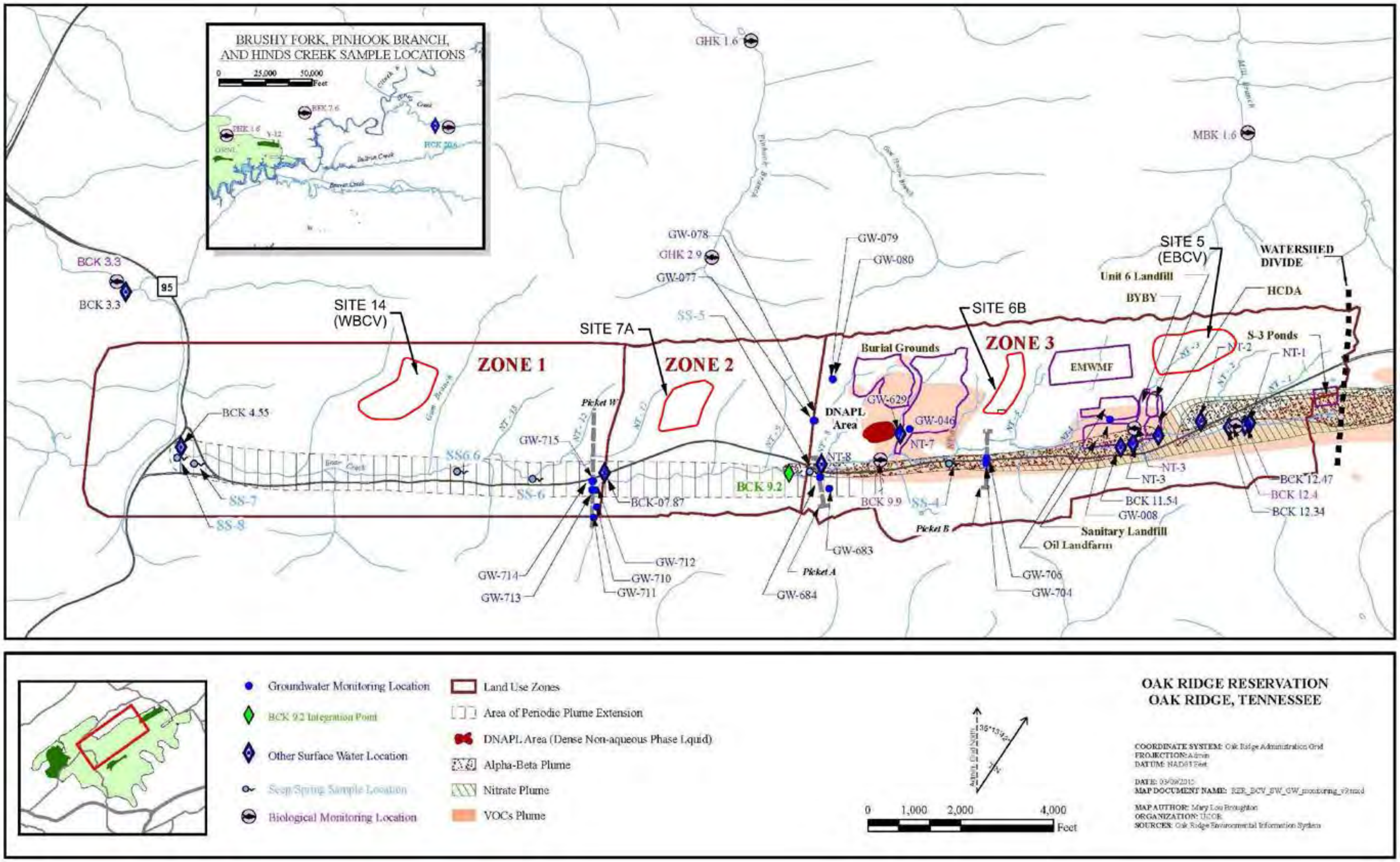

Figure E-2. Existing contaminant source areas, ground water plumes, and monitoring locations in Bear Creek valley with respect to Sites 14, 7a/6b, and 5

[From DOE 2015a]

parallel ridges and intervening valleys. Ten major imbricate thrust faults, in which thrust sheets overlap somewhat like roof shingles, have been mapped in East Tennessee. Two of these thrust sheets, defined by the Copper Ridge and Whiteoak Mountain thrust faults, cross the ORR (see Figures E-3 and E-4; Lemiszki 2000; Hatcher, et al. 1992). The ridge-and-valley terrain within the ORR trends east-northeast–west-southwest (approximately 60°–240°). Bedding planes mostly dip to the southeast with dip angles averaging around 45° but dips may vary widely on a local scale. Strike and dip measurements within BCV taken along the Northern Tributary (NT) stream paths near the proposed sites are shown on the Geologic Map of the Bethel Valley Quadrangle (Lemiszki 2000) and vary from 23° to 80° southeast to vertical (Figure E-3). Bedrock on the ORR consists of a variety of interbedded sedimentary clastic and carbonate rocks. The rocks are variably fractured and weathered resulting in significant vertical and horizontal subsurface heterogeneity. The differing degrees of resistance to erosion of the shales, sandstones, and carbonate rocks that comprise the regional bedrock influence local relief. Carbonate units (limestone/dolostone) are commonly extensively weathered with massive clay overburden with dispersed residual chert nodules and pinnacled bedrock surfaces. The more resistant clastic rocks (sandstone, siltstone, mudstone/shale) generally weathers to an extensively fractured residuum (saprolite) with highly interconnected fracture networks overlying less weathered to unweathered more intermittently fractured bedrock. BCV is bounded by Pine Ridge on the northwest and Chestnut Ridge on the southeast. The ground elevations within the ORR range from a low of 750 ft above mean sea level (MSL) along the Clinch River to a high of over 1,300 ft MSL on Copper Ridge. The topographic relief between valley floors and ridge crests is generally on the order of 300 to 350 ft.

2.4 LAND USE AND DEMOGRAPHICS

The ORR currently occupies 33,542 acres in Anderson and Roane Counties. The land on the ORR is used for multiple purposes to meet DOE’s mission goals and objectives, and approximately one-third of the land (11,300 acres) is intensively developed (ORNL 2002) as the East Tennessee Technology Park (ETTP), Oak Ridge National Laboratory (ORNL), and the Y-12 National Security Complex (Y-12). Land uses near, but outside, the ORR, are predominantly rural, with agricultural and forest land dominating, and urban, mainly represented by the City of Oak Ridge. The residential areas of the city of Oak Ridge that abut the ORR are primarily along the northern and eastern boundaries of the reservation. Some Roane County residents have homes adjacent to the western boundary of the ORR. The Clinch River forms a boundary between Knox County, Loudon County, and portions of Roane County.

2.4.1 Land Use

Uses of the land area within and surrounding the developed DOE facilities include safety, security, and emergency planning; research and education; cleanup and remediation; environmental regulatory monitoring; wildlife management; biosolids land application; protection of cultural and historic resources; wildland fire prevention; land-stewardship activities; use and maintenance of reservation infrastructure; and activities in public areas (DOE 2008). The largest mixed use is biological and ecological research in the Oak Ridge Environmental Research Park (ORERP), which encompasses 20,000 acres, the majority of the ORR (DOE 2011). The ORERP, established in 1980, is used by the nation’s scientific community as an outdoor laboratory for environmental science research on the impact of human activities on the eastern deciduous forest ecosystem.

Land use zones designated in the BCV Phase I ROD are shown on Figure E-1. The remedial action objectives (RAOs) for the BCV Phase I ROD are to:

- protect future residential users of the valley in Zone 1 from risks from exposure to ground water , surface water, soil, sediment, and waste sources;
- protect a passive recreational user in Zone 2 from unacceptable risks from exposure to surface water and sediment; and
- protect industrial workers and maintenance workers in Zone 3 from unacceptable risks from exposure to soil and waste.

Figure E-3. Geologic map of the Bethel Valley Quadrangle (Lemiszki 2000) showing geologic formations at and near BCV, the outcrop trace of the Whiteoak Mountain thrust fault, strike and dip measurements along BCV, and the approximate locations of the proposed EMDF sites

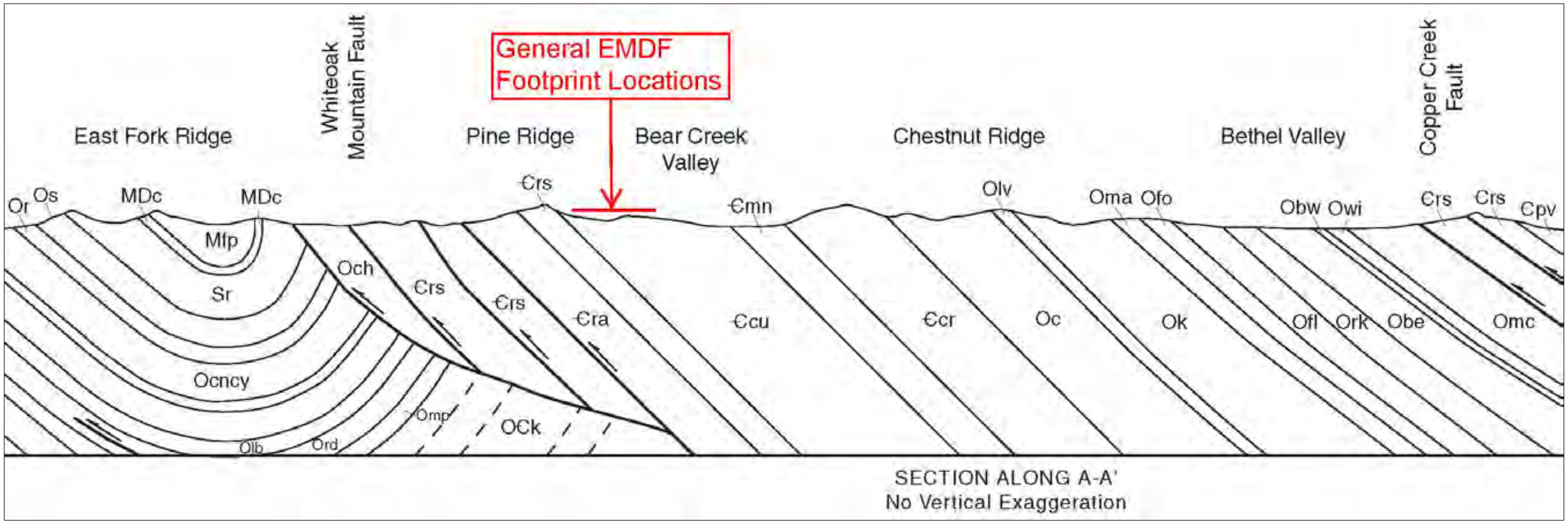

Figure E-4. Northwest-southeast cross section across BCV (see line of section in preceding figure) showing relationship of EMDF footprints to predominantly clastic rocks of the Conasauga Group and the Maynardville Limestone

Notes for Geologic Map and Cross Section from Lemiszki 2000:

Cra/Crs – Lower Cambrian Rome Formation; Apison Shale Member and Sandstone Member

Ccu – Middle Cambrian Conasauga Shale Undivided – includes in ascending order the Pumpkin Valley Shale, Rutledge Formation (Friendship), Rogersville Shale, Maryville Formation (Dismal Gap), and Nolichucky Shale; Names in parentheses are informal names adopted by Hatcher et al (1992) for the ORR.

Cmn – Upper Cambrian Maynardville Limestone

Ccr – Upper Cambrian Copper Ridge Dolomite

For other notations and detailed lithologic descriptions see *Geologic Map of the Bethel Valley Quadrangle, Tennessee* by Peter J. Lemiszki, 2000, Draft Open File Map

2.4.2 Demographics

The five counties nearest to the proposed candidate sites in BCV - Anderson, Knox, Loudon, Morgan, and Roane counties - have a total 2010 census population of 632,079 and over 286,000 housing units. Table E-1 summarizes basic demographic data for the five-county area.

Oak Ridge, the nearest city, has a population of 29,330 (2010 census); of these, 3,059 reside in Roane County with the remaining 26,271 residing in Anderson County. The estimated population of Oak Ridge for 2014 was 29,419(± 33)[1]. The Option 7a and 14 sites lie in Roane County while the Option 5 and 6b sites lie within Anderson County. All candidate sites in BCV are located on the ORR under DOE control with land use restrictions that preclude residential populations. Populations of adjoining census tracts are provided in Table E-2. Counties and nearby census tracts in vicinity of the proposed sites are shown in Figure E-5.

Table E-1. Total 2010 populatoin in five nearest counties

County	Population	Housing Units
Anderson	75,129	34,717
Knox	432,226	194,949
Loudon	48,556	21,725
Morgan	21,987	8,920
Roane	54,181	25,716
TOTALS	632,079	286,027

Source: U.S. Census Bureau, 2010 Census

Table E-2. Population data for adjacent census tracts in the 2010 census

County	Tract	2010 Population	% of Population Under Age 17	2010 Total Housing Units	2010 Occupied Housing Units
Anderson	201	3,111	22.7	1,794	1,546
	202.01	3,670	21.2	1,691	1,535
	202.02	4,507	18.9	2,215	2,025
	9801	0	0	0	0
Roane	9801	0	0	0	0
Knox	59.06	1,671	23.8	644	617
	59.07	2,970	25.7	1,267	1,153

Source: U.S. Census Bureau, 2010 Census

[1] http://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk accessed January 5, 2015. Estimates are not provided at the level of census tracts.

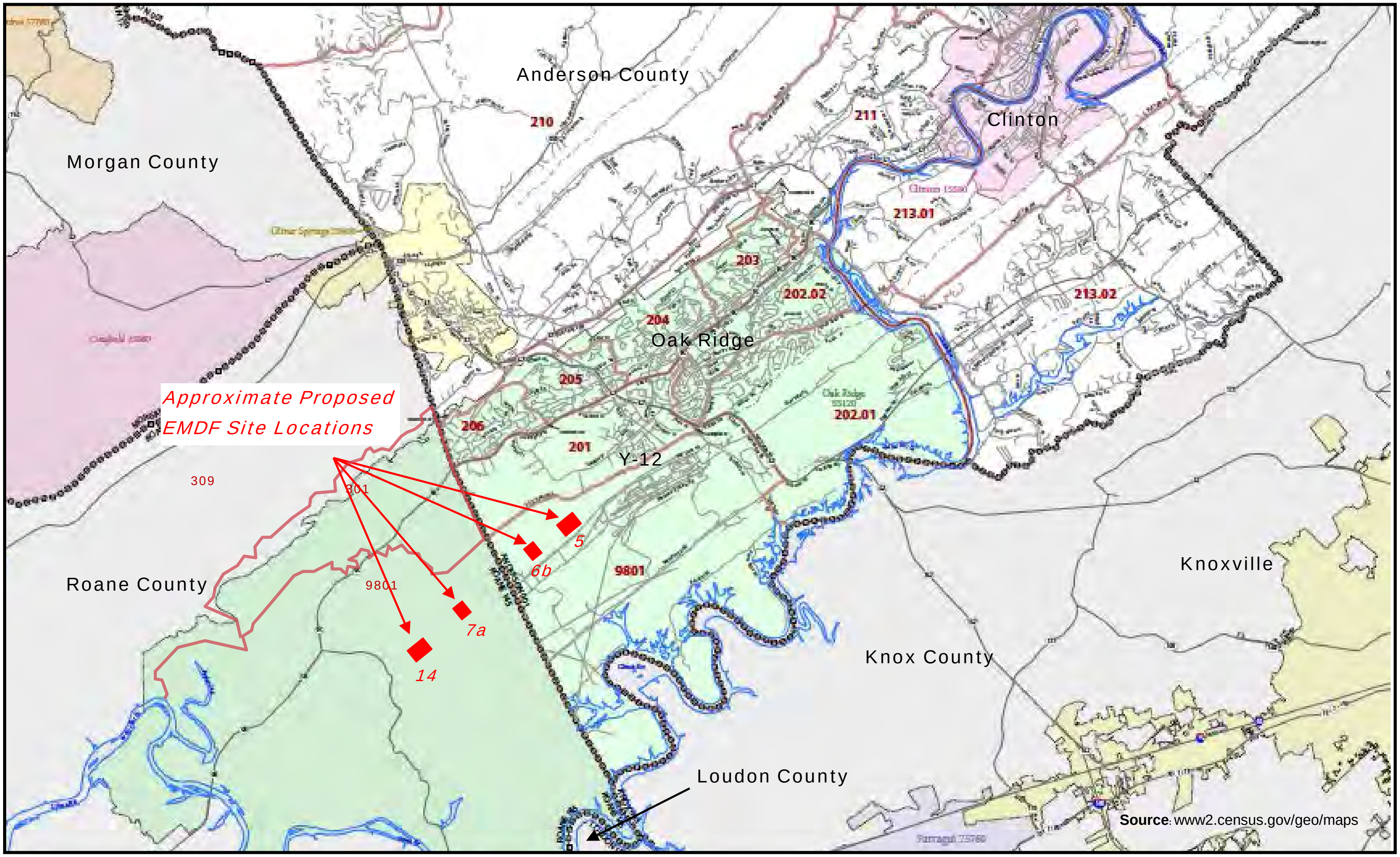

Figure E-5. Oak Ridge Reservation and nearby census tracts in the vicinity of the proposed EMDF sites

The age distribution for Oak Ridge is skewed towards an older population than for the state of Tennessee as a whole, with slightly lower percentages in the age groups from birth to age 44, and slightly greater population in the age groups from age 45 to over age 85. The sex distribution for Oak Ridge is similar to that of Tennessee. The estimated 2014 racial composition of Oak Ridge is 84.3% white, 9.5% black, 2.7% Asian, and 0.5% other races. About 2.9% of the population identifies as mixed-race, and 4.9% identifies as Hispanic or Latino.

The number of employees involved in DOE-Oak Ridge Office (ORO) work during 2009 was 13,621. This total includes both Federal and contractor employees. The 2009 payroll was $1,067,919,527. Employees reside in over 20 counties, as shown in Figure E-6. Knox, Anderson, and Roane counties together hold about 82% of these employees. The top five counties account for 89% of employees and 92% of the 2009 DOE payroll. Data for the top five counties are provided in Table E-3.

Table E-3. DOE-ORO employees and payroll for the top five counties in 2012

County	2012 Employees	2012 Payroll
Knox	5,721	$511,329,075
Anderson	3,065	$246,469,051
Roane	1,978	$157,088,580
Loudon	669	$56,489,413
Blount	405	$31,332,173

Source: http://www.oakridge.doe.gov/external/portals/0/hr/12-31-12%20payroll%20&%20residence.pdf

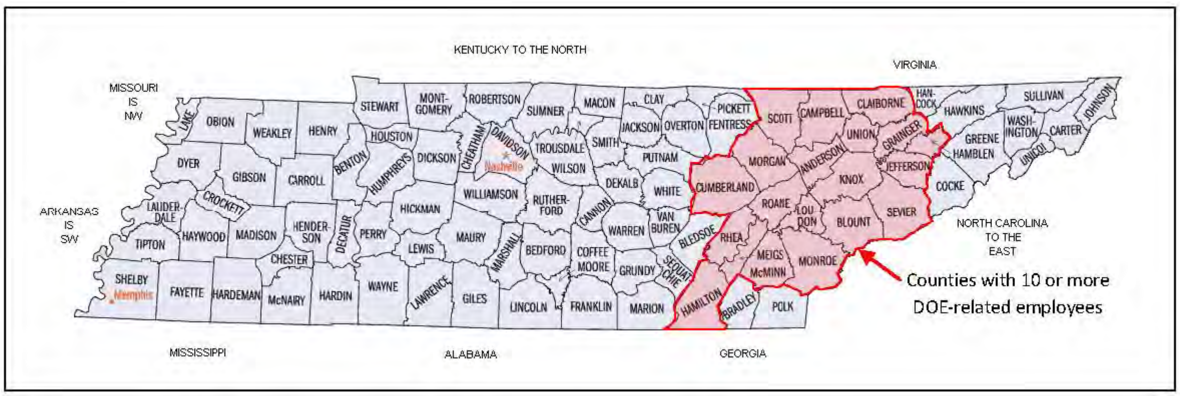

Figure E-6. Tennessee counties in which ten or more ORO employees lived during 2012

Figure E-7 shows the prospective EMDF site locations in BCV with respect to the nearest residential areas bordering the DOE property boundary to the north (areas to the south of BCV include non-residential DOE controlled land). The nearest Oak Ridge communities include Country Club Estates and the Scarboro community as well as isolated homes located across the more rural intervening area. Distances to the nearest residences are shown with respect to the possible EMDF sites.

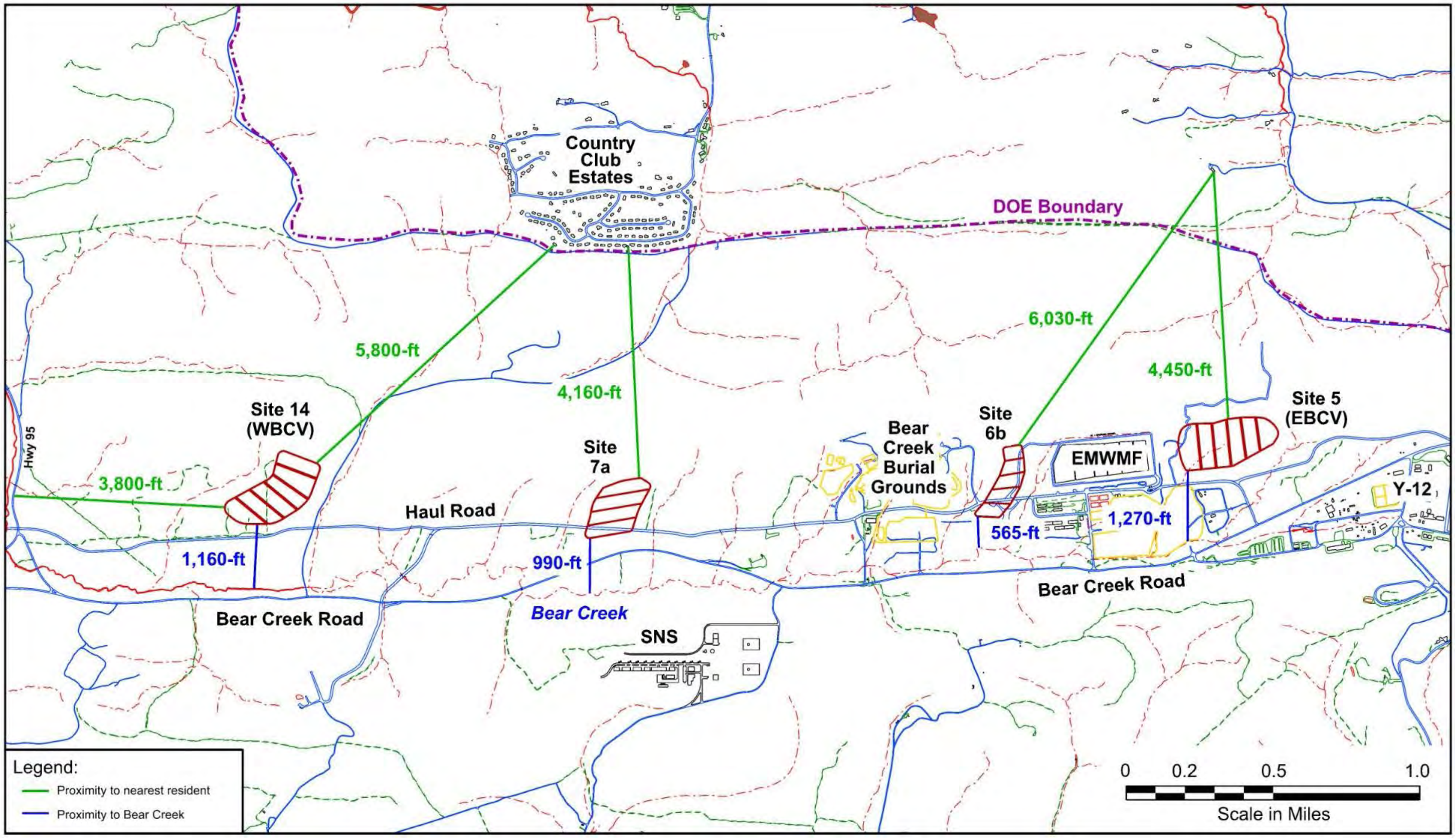

Figure E-7. Potential EMDF sites in BCV with respect to the northern DOE site boundary and the nearest Oak Ridge residents

Anderson County census Tract 201 is closest to the proposed EMDF site, had a population of 2,463 in 2000 and 3,111 in 2010, a 26.3% gain. Tract 201 had 1,794 housing units in 2010. The 2010 population density for tract 201, which includes much of the center of Oak Ridge, is 585 persons per square mile. Most of the Tract 201 population lives in the eastern half of the tract. Roane County census tract 301 is immediately west of Anderson County census tract 201, and had a 2010 population of 3,224. This tract includes the entire west end of Oak Ridge east of the Clinch River. Tract 301 had a population density of 459 persons per square mile in 2010. Most of the population of Tract 301 is along or north of Oak Ridge Turnpike. Tract 9801 includes the DOE property in Anderson and Roane counties north and west of the proposed sites with a population of zero. The U.S. Census Bureau projected that Anderson County population would grow by 19% from 2010 (75,129) to 2064 (89,814), and that Roane County population (54,181) would decline by about 10% over the same period (53,373).

Environmental justice concerns have been raised regarding the Scarboro community immediately north of the main Y-12 industrial area. This area is more than 1.5 miles from the nearest of the proposed sites (Option 5) and physically and hydrologically separated from this community by Pine Ridge. In addition, the proposed disposal sites are all located at distances much further away from the Scarboro area than the existing heart of the main Y-12 industrial complex. A former golf course and recently developed subdivision lie between the Option 5 site and the edge of the Scarboro community. Surface and ground water flow paths within BCV are physically separated from Scarboro by Pine Ridge and move toward the southwest away from the Oak Ridge and Scarboro areas.

No adverse impacts to Scarboro or any other Oak Ridge community have been noted during weekly site monitoring at the EMWMF, which is located directly adjacent to the proposed Option 5 site closest to Scarboro. Environmental monitoring has been conducted and reported each year since the beginning of disposal operations at the EMWMF in May 2002. Monitoring includes sampling and analysis of ground water, surface water, stormwater, contact water, leachate, sediment basin discharge and ambient air. The monitoring is conducted to demonstrate protection of workers, public health, and the environment. Annual monitoring reports are released to the public documenting the monitoring results (See for example the latest EMWMF annual monitoring report for Fiscal Year 2015: DOE 2015b) and have demonstrated no significant negative impacts to human health or the environment. Because of the physical isolation provided by Pine Ridge, the only potential means of contaminant migration to the citizens of Oak Ridge and the Scarboro community is via an air pathway. Ambient air monitoring is conducted at stations located along the upwind and downwind perimeter of the EMWMF. Air samples are analyzed for hazardous and radiological contaminants and compared against exposure limits. During FY 2014, 204 air samples were collected and analyzed. Weekly air samples are collected during dumping and waste movement from a minimum of three air samplers located along the perimeters of the waste cells. None of the samples reported values over the exposure limits designed to protect landfill workers and the general public. The absence of maximum air concentrations exceeding protective levels at the site perimeter suggest that impacts anywhere beyond the site are unlikely, particularly those on the order of a mile or more from the site.

2.5 TRANSPORTATION

The proposed BCV sites are accessible via Bear Creek Road to State Route (SR) 58 and SR 95, which connect to I-40 within 4.5 miles. Note, however, that all waste movement on the ORR for the On-site Disposal Alternative would be on non-public controlled-access haul roads constructed specifically for transporting wastes to the disposal site. The existing haul road from K-25 to the EMWMF follows BCV in close proximity to each of the proposed BCV disposal sites. Reeves road, leading from ORNL north to BCV could serve as a haul road. The haul road recently constructed for the Uranium Processing Facility (UPF) at Y-12 could serve as a haul road accessing buildings scheduled for demolition and other remediation sites in the main Y-12 industrial complex northeast of BCV.

2.6 CLIMATE AND AIR QUALITY

Abundant climate data are available from the National Oceanic and Atmospheric Administration station in Oak Ridge, as well as from ORNL, which operates seven meteorological towers scattered over the ORR.

2.6.1 Climate

The Oak Ridge area climate may be broadly classified as humid subtropical (Parr and Hughes 2006). The region receives a surplus of precipitation relative to the calculated amount of evapotranspiration that is normally experienced throughout the year. The region experiences warm to hot summers and cool winters.

Annual precipitation averages 52.6 inches water-equivalent, with an average of 10.4 inches snow per year.[2] The wet season typically occurs from November to May, and there is a short typical dry season from August through October.

The ORNL Meteorological Program compiles 30-year average and 63-year record temperature and precipitation data. The 30-year average maximum daily temperatures range from a low of 46.9° F in January to 88.5° F in July, and the mean annual maximum temperature is 69.6° F. The 30-year average minimum temperatures vary from 28° F in January to 67.5° F in July. The mean annual temperature is 58.5° F.

Wind direction is slightly bimodal. The dominant wind direction is from the southwest and winds from the northeast form the secondary wind direction. Figure E-8 provides an annual wind rose for the Y-12 West Tower for 10 m above ground level; the wind roses from 15 m and 60 m are very similar. The Y-12 West Tower is approximately 0.8 miles northwest of the Option 5 site. Additional assessments of meteorological data are provided in Attachment A in relation to the recent Phase I site investigation completed at Site 5.

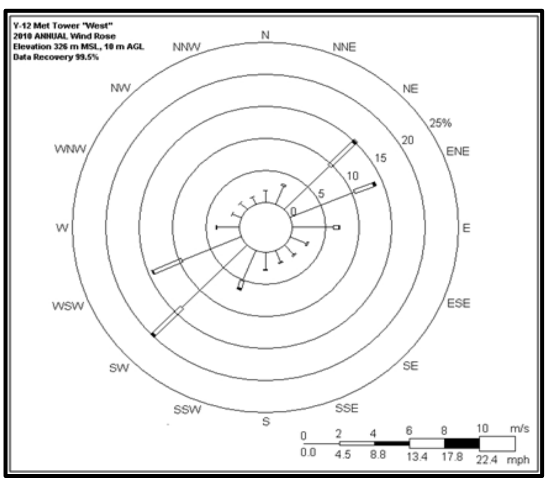

Figure E-8. Representative wind rose diagram for theY-12 West meteorology tower in 2010

Source: http://www.ornl.gov/~das/web/page7.cfm

[2] Climate statistics are from http://www.ornl.gov/~das/web/ Normals/30YRNorm.pdf

2.6.2 Air Quality

The U.S. Environmental Protection Agency (EPA) Office of Air Quality Planning and Standards set National Ambient Air Quality Standards (NAAQS) for six criteria pollutants: carbon monoxide (CO), carbon dioxide (CO_2), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3), particulate matter with aerodynamic diameter less than or equal to 2.5 µm ($PM_{2.5}$), particulate matter with an aerodynamic diameter less than or equal to 10 µm in diameter (PM_{10}), and lead (Pb). Areas that meet NAAQS limits are classified as attainment areas, while areas that exceed NAAQS for a particular pollutant are classified as nonattainment areas for that pollutant. On March 12, 2008, the EPA promulgated the new ozone standard of 0.075 parts per million.

The ORR located in Anderson and Roane Counties is part of the Eastern Tennessee-Southwestern Virginia Interstate Air Quality Control Region (40 CFR 81.57). The EPA has designated Anderson County an 8-hour ozone and $PM_{2.5}$ non-attainment area. Air quality in the greater Knoxville and Oak Ridge area is in attainment for all other criteria pollutants, as defined by NAAQS.

2.7 WATERSHED TOPOGRAPHY, DRAINAGE, AND LAND USE ZONES

The topography of the BCV watershed and surrounding areas with general drainage pathways for surface water and shallow ground water is illustrated in Figure E-9. The valley trends northeast-southwest and is bounded by Pine Ridge on the northwest and Chestnut Ridge on the southeast. Bear Creek drains to the southwest along the lower elevation southeast side of the valley. Several smaller tributaries, designated as the North Tributaries (numbered sequentially as NT-1, 2, etc. from northeast to southwest) drain southward from Pine Ridge across the geologic strike of the valley feeding into Bear Creek. Elevations range from highs near 1260 ft along the crest of Pine Ridge to around 800 ft at the Bear Creek water gap in Pine Ridge at SR 95.

BCV is approximately 10 miles long and extends from the topographical divide near the west end of the Y-12 industrial area southwestward to the Clinch River. The BCV drainage includes two main creeks, Bear Creek and Grassy Creek. Bear Creek drains the entire Bear Creek watershed which includes the three potential EMDF sites and historical Y-12 waste sites in the middle and upper portions of the valley. Bear Creek exits BCV through a water gap alongside SR 95 (White Wing Road) just southwest of the WBCV Site 14. Grassy Creek further southwest of SR 95 drains a separate smaller watershed within BCV directly into the Clinch River. The surface water drainage divide between Grassy Creek and Bear Creek lies about one mile southwest of SR 95.

The geomorphology of BCV directly reflects the erosional resistance of the underlying geologic formations. Slopes on the south flank of Pine Ridge underlain by the more resistant Rome Formation are concave and flatten toward Bear Creek along the valley floor. First and second order stream valleys are organized in trellis/dendritic drainage patterns draining from Pine Ridge to Bear Creek. Upper slopes along Pine Ridge feature several interfluves separated by incised steep-sided ravines. A lower elevation subsidiary ridge runs parallel with Pine Ridge to its southeast. This subsidiary ridge is underlain by more resistant beds in the Dismal Gap/Maryville formation. A strike valley underlain by less resistant formations (the Pumpkin Valley Shale, Friendship/Rutledge formation, and Rogersville Shale) is located between the two ridgelines. Further southeast the valley flattens into broad low relief areas underlain primarily by the Nolichucky Shale and the Maynardville Limestone (See Figure E-9).

The current geomorphic surface appears relatively stable. Available satellite images and field reconnaissance at Site 5 suggest there is no visible evidence of recent large scale mass movement at the proposed EMDF sites in BCV. Topographical maps show no indications of sinkholes, sinking streams, resurgent springs, or other surface features related to karst terrain at or near the proposed EMDF footprints, although karst flow is well documented within the outcrop belt of the Maynardville Limestone along the general course of Bear Creek. No karst features have been identified

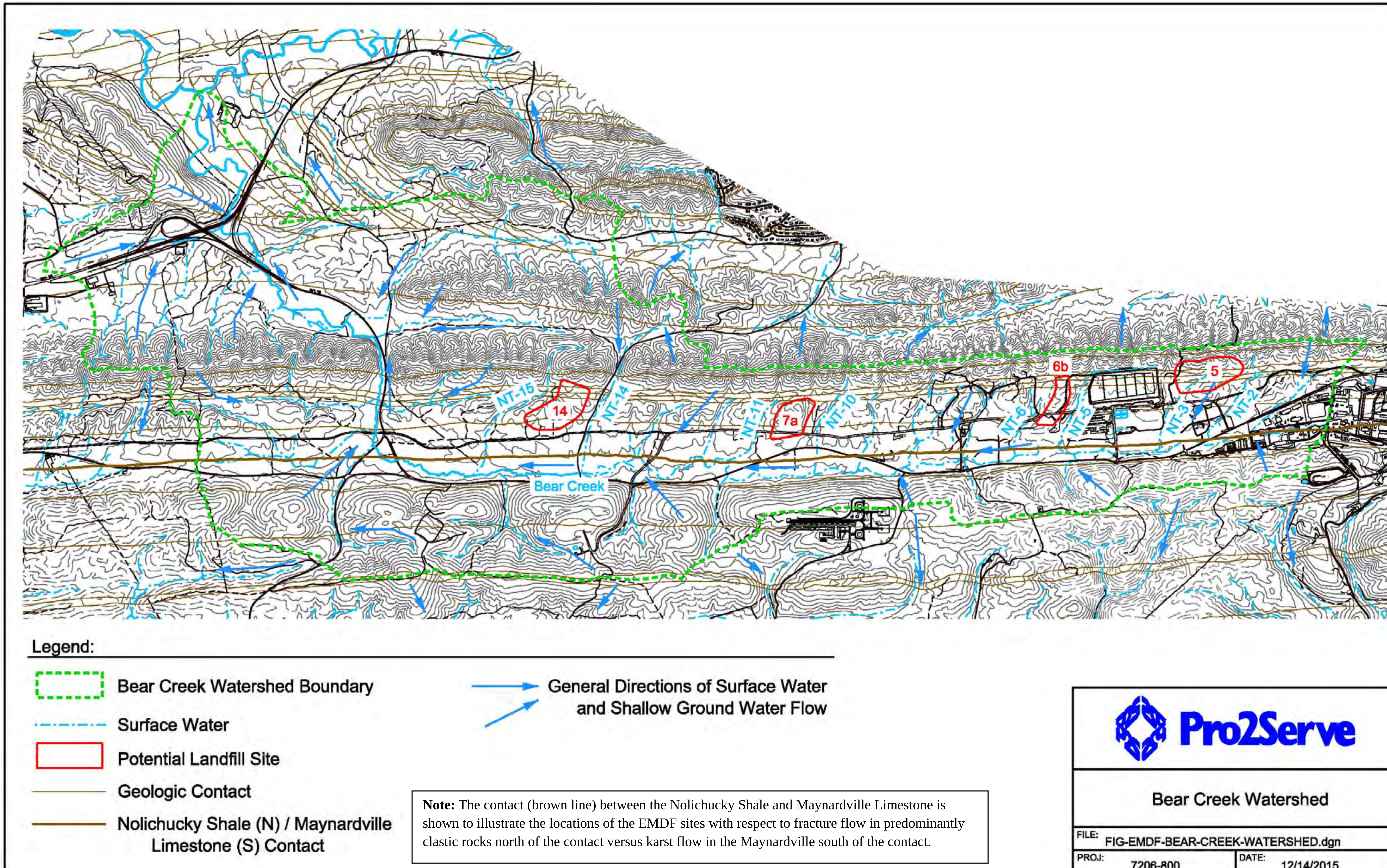

Figure E-9. Watershed for BCV and adjacent areas showing generalized directions of stream flow and shallow ground water.

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during field reconnaissance at Site 5. Karst features have not been reported at other waste sites elsewhere in BCV except in areas associated with the Maynardville Limestone.

The BCV Phase I ROD (DOE 2000) divides the BCV watershed into three zones (Figure E-1) for the purposes of establishing and evaluating performance standards for each zone in terms of land and resource uses and human health and ecological risks following remediation. The proposed EBCV Site 5 is located in Zone 3, which is an industrialized historical waste management area. Zone 3 has a designated future land use classification of "Controlled Industrial Use" in the BCV Phase I ROD. Sites 6b/7a are split among Zone 2, designated for future recreational use (7a), and Zone 3 (6b), while Site 14 (WBCV) is exclusively in Zone 1 designated for unrestricted use.

2.8 HYDROGEOLOGICAL CONCEPTUAL MODELS

Hydrogeological conceptual models were developed in the early 1980's and 1990's to facilitate site characterization and remediation of contaminant sources and plumes within the unique site conditions across the ORR. The conceptual model for the BCV watershed is perhaps best described in the BCV RI Report (DOE 1997), which incorporates the hydrologic framework for the ORR developed by ORNL researchers (Solomon et al 1992, Moore and Toran 1992, Hatcher et al 1992), with the specific conditions unique to BCV and to contaminant fate and transport within BCV. The site-specific conceptual models for the proposed EMDF sites are a subset of the overall conceptual model for the BCV watershed as the potential future release of contaminants via ground water and surface water pathways would migrate initially from the footprint areas downgradient across the lower elevation areas of BCV dissected by the NTs and ultimately toward the main channel of Bear Creek.

The hydrogeological conceptual models presented for BCV and reviewed below for the proposed EMDF sites present surface water and ground water flow patterns under natural conditions before landfill construction. It is important to recognize, however, the significant alterations to natural conditions that will occur during and after construction of the proposed EMDF which significantly change runoff and recharge conditions at and near the footprint areas. Subsequent sections address both the natural pre-construction conditions and anticipated changes during and after construction.

2.8.1 Hydrogeological Conceptual Model for Bear Creek Valley

The BCV RI Report (DOE 1997) includes a hydrogeological conceptual model that integrates existing contaminant source areas and ground water plumes within the overall context of the geology, and surface water and ground water hydrology of the BCV watershed. Most relevant to the proposed EMDF sites, this conceptual model addresses the contrast in surface and subsurface flow conditions within and across the predominantly clastic formations of the Rome, Pumpkin Valley, Friendship/Rutledge, Rogersville, Dismal Gap/Maryville, and Nolichucky formations underlying most of the valley floor and those within and across the predominantly carbonate formations of the Maynardville Limestone and lower Copper Ridge Dolomite underlying a more narrow swath along the southern lowest parts of BCV. This contrasting nature of the clastic and carbonate rocks is illustrated conceptually in Figure E.10. The figure illustrates the open conduits in the subsurface karst network of the Maynardville Limestone underlying the valley floor along Bear Creek relative to the predominantly clastic rocks without karst features to the north of the Maynardville/Nolichucky contact. As shown on the index map, the cross section is located near the center of the BCV watershed across the BCBG. Similar to the BCBG footprints shown in yellow, the proposed EMDF footprints are centered across varying widths above the outcrop belts between the Pumpkin Valley Shale and the lower half of the Nolichucky Shale.

Chapter 2 of the BCV RI Report (DOE 1997) presents a summary presentation of the BCV conceptual model, but a more detailed presentation of the model is presented in Appendix C of the BCV RI report including extensive data from surface water and ground water monitoring activities conducted over

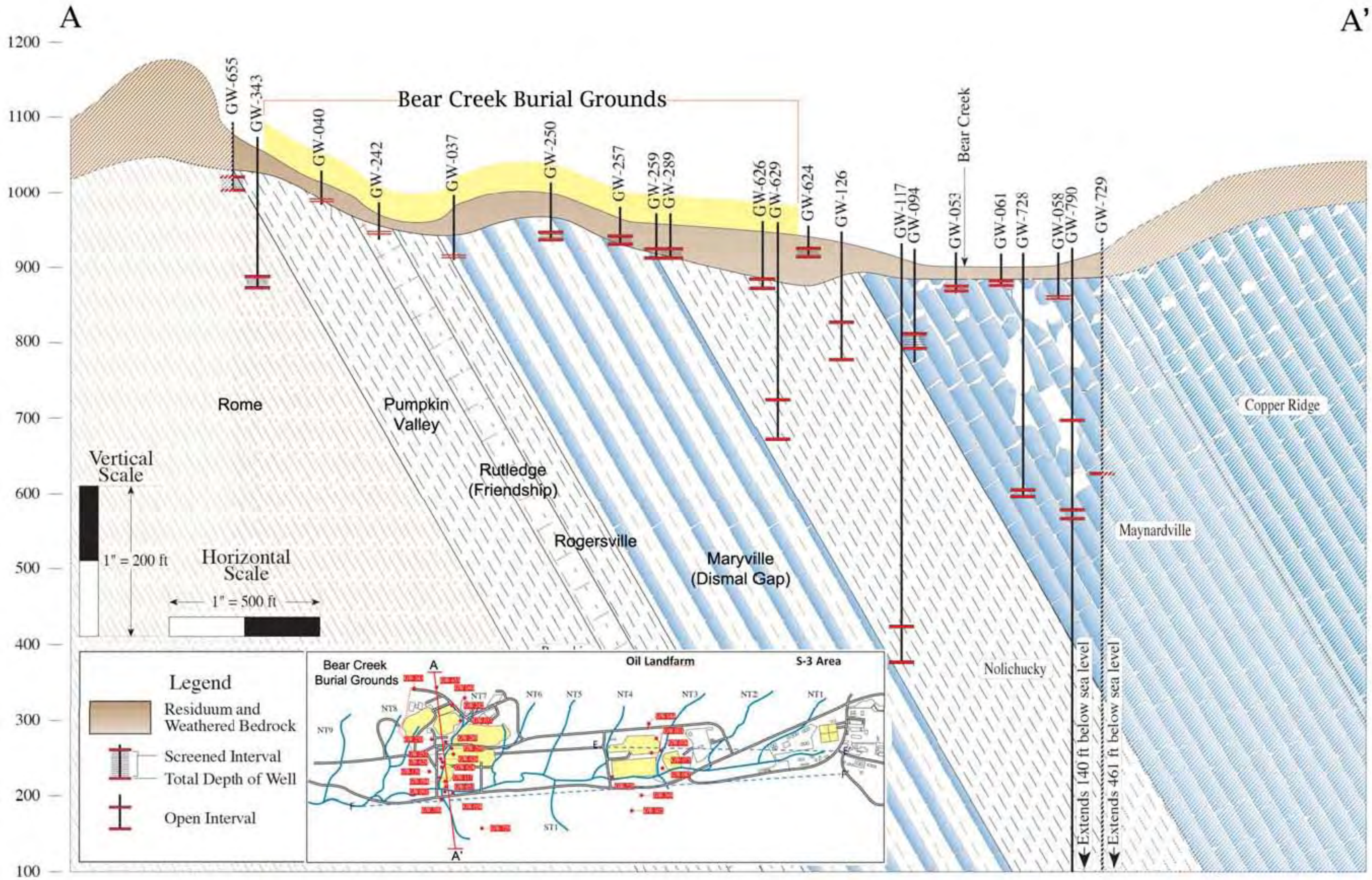

Figure E-10. North-south cross section across BCV illustrating the karst conduit ground water flow system in the Maynardville Limestone relative to the predominantly clastic rocks characterized by fracture flow and the absence of karst north of the Maynardville/Nolichucky contact

[From the ORR Ground Water Strategy Report, UCOR 2013a] three decades of investigations and reporting. The BCV RI report (DOE 1997) provides comprehensive details, interpretations, and supporting data and figures that should be reviewed for additional information only summarized below and in subsequent sections reviewing the surface water hydrology and hydrogeology for BCV.

The subsections that follow present details of surface water hydrology and hydrogeology that form the detailed basis of the site conceptual model for BCV and the site-specific conceptual models for each of the proposed EMDF sites. The BCV conceptual model, including the proposed EMDF sites, makes an important distinction between surface water flow along the NTs and ground water flow within and across the outcrop belts of predominantly clastic rocks, versus surface water flow along Bear Creek and ground water flow within the karst conduit network of the Maynardville Limestone. The ground water flow paths through regolith materials and bedrock fractures within the predominantly clastic rocks, differs greatly from that of the karst network of the Maynardville. The clastic formations with predominantly shaley rocks cover roughly 80-90% of the BCV floor versus the relatively narrow strip with karst features in the Maynardville (as shown in the geologic map and cross sections above). Across the clastic outcrop belts overall shallow/intermediate level ground water tends to flow southe to southwest, whereas flow within the Maynardville and along Bear Creek tends to follow the geologic strike toward the southwest. Ground water contaminants reaching Bear Creek and the Maynardville from sites to the north may move more rapidly within karst conduits but may also be subject to dilution and commingling of ground water and surface water.

2.8.2 Hydrogeological Conceptual Models for EMDF Sites in Bear Creek Valley

The footprints for each of the proposed EMDF sites in BCV are located on the predominantly clastic rocks of the Conasauga Group ranging from the lower Pumpkin Valley Shale to the lower Nolichucky Shale. Potential subsurface contaminant releases from these source areas must initially migrate in dissolved aqueous solution from the unsaturated waste downward through an underlying unsaturated zone composed of low permeability engineered liner, geobuffer materials (15ft thick), structural fill, and naturally occurring in-situ materials to reach the underlying water table at the top of the saturated zone. From there dissolved contaminants migrate along horizontal and vertical ground flow paths downgradient of the footprint toward discharge zones along adjacent valley floors. Depending on the conditions at each of the proposed footprints, the contaminant migration path(s) may also intersect with portions of high permeability underdrain trench and blanket materials. The proposed underdrain networks are designed to establish new base levels for the water table that will prevent upward movement of the water table surface into the geobuffer. The underdrain networks at the proposed sites comprise no more than 10% of the landfill footprint area. Ground water and surface water flow paths along and adjacent to the NT valleys adjoining the proposed sites ultimately lead downgradient toward the base level elevations imposed by Bear Creek which drains the entire valley toward the southwest.

The most detailed EMDF conceptual model illustrations were previously developed for Site 5, but are conceptually applicable to each of the other proposed EMDF sites in BCV. Figures presenting generalized conceptual models for Sites 6b, 7a, and14, are presented that mimic those developed for Site 5. The site-specific hydrogeological conceptual model for Site 5 is presented in the Plate 1 of Attachment A and in subsequent figures and summary descriptions. The illustrations and descriptions provided in the cross sectional views and details of Plate 1 summarize fundamental aspects of the model. The Plate 1 cross section is drawn to scale near the center of the Site 5 footprint and oriented from northwest to southeast perpendicular to geologic strike. Closeup inserts illustrate details of the hydrogeological model for upland areas and for lowland areas along the valley floor of NT-3 that are characteristic for each of the proposed sites. Intermediate elevation areas of the site which comprise much of the footprint are transitional between the upland and lowland areas. The relative positions of the stormflow zone, vadose zone, water table interval, and intermediate and deep ground water intervals are illustrated in cross sectional views. The closeup views also highlight the zone of water table fluctuation that commonly occurs within saprolite of the regolith and the upper portion of bedrock below auger refusal depths. The detailed vertical profiles also schematically illustrate the relative change from relatively more porous and permeable unconsolidated regolith materials and shallow weathered and fractured bedrock downward into denser less fractured and unweathered bedrock at greater depths. The naturally occurring regolith typically includes a thin topsoil layer and silty/clayey residuum layer that grades downward into a variably weathered and fractured bedrock (saprolite) layer above solid bedrock. Along the flanks and floors of stream valleys, the regolith may include relatively loose porous and permeable colluvial and alluvial materials that mantle the residuum and saprolite (see details of Plate 1).

As shown in Figure E.11, Solomon et al (1992) defined hydrologic subsystems for areas underlain by predominantly clastic (non carbonate) rocks referred to on the ORR as aquitards. The technical basis for these subsystems are not reviewed here but are described in detail in Solomon et al (1992), and Moore and Toran (1992). The subsystems include: the stormflow zone, the vadose zone, three intervals within the saturated zone (the water table, intermediate, and deep intervals), and an aquiclude at great depth where minimal water flux is presumed to occur. Detailed water budget research on ORR watersheds that are similar to those of the EMDF sites demonstrate that the majority (>98%) of ground water flux occurs via two subsurface pathways: 1) within the stormflow zone associated with the surficial topsoil layer and 2) within the water table interval which commonly occurs within regolith saprolite and weathered bedrock within and below the zone of water table fluctuations. Solomon et al (1992) reported that >98% of the estimated subsurface water flux occurs via two subsurface intervals: 1) the stormflow zone (>90%) within the surficial topsoil/root zone and 2) the uppermost part of the saturated zone defined as the water table interval (~8%). The intermediate and deep intervals of the saturated zone at depths on the order of 100 ft or more accounted for <2% and <1% of water flux, respectively. However, subsequent watershed studies reported by Clapp (1998) have shown that the proportion of flux via the stormflow zone may be much less. His results suggested that the stormflow zone contribution is closer to 70% during an average year (rather than the >90% reported by Solomon et al (1992)). The overall conclusions of the study suggest that annual ground water recharge and ground water flux from the water table interval to stream flow may be much higher than originally proposed by Solomon et al (1992), and closer to 30% or more on average rather than the 8% water flux originally reported. The relative proportions of the intermediate and deep intervals of the ground water zone would remain proportionally low, similar to those presented by Solomon et al (1992), as illustrated in Figure E-11. Most of the active ground water flux would still occur via the stormflow zone and water table interval. However, landfill construction will eliminate virtually all natural flux via the stormflow zone, leaving the water table interval as the primary route for lateral migration of contaminants that may leave the subsurface waste footprint below the proposed EMDF sites.

The boundaries between the water table/ intermediate levels and deep level were also based on changes in ground water chemical compositions with depth thought to be related to water residence time. The approximate boundary between mixed-cation-HCO_3 water and Na-HCO_3 water was defined at depths ranging from 30-50m (~100-165 ft) for the predominantly clastic rocks on the ORR such as those at and near the proposed EMDF sites. The deep "aquiclude", composed of saline water having total dissolved solids ranging from 2,000 to 275,000 milligrams per liter lies beneath the deep interval at depths in portions of BCV believed to be greater than 300 m (~1000 ft) [see Solomon et al (1992) for details].

Figures E-12, E-13, and E-14 present three dimensional (3D) perspective views at and downgradient of Site 5. These figures provide additional tools for visualizing the conceptual model of surface and ground water flow patterns typical for the proposed EMDF sites. The conceptual model cross section (Plate 1) and 3D figures illustrate the relationships between the key conceptual engineering design elements for Site 5 and site specific topography, surface water features (springs, seeps and wetland areas, and NT drainage paths), and estimates of the current water table surface. Preliminary conceptual engineering design drawings, including underdrain trench/blanket networks, geobuffer/liner systems, and final landfill surface grades, have also been developed for Sites 6b, 7a, and 14, defining waste cell base elevations that allow for preliminary 3D analysis of each site with respect to local topographical, surface water, and

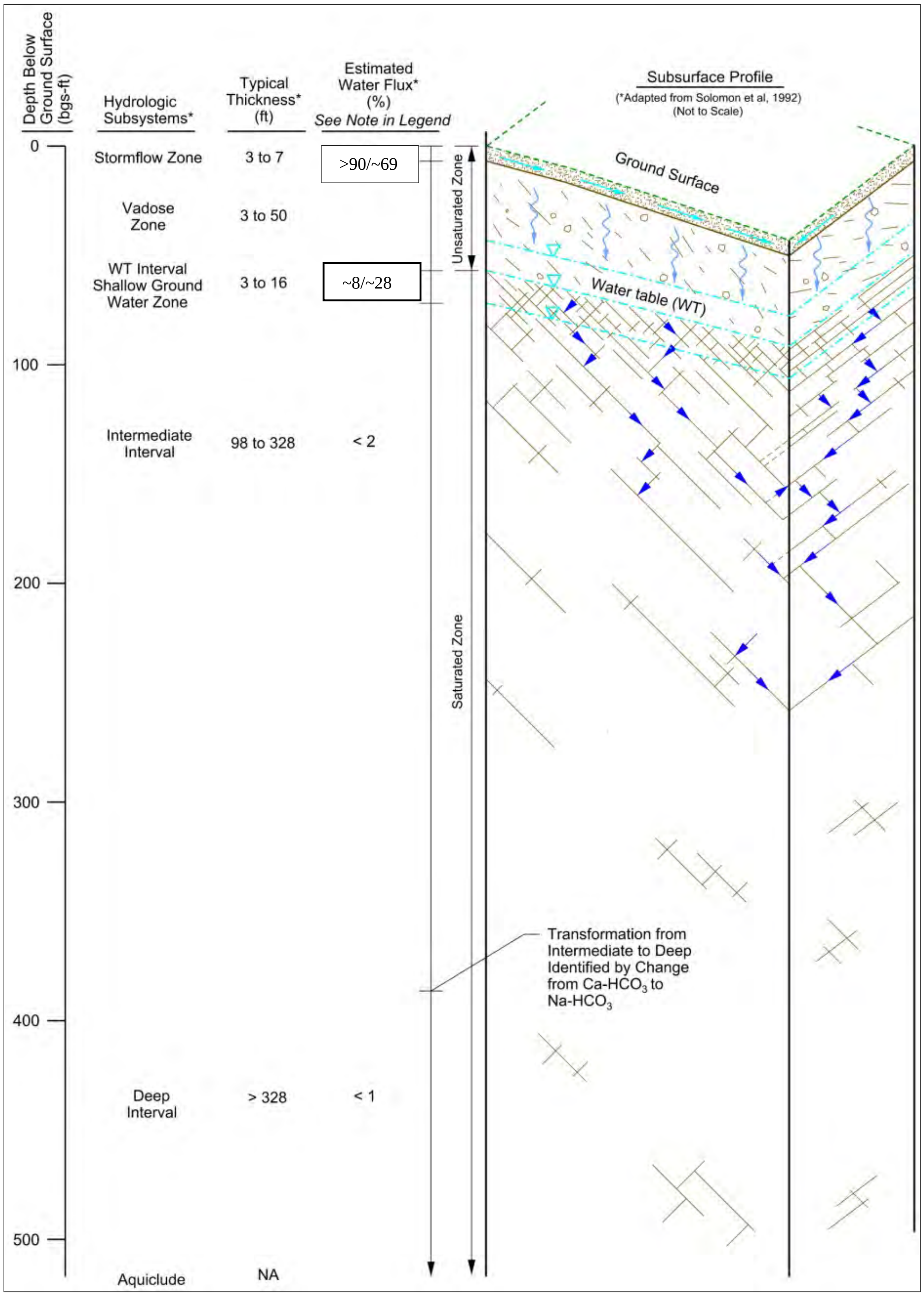

Figure E-11. Subsurface conceptual profile indicating hydrologic subsystems for predominantly clastic rock formations on the ORR (based on Solomon et al 1992)

Figure Notes:

Hydrologic subsystems are defined on the basis of subsurface water flux which decreases with depth

Subsystems are vertically gradational and not separated by discrete boundaries.

Depths shown are approximations for conceptual purposes only

Research by Clapp (1998) suggests that the original estimates of >90% and 8% water flux for the stormflow and water table intervals shown may actually be more on the order of ~69% and ~28%, respectively with the remaining ~3% flux attributable to the intermediate and deep intervals.

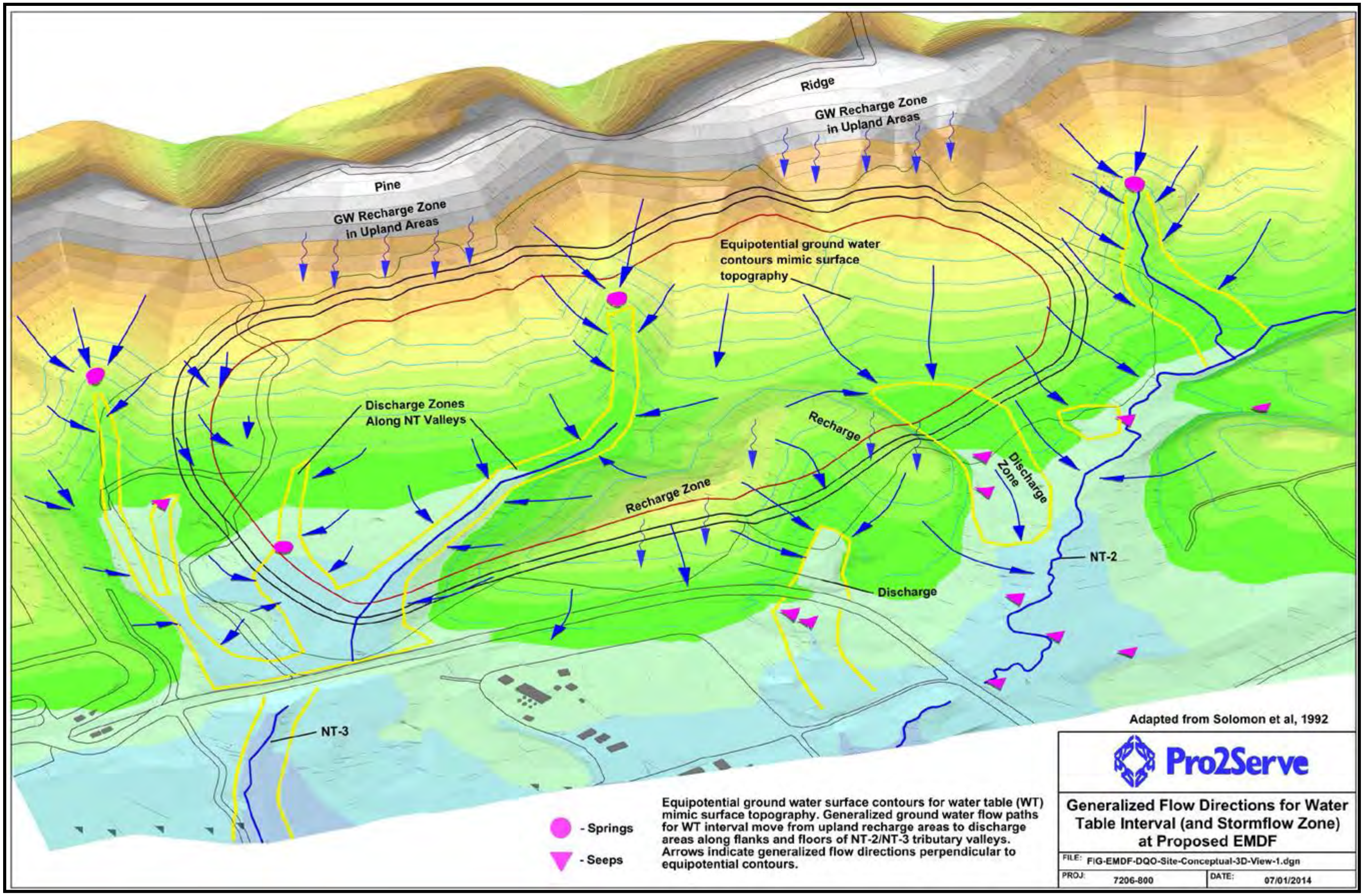

Figure E-12. Pre-construction hydrogeological site conceptual model for ground water flow within the shallow water table interval at Site 5

Note: color shading in these figures reflects 10 ft topographic contour interval changes from highest (light gray) to lowest elevations (pale blues)

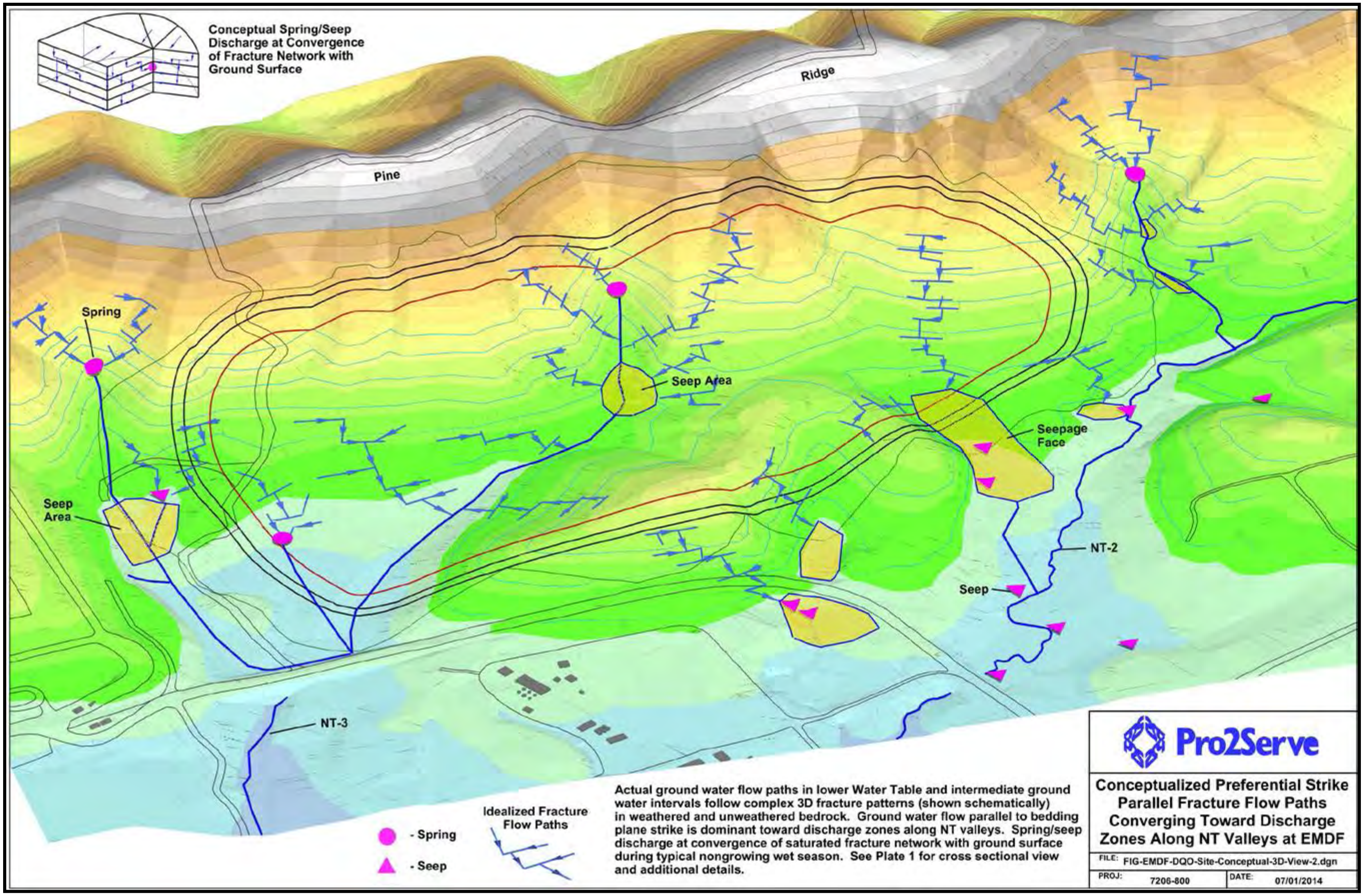

Figure E-13. Pre-construction hydrogeological site conceptual model illustrating several individual and idealized conceptual ground water fracture flow paths in the water table and intermediate ground water intervals at Site 5

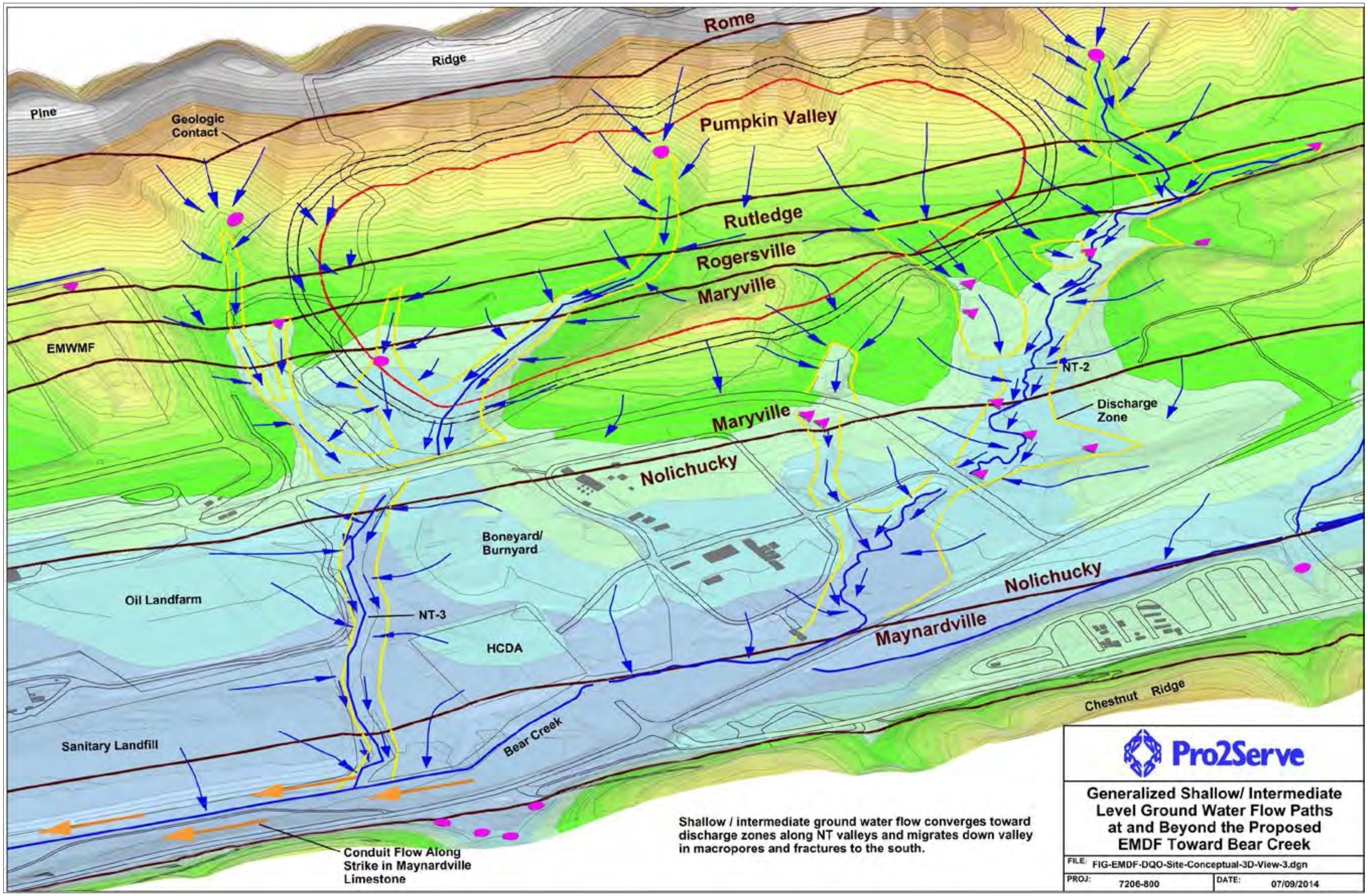

Figure E-14. Pre-construction hydrogeological site conceptual model for generalized ground water flow paths in the water table and intermediate levels of the saturated zone at and downgradient of Site 5

ground water conditions. Previous investigations at Sites 14 and 5 provide data on subsurface conditions that are not available for Sites 7a and 6b where previous investigation data is limited or nonexistent.

As illustrated conceptually in Figures E-12 through E-14, ground water flow in the water table and intermediate intervals migrates from recharge zones in upland areas and converges toward and slowly discharges along valley floors supporting baseflow along the NT stream channels. Hydrographs from continuous monitoring of water levels in monitoring wells at Site 5, at the BCBG site, and elsewhere in BCV and on the ORR in similar settings indicate that ground water levels rise fairly quickly in response to rainfall/recharge events but fall to lower levels relatively quickly in the absence of rainfall/recharge events. The recession curves of the hydrographs indicate relatively quick drainage of the shallow water table interval via lateral ground water flow and baseflow discharge to the nearest tributary stream channels. In addition to the more lateral flow at and near the water table, upward seepage may occur from the water table and intermediate ground water intervals via transmissive and interconnected regolith and bedrock fractures that intersect with valley floors. Flow along fracture paths tends to be more rapid and preferential along geologic strike toward the cross cutting NT tributary valleys, where hydraulic gradients are parallel to geologic strike, as illustrated conceptually in Figure E-13. Actual fracture flow paths are three dimensionally complex and cannot be accurately defined far beyond their locations in individual monitoring wells. The individual fracture paths illustrated in Figure E-13 are greatly simplified and purely conceptual and schematic. The number of transmissive fractures shown is also extremely limited relative to the greater number that are likely to exist at the local scale of Site 5. The figures also do not illustrate the 3D complexities and relationships between fractures and geological attributes associated with the regional dip to the southeast, micro and mesoscale deformation, and variations in lithologies and stratabound fracture networks that have been demonstrated in research on the ORR. Individual fractures or fracture sets are commonly not identified during the drilling and logging process and generally require rock coring and detailed in-situ hydraulic testing profiles to accurately identify permeable from impermeable intervals. Ground water discharge through macropores and preferential pathways of shallow regolith materials (topsoil and clayey residuum) and through highly weathered and fractured saprolite and bedrock is commonly expressed at individual seeps and springs, and broader seepage faces delineated as wetland areas. These ground water discharge areas occur along lower slopes of the NTs and along upper reaches of the NTs where abrupt slope transitions occur (see springs/seeps and wetland areas shown on Figures E-12 through E-14, and similar figures for Sites 6b, 7a, and 14).

Another important aspect of the conceptual model relates to ground water flow paths and rates that are dominant along fractures that trend parallel to geologic strike. Tracer tests and investigations of ground water contaminant plumes on the ORR and in BCV demonstrate that ground water tends to move more rapidly along fracture flow paths that are parallel to geologic strike versus flow paths that are perpendicular to strike. This is particularly true for the water table and upper intermediate intervals of the saturated zone where most ground water flux occurs. For the proposed EMDF sites, it is therefore important to view the topography at each site footprint with respect to geologic strike (which is parallel to the crest of Pine Ridge) and the orientation of adjacent NT valleys. Water table contour maps for Site 5, Site 14, and similar areas in BCV (shown in subsequent sections) tend to mimic surface topography. Footprint areas where water table (or potentiometric surface) contours trend at right angles to geologic strike would suggest areas with more rapid ground water flux toward the nearest NTs. In contrast, footprint areas where water table contours trend parallel with geologic strike would suggest areas with slower ground water flux toward the nearest NTs or southward toward Bear Creek. Footprint areas intermediate between these extremes would constitute areas where hydraulic heads, common orthogonal fracture orientations, and topography result in flow directions and rates of intermediate proportion. Above all, the conceptual model suggests that at each of the proposed footprints, the most rapid ground water flux will tend to occur along strike parallel flow paths toward the adjacent north-south trending NTs. At each site, the NTs form base level zones for ground water discharge adjacent to the upland footprint areas. The NTs immediately east and west of the footprints cut across the geologic strike of the formations and in areas closest to the footprint determine and constrain the lowest elevations of the water table surrounding the higher elevations of the water table in the uplands between the bounding NTs.

Figures E-15, E-16, and E-17 are 3D perspective views of proposed Sites 6b, 7a, and 14 illustrating the generalized flow paths for surface water and shallow/intermediate ground water from each site downgradient toward Bear Creek. The figures present site-specific conceptual models conveying the generalized subsurface ground water pathways through regolith and bedrock materials that are dominantly parallel to geologic strike and that discharge to the NT stream channels adjacent to each of the sites. A smaller portion of ground water flow at each site occurs through fracture networks that are perpendicular to strike. Travel time for ground water flow (and dissolved contaminants) along the latter subsurface pathways are presumed to be longer and possibly more tortuous than those parallel with strike that discharge more readily to the NT valley floors.

It is important to note that the natural conditions just described will be significantly altered during the construction and post-closure period of the proposed EMDF. As the landfill is constructed the area formerly available for direct and rapid ground water recharge across the footprint will be eliminated. Remaining areas available for rapid recharge to the water table will be restricted to undisturbed areas outside of the footprint, upgradient and adjacent to the landfill. The significant reduction in direct recharge combined with the proposed underdrain networks will lower the water table below the footprint and reduce the lateral flux of ground water passing below the footprint. Section 2.9 below explores changes to natural conditions and the site conceptual model that are likely during and after landfill construction. These changes are addressed in the 3D fate and transport model simulations described in Appendix H that include changes to recharge, surface and ground water flux, and potential contaminant transport. These changes are also reflected in the post construction water table configurations reviewed elsewhere in Appendix E.

2.9 EFFECTS OF LANDFILL CONSTRUCTION ON THE WATER TABLE

Figure E-18 illustrates key changes to surface and ground water hydrology from pre construction through construction, capping, and closure. The figure is based on an accurately drawn northwest-southeast cross section located near the center of the proposed EBCV Site 5, but the changes noted in the figure and described below are applicable to each of the other possible EMDF locations in BCV. The figure illustrates the relationships between the water table and the primary components of the conceptual design for the EMDF, and the progressive lowering of the water table from its pre construction natural configuration to that during and after landfill construction and final capping.

The Stage I pre construction phase shows the water table or potentiometric surface of the shallow water table interval for April 21, 2015, the seasonally highest level recorded at Site 5 based on the Phase I investigation. Hourly measurements were collected in the Phase I monitoring wells at Site 5 over a one year period from December 1, 2014, through November 30, 2015. A lower water table is shown in Stage I as well to illustrate the overall range in water level fluctuations that occur not only seasonally but over much shorter periods of several days during and after significant rainfall/recharge events that may occur during almost any month of the year. The April 2015 water table surface is representative of the relatively higher water levels that occur each year during the wet non-growing winter and spring seasons. The cross sections illustrate the surface topography, the configuration of the 15 ft thick geobuffer/liner system, the lower and upper boundaries of the waste, and the final surface of the cap upon closure. Note that the vertical scale of the cross sections has been exaggerated 1.5 times the horizontal scale to better illustrate the various layers. Actual slopes and topographic relief across the site are less than shown (accurate cross sections without vertical exaggeration are provided in Plates included with Attachments A and B for greater detail and accurate portrayal of site conditions).

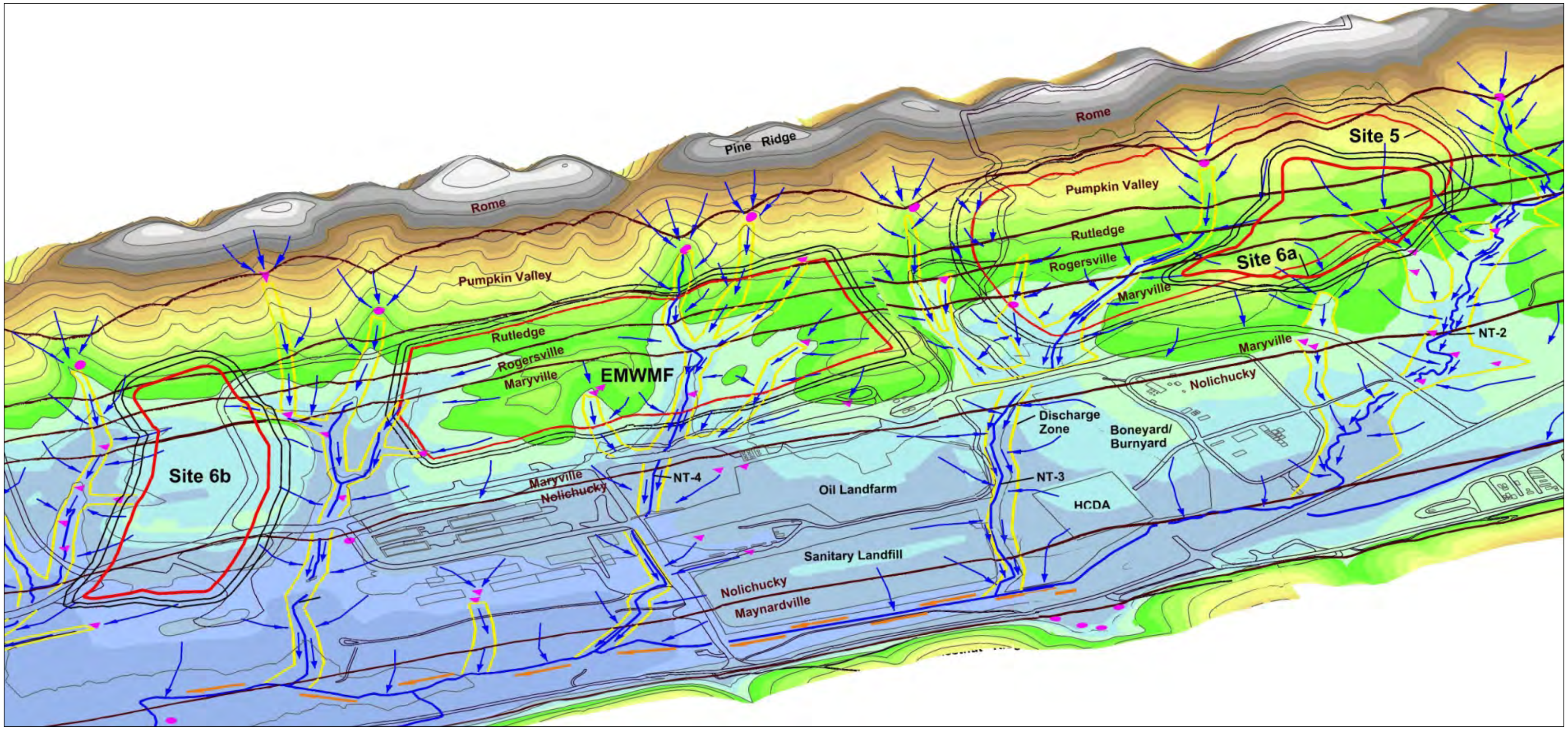

Figure E-15. Pre-constructin hydrogeological site conceptual model for generalized ground water flow paths in the water table and intermediate levels of the saturated zone at and downgradient of Sites 6b and 5, and for the existing EMWMF prior to landfill construction.

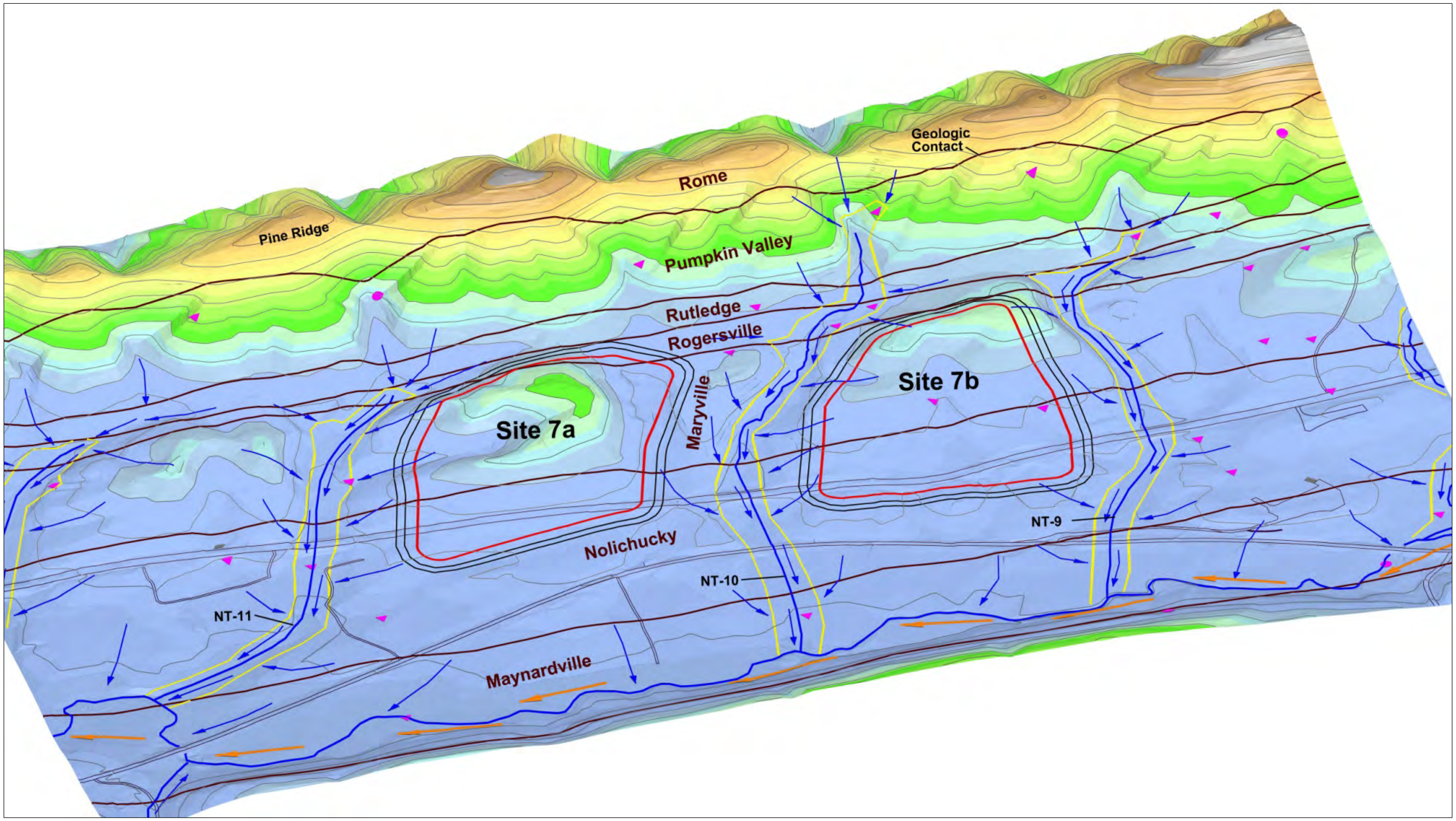

Figure E-16. Pre-construction hydrogeological site conceptual model for generalized ground water flow paths in the water table and intermediate levels of the saturated zone at and downgradient of Site 7a (and 7b)

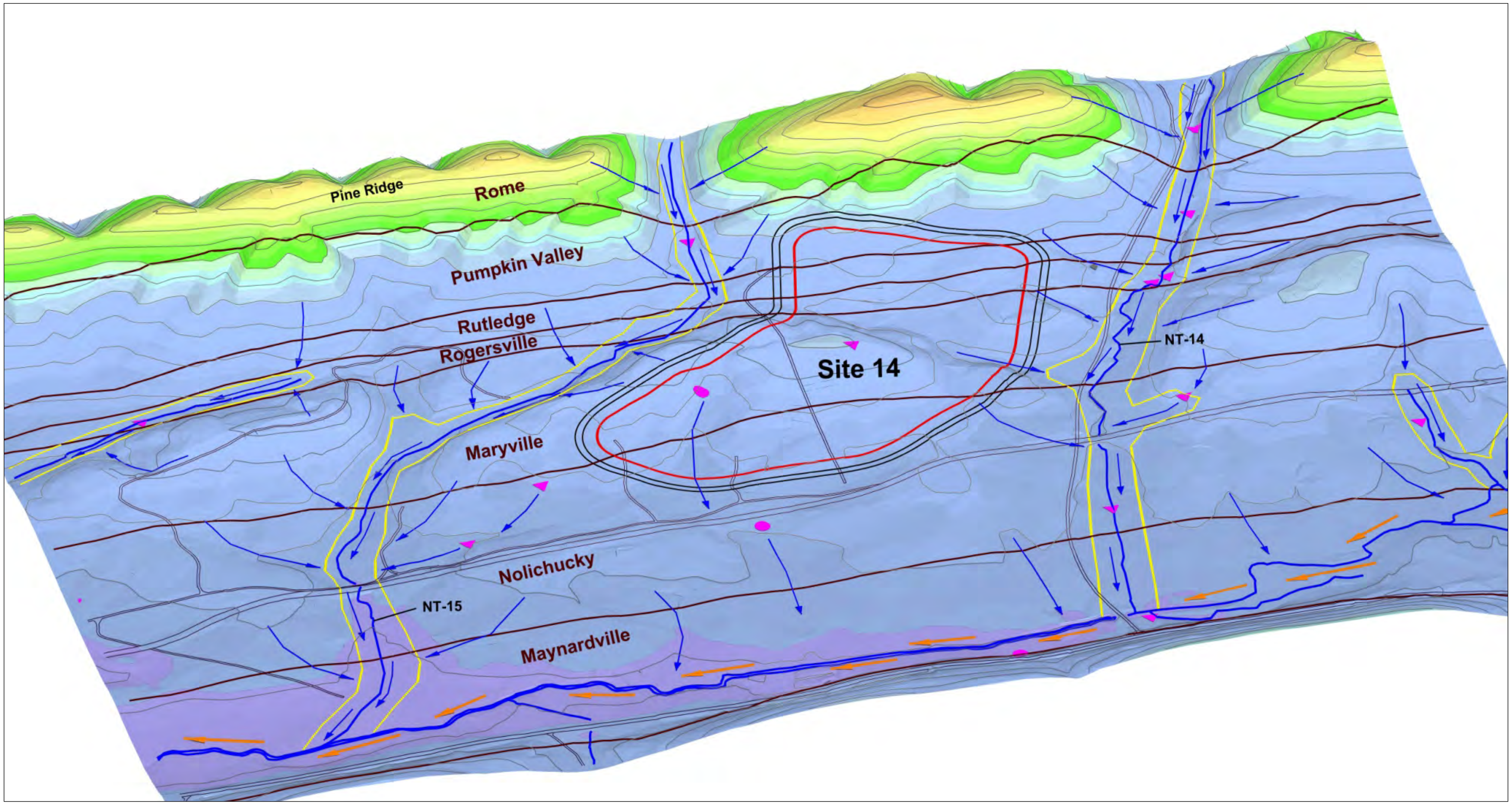

Figure E-17. Pre-construction hydrogeological site conceptual model for generalized ground water flow paths in the water table and intermediate levels of the saturated zone at and downgradient of Site 14

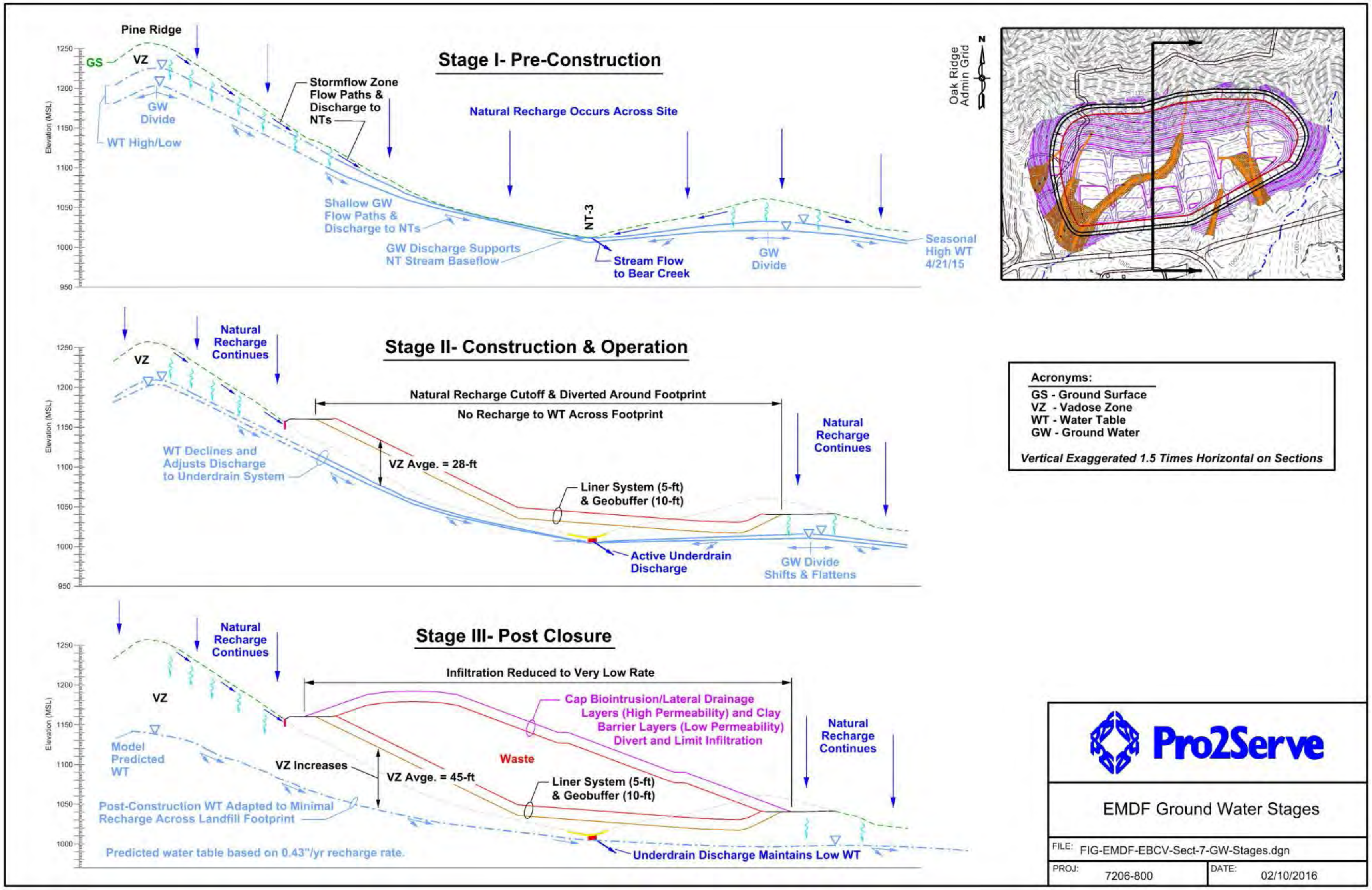

Figure E-18. Key changes to surface and ground water hydrology from pre-construction through EMDF construction, capping, and closure

[Note: The model predicted water table in Stage III is based on an assumed infiltration rate of 0.43 inches/year from 500-1000 years post closure]

The cross sections illustrate the progressive lowering of the pre-construction water table that would occur during construction and operations (Stage II). Progressive lowering and stabilization of the water table would occur from the combined effects of:

- gravity drainage of shallow ground water into the underdrain trench at elevations several feet below current NT stream channel elevations,
- elimination of active recharge across the footprint by the impermeable layers of the liner/cap system (umbrella effect),
- capture and diversion of upslope surface water and topsoil stormflow zone water, and
- recharge limited to undisturbed surface areas upgradient of the footprint

2.9.1 Underdrain Effects

The blanket/trench underdrain system is designed to provide a high permeability lower base level drain for the uppermost portion of the saturated zone. The conceptual design base elevations of the underdrain trenches are at least 4.5 feet below the existing NT-2/NT-3 stream channel elevations. During and after the Stage II construction cycle, the impermeable plastic and very low permeability compacted soil components of the liner system installed across the footprint area eliminate ground water recharge to the underlying water table, and restrict natural recharge to a narrow swath on the south flank of Pine Ridge. The upgradient perimeter ditch and French drain system along the north perimeter of the landfill captures and diverts sheet flow, channel flow, and topsoil stormflow zone waters from upslope areas away from the footprint further reducing potential recharge to the water table. Stage III post closure conditions illustrate the model predicted water table surface adapted to a condition of relative equilibrium with the underdrain network and minimal natural recharge through a thicker vadose zone across the remaining undisturbed slopes of Pine Ridge adjacent to the north side of the landfill.

Initial site grading would remove all loose and unstable topsoil, and colluvial and alluvial materials across the site footprint so that the underdrain network would be mostly in contact with in-situ stable residuum and/or underlying saprolite and bedrock. The underdrain composition of graded highly porous and permeable materials would ensure a large contrast between the relatively low hydraulic conductivity (K) of the in-situ natural materials, and the high K of underdrain materials. The location of the underdrain network along the pre-existing valley floors and the orders of magnitude difference between the K and effective porosity of the underdrain and the adjacent in-situ materials would facilitate persistent long-term ground water seepage into the underdrain. The underdrains would also be extended far into the uppermost reaches of the headwater NT sub-tributaries to intercept and drain the headwater springs/seeps and ground water discharge zones along the main ravines and stream channels cutting into the southern flanks of Pine Ridge. The extensive underdrain network proposed for Site 5 contrasts greatly with the single straight line underdrain retrofitted for Cell 3 of the EMWMF. Placement of the underdrains along the entire lengths of the former stream channels and ravines is more likely to alleviate the potential for any upward incursions of the water table below the footprint that have been of concern at the EMWMF.

The underdrain trench would establish a new base level for the water table at elevations 4.5 ft or more below the higher pre-construction elevations of the former NT stream channels. Shallow ground water flowing mostly laterally and converging and discharging as base flow to the former stream channels along the valley floors would be intercepted and captured by the blanket and trench drain system placed at lower elevations relative to the pre construction stream channels. Site characterization and tracer testing has demonstrated that shallow ground water flow tends to migrate more rapidly along fracture pathways (bedding planes and joints) that are parallel to subparallel with geologic strike, so that the middle and upper NT tributaries in BCV (where the EMDF footprints occur) capture most of the ground water flux. The broad surface area across the base and sidewalls of the underdrain network against the face of in-situ materials would also act to ensure an effective drainage system to lower the water table and prevent upward migration of the water table. The lower base level elevations of the underdrain trench would result in a lowered water table that would propagate back through the in-situ materials ultimately lowering the water table across the entire footprint area as reflected in the model predicted post closure surface [Note that the conceptual design for the base of the trench is at least 4.5 ft below ground surface and 5-15 ft wide – See Section 6 of the RI/FS Report for additional details and underdrain drawings].

The conceptual design assumes the EMDF underdrain system will function effectively to encourage and maintain natural ground water drainage below the landfill footprint. Even with some degree of diminished porosity and permeability, the underdrain is assumed to provide an effective avenue for long term drainage based on a much higher permeability of underdrain materials relative to that of in-situ materials. The measured K of in-situ soils/saprolite and bedrock materials generally ranges between 10^{-4} cm/sec to 10^{-6} cm/sec or less. The design calculation sheets by Bechtel Jacobs in 2003 for the underdrain installed below Cell 3 at the EMWMF, indicate K values for various underdrain materials ranging from 2.0×10^{-2} cm/sec for sand, to 15 cm/sec for gravel (#57 size stone), to 35 cm/sec for rock (#3 ballast stone). They calculated total flow capacities for the underdrain of 476 gpm for a 5% slope and 192 gpm for a 2% slope with a calculated underdrain design flow of 8 gpm based on ground water modeling. Even with some degree of potential clogging, the minimum of five orders of magnitude difference between underdrain and in-situ K values will help to ensure the persistence of a lowered water table. The EMDF underdrain design calls for alignment of the underdrain network directly along each of the former stream channel pathways for the valleys/ravines that underlay the footprint. This layout takes advantage of natural ground water fracture flow paths toward the NT tributary valleys that have developed over eons of ground water recharge and discharge at a local watershed scale unique to each EMDF site. Refinements to the conceptual design for the underdrain system will be made as the detailed design progresses, site characterization data are obtained, and regulatory review and input is made. In addition, the design will account for the long-term potential for underdrain clogging.

2.9.2 Umbrella, Diversion, and Upslope Recharge Effects

After landfill construction and final capping, recharge to the water table is effectively eliminated across the EMDF footprint by low permeability cap and liner systems above and below the waste mass. Reduced zones of ground water recharge would remain upslope of each of the site footprints along the undisturbed south facing slopes of Pine Ridge, but across the footprint, ground water recharge is reduced to a very low infiltration rate designed to keep the waste in an unsaturated state well above the water table. In all cases, the elimination of recharge across the footprint combined with the reduced area available for upgradient recharge would decrease the flux of ground water passing below the footprint and contribute to lowering the water table at and near the footprint. The base elevations in the conceptual design for the landfill footprints have also been set to avoid significant cuts into the existing ground surface to avoid the potential for upward vertical gradients to encroach on the unsaturated zone of the geobuffer/liner system. The potential for strong upward gradients appears to be of most concern at Site 5 which is located in closest proximity to Pine Ridge. However, as illustrated in Figure E-18, the floor and sidewall elevations adjacent to Pine Ridge are generally well above the current existing land surface and water table, thereby avoiding the potential for artesian flow. The combined effect of the engineered features above and below the landfill is to lower and maintain the water table at elevations that do not rise or encroach on the geobuffer, liner system, or waste.

The combined effects would also result in greatly reduced water table fluctuations below the site footprint in response to rainfall/recharge events. Water level fluctuations in shallow monitoring wells located in natural undisturbed settings such as the existing proposed sites in BCV generally respond rapidly to significant rainfall events (See Section 2.10.4 below and Attachments A and B for detailed examples). Isolation of relatively large areas from active recharge creates a large umbrella effect that will dampen the effects of these recharge events and greatly reduce the range of water table fluctuations below the footprint.

2.9.3 Model Simulations of the Water Table

Regulatory standards require that the water table remain below the base of the geobuffer/liner system underlying the landfill waste mass. It is therefore critical to estimate the probable changes to the water table after construction, capping, and closure. Ground water modeling provides one of the few reliable methods for predicting three dimensional future water table conditions. The depth and configuration of the future post-closure water table surface at Site 5 was simulated through steady state ground water modeling runs to demonstrate the water table decline from the collective effects noted in the previous sections. The model simulations are based on incremental increases in infiltration rates assumed for several post closure periods consistent with the preliminary Waste Acceptance Criteria (PreWAC) modeling described in Appendix H: 1) no recharge assumed for 0-200 years post closure, 2) limited infiltration of 0.033 in/year from 200-500 years, 3) 0.43 in/year infiltration from 500-1000 years, and 4) 1.32 in/year beyond 1000 years.

Of the proposed EMDF sites, the hourly water level data from the Phase I monitoring at Site 5 provides the only complete record of water table fluctuations over a full year of record. Figure E-19 illustrates the Site 5 seasonal high water table measured on April 21, 2015, reflecting the annual wet season peaks observed each year during periods of relatively heavy winter/spring precipitation (see Attachments A and B for details). Control points for the water table contours in Figure E-19 are limited to the five Phase I well locations and the reasonable assumption that the water table remains close to but not above the elevations of the stream channels and ravines cross cutting and adjacent to the Site 5 footprint coincident with the local zones of ground water discharge. Note that no control points exist north of Site 5 along the upper slopes of Pine Ridge underlain by the Rome formation. The depths to the water table in those areas are currently undefined and represent an area of uncertainty both for the mapped surface and the model predictions. Among the network of monitoring wells at the EMWMF, only one shallow well (GW-918) is completed within the outcrop belt of the Rome upgradient of the EMWMF footprint, but the well is situated along the former valley of upper NT-4 that was filled during construction of the EMWMF. As noted in UCOR (2013b), "blocking this surface drainage feature may have removed the natural ability of ground water to drain from the hill north of the EMWMF into the swale." (p. B-7). The single well location and the relatively shallow water levels monitored in GW-918 are therefore considered unreliable for comparison to the water table conditions anticipated at Site 5 where the upgradient trench drain and underdrain network are designed to preclude the development of such conditions. If Site 5 is selected for the EMDF, additional hydrogeological data will be needed to more completely establish baseline conditions for ground water in, adjacent to, and upgradient of the Site 5 footprint.

Figure E-19 provides a preliminary baseline pre-construction seasonal high water table surface for comparison with model simulations. Analysis of the simulated water table contours for each of the four scenarios indicates that the most dramatic changes occur during the initial period of no recharge, with relatively minor changes subsequently occurring up to the highest infiltration rate of 1.32 in/year. Figures E-20 and E-21 illustrate the model-simulated decline in the water table surface at Site 5 relative to the water table on April 21, 2015. These figures exemplify water table declines anticipated to occur at any of the proposed EMDF sites after construction and closure.

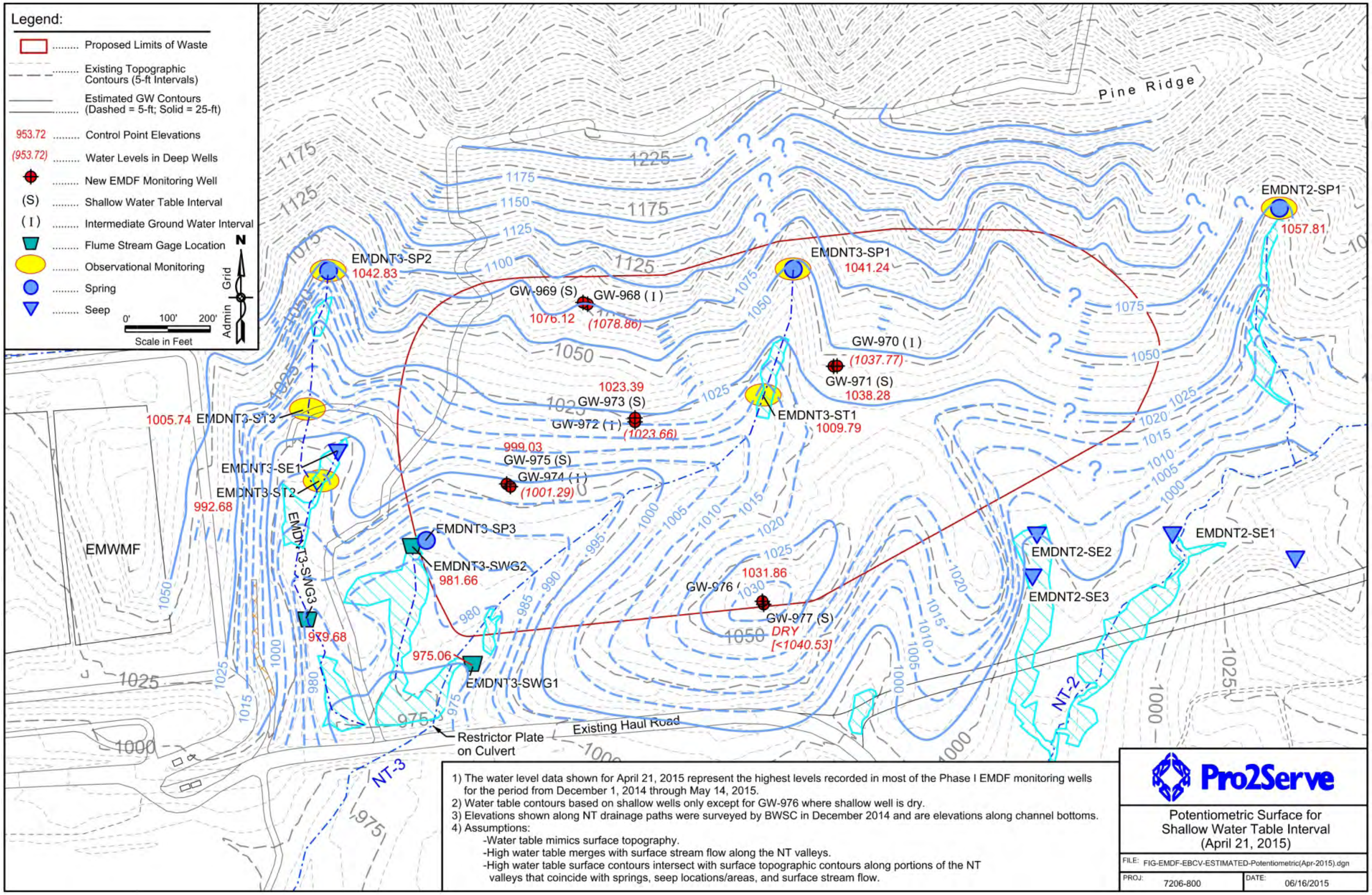

Figure E-19. Water table contour map for Site 5 representing the highest ground water levels for the winter/spring 2015 wet season

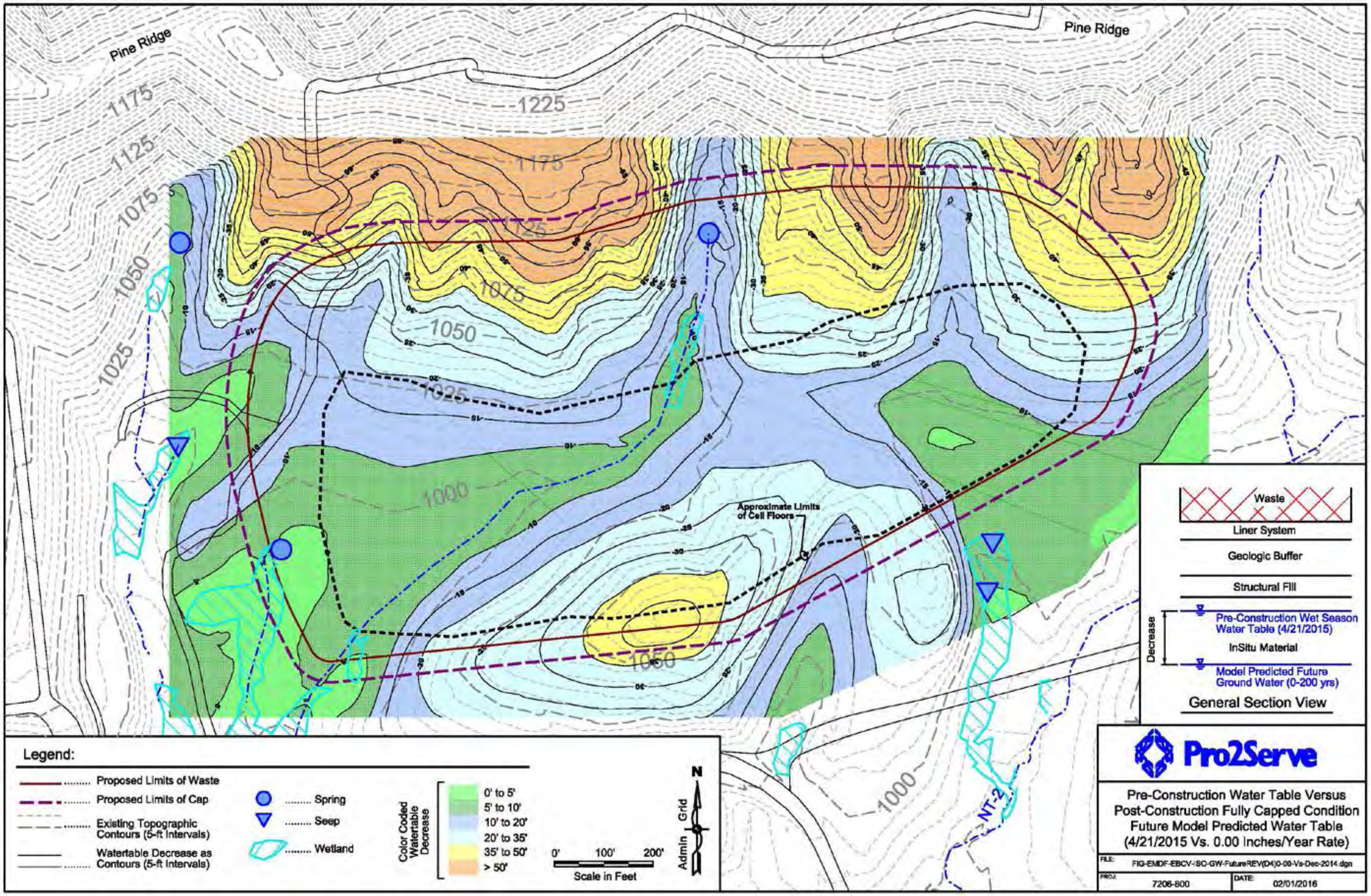

Figure E-20. Contour map showing model-simulated water table decline from pre construction 2015 highest levels to post construction conditions assuming no infiltration through the landfill for the initial post-closure period from 0 to 200 years

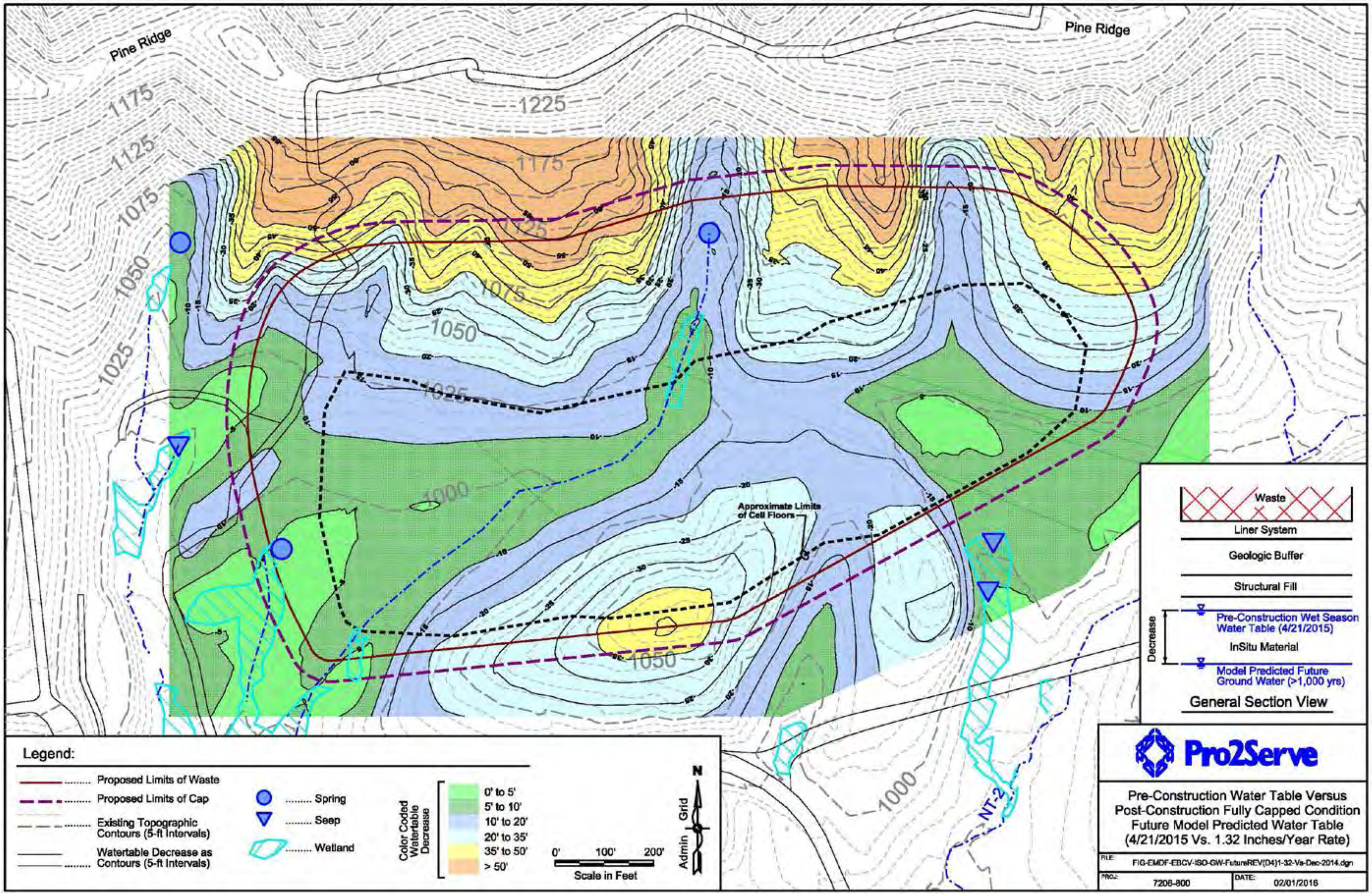

Figure E-21. Contour map showing model-simulated water table decline from pre construction 2015 highest levels to post construction conditions assuming 1.32 inches/year of infiltration through the landfill to the water table for the post-closure period after 1000 years

While the detailed configuration of the water table will vary among the proposed EMDF sites depending on local topography, adjacent NT stream channel elevations, and the layout and base level elevations of the footprint, post construction water table declines will inevitably occur at each of the proposed sites. As illustrated in the cross sectional views in Figure E-18, the greatest declines in the water table occur along the north side of the footprint below the steepest flanks of Pine Ridge where the vadose zone is thickest, and along the south side of the footprint under the boot shaped spur ridge. The greatest water table declines occur in the range of 40-60 ft or more along the north edge of the footprint, and directly below the spur ridge with declines of 40 ft or more. The least decline occurs along the valley floor areas of the NT-2 and NT-3 tributaries cross cutting the footprint where ground water converges into the underdrains. A comparison of Figures E-20 and E-21 shows that although the water table would be raised slightly with the higher infiltration rate of 1.32 in/year, the overall effects are minimal, and that a significant unsaturated zone remains below the base of the geobuffer even with higher infiltration rates. The great thickness and relatively low bulk permeability of the landfill still acts to retard infiltration and maintain the waste mass and underlying geobuffer/liner system in an unsaturated condition. The water table simulations suggest that ground water underflow and drainage via the underdrain network exercise a much more significant control on the post construction water table than the infiltration rate. Model simulation of the water table surface where the K of the underdrain network is equivalent to the K values for in-situ materials (i.e. – mimicking the effects of total underdrain clogging) suggest that the water table would climb significantly upward into the geobuffer/liner system if constructed without the underdrain network.

As another means of illustrating the water table changes, Figure E-22 illustrates the water table contour elevations simulated for the initial period assumed with no recharge (in green) versus the water table surface assuming the maximum infiltration rate of 1.32 in/year (in purple). The most pronounced effect of the higher infiltration rate is shown in the figure as a slight increase in the water table across the southern half of the footprint. This is particularly evident below the spur ridge area along the south center section of the footprint where the water table increases by around 2-3 ft as recharge is increased from zero to the 1.32 in/year maximum rate. Elsewhere across most of the northern half of the site the increase is typically 1 ft or less. Note how the contours converge along the paths of the underdrain network where constrained by the base elevations of the underdrain trench. The contours also converge outside of the footprint where the infiltration rates increase to natural conditions and the water table merges with natural stream channels along the west branch of NT-3 between Site 5 and the EMWMF, and along the NT-2 tributaries east and southeast of the footprint. The increases in the water table surface simulated with the highest infiltration rate shown are still far below levels that would encroach on the base of the geobuffer (i.e. – 10 ft or more below the base of the geobuffer; See Appendix H – PreWAC modeling for additional details and graphics).

2.9.4 Water Table and Ground Water Flow Patterns Among the Proposed EMDF Sites

The changes to the water table presented for Site 5 would generally apply to each of the other proposed sites, primarily in relation to the umbrella effect across each footprint. However, some differences appear likely based on site-specific conditions at each location. Variations among the environmental settings at each site are associated with local topography, NT stream channel configurations, locations of springs, seeps, and wetland areas, and locations with respect to Pine Ridge and underlying geologic formations. The preliminary design layout and 3D configurations of cell floor elevations and underdrain networks are influenced by these various factors. Some of the key differences among the proposed EMDF locations are reviewed below relative to potential impacts on the local water table. The umbrella effect is relatively consistent for all sites in terms of cutting off active recharge to the footprint areas and lowering water tables and greatly reducing ground water level fluctuations in response to storms and seasonal trends.

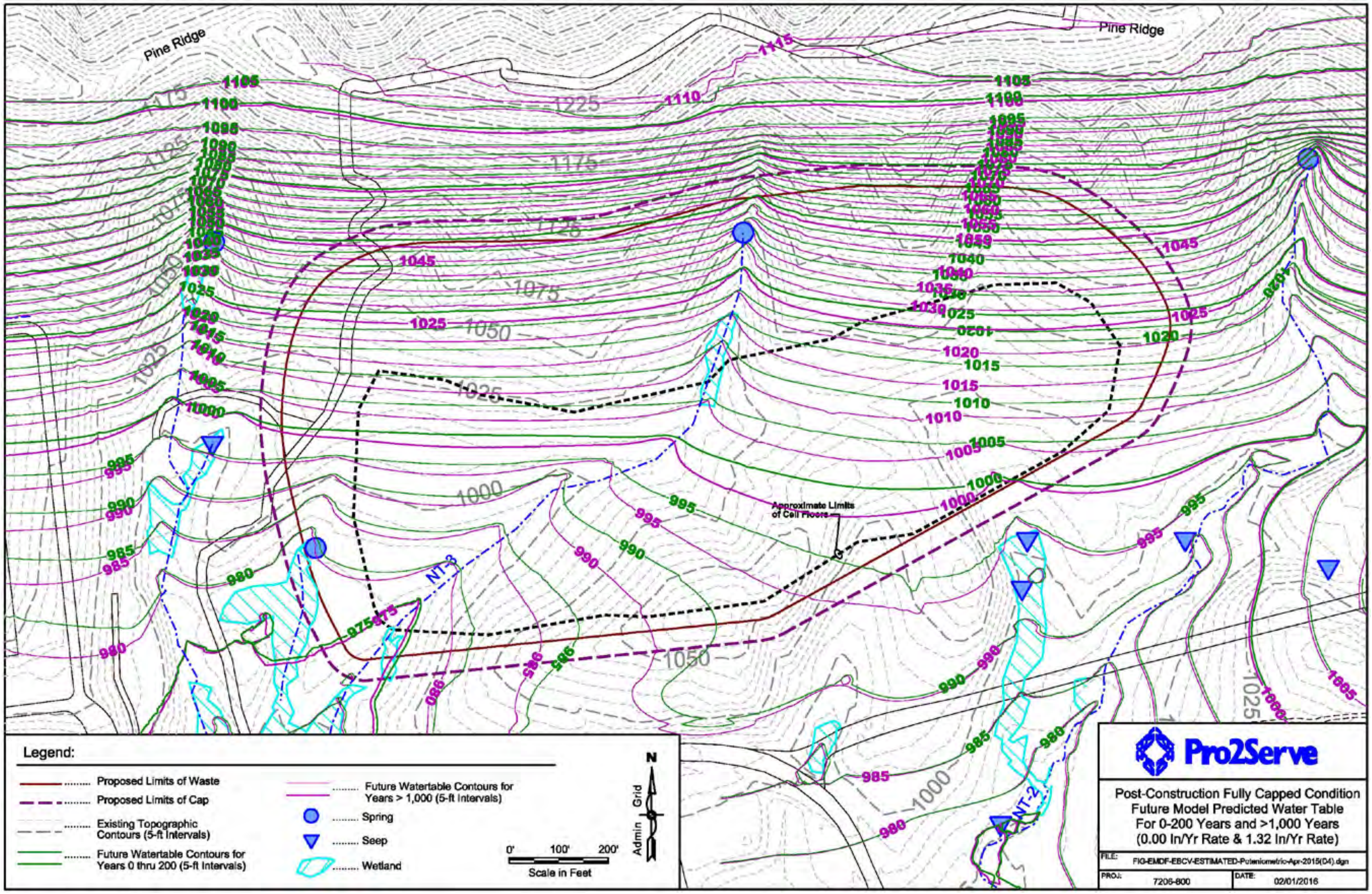

Figure E-22. Post-closure model-simulated water table contour surfaces assuming no infiltration for 0-200 years (green) and 1.32 in/yr infiltration at and beyond 1000 years (purple)

But the remaining influences from natural recharge in upslope/upgradient and cross gradient areas, and from the relationships between waste cell bottom elevations, site topography, and the base elevations of adjacent stream channels and underdrain trenches exert additional controls over ultimate post construction changes to the water table.

The extent of post construction undisturbed areas that are upslope of the sites and available for natural recharge varies with local topography and proximity to the crest of Pine Ridge. The effect of upslope recharge is also influenced in part by the width of the footprints relative to adjacent NT stream channels. Site 5, closest to Pine Ridge, has the least upslope recharge area that would contribute to ground water underflow below the site. Site 5 is centered roughly over the outcrop belts of the Friendship/Rutledge formation and Rogersville Shale. Sites 14, 7a, and 6b are each centered slightly further south and across the subsidiary ridge underlain by the lower Maryville/Dismal Gap formation. The locations of thesefootprints across more topographically isolated upland areas further south of Pine Ridge reduces the influence of recharge from upgradient areas along Pine Ridge and potential ground water underflow toward the south underneath the footprint areas. Ground water drainage in the headwater areas of Pine Ridge will generally move toward the nearest NT headwater valleys in unconsolidated regolith materials and along dominant strike parallel fractures in saprolite and bedrock. Much of this shallow ground water flow from recharge zones along Pine Ridge would naturally bypass ground water flow paths directly below the footprints of Sites 6b, 7a, and 14 which are more isolated from Pine Ridge than the Site 5 footprint. This bypass process would occur via discharge of shallow ground water to NT stream channels and springs and seeps in headwater areas.

The conceptual footprints for Sites 6b, 7a, and 14 generally require less extensive underdrain networks than those proposed for Site 5, however, the water table would remain relatively shallow at these sites because the stream channels along adjacent undisturbed stream valleys largely dictate base level elevations for the water table surrounding the site footprints. The more extensive underdrain trench network at Site 5 established at lower elevations directly along the major tributary stream channels would provide a lower post construction water table surface relative to that provided at Sites 6b, 7a, and 14.

Water table contour maps from 1987/1988 at Site 14 (WBCV) and from 2015 at Site 5 (EBCV) indicate that water table “mounds” occur below the elevated subsidiary ridges that are underlain by the lower Dismal Gap/Maryville formation at both sites (see maps in Sections 3 and 5). Parts of the footprint areas of Sites 7a and 6b are similarly located across the subsidiary ridges that are underlain by the lower Dismal Gap/Maryville formation. The proposed footprints for Sites 6b, 7a, and 14 completely span the crest and sides of this subsidiary ridge, but at Site 5 only the southern edge of the footprint reaches the ridge crest. The current conceptual design for Site 5 requires that a portion of the north side of the spur ridge be excavated down to elevations below the water table mapped during the 2015 Phase I investigation. The remaining undisturbed southerly section of the spur ridge would remain as a natural buttress along the southern edge of the landfill. It is assumed that the water table within this local area of the footprint could be effectively dewatered and reduced during landfill construction. Additional site characterization and water table monitoring at Site 5 in conjunction with more detailed engineering analysis are envisioned to resolve whether the conceptual base elevations would need to be raised in this area or whether dewatering before or during construction would be required. The similar water table mounds that appear likely below the topographic highs at Sites 6b, 7a, and 14, will place similar engineering design constraints on the base level elevations of cell floors placed across these ridge lines. The base level elevations for the waste cells at each of the proposed sites are constrained by the local pre-construction water table surface and anticipated changes to that surface following construction and closure.

2.10 SURFACE WATER HYDROLOGY

The surface water hydrology for BCV is well documented based on both valley wide and site-specific investigations. The results indicate the close interrelationships among precipitation, runoff, and surface water/ground water flux. The following subsections review the results of previous surface water investigations in BCV, the surface water features of the NT tributaries and Bear Creek, important relationships between rainfall, runoff, and ground water, and the results of water budget analyses conducted for BCV. Site-specific surface water hydrology is addressed in subsequent sections for each of the proposed sites.

2.10.1 Previous Surface Water Investigations

The U.S. Geological Survey (USGS) prepared an inventory of spring and seep locations, and made single measurements of flow at spring, seep, and selected stream locations across the entire length of BCV in 1994 that included all NTs adjacent to each of the prospective EMDF sites in BCV (Robinson and Johnson, 1995, and Robinson and Mitchell 1996). Locations were pinpointed with GPS coordinates at 680 sites (±3-5 meter accuracy) and point measurements of flow were made using various relatively simple field methods. The single event measurements were made during March 1994 to represent wet season base flow conditions and again in September 1994 to represent dry season base flow conditions. The measurements were made during periods at least 72 hours after rainfall events when base flow runoff was relatively low and stable. The USGS measurements were made using a variety of field equipment and methods designed to encompass the wide range of flow rates from the large channels along Bear Creek to the small headwater springs of the NTs. The lowest USGS measureable flow rates were 0.005 cubic feet per second (cfs) or 2.2 gallons per minute (gpm). Flow rates below that level were designated as zero (or dry) on their report drawings. The USGS GPS coordinates were used to plot the locations shown on figures for each of the prospective EMDF sites in subsequent sections, but some of the locations do not coincide with surface topographical drainage features (e.g. – stream valleys), and probably reflect the inaccuracy of the GPS equipment and conditions at the time. The actual field locations are probably nearby but may in some cases be closer to the closest topographic lows. The USGS spring and seep locations were verified in the field for Site 5, and those monitored in the Phase I investigation were accurately surveyed. The USGS locations have not been verified by field reconnaissance at the other proposed EMDF sites.

More accurate stream flow and contaminant monitoring has been completed at several flume/weir locations in BCV associated with site-specific investigations and valley wide assessments of contaminant migration and flux. Stream flow and contaminant monitoring has been conducted for a decade or more and continues at many locations along various NTs and along the main channel of Bear Creek as part of ORR-wide CERCLA monitoring of surface and ground water contamination. Episodes of continuous monitoring of stream flow have been conducted along the NTs and Bear Creek at and near Site 14 (WBCV), at the EMWMF, and at Site 5 (EBCV). Ongoing surface water and ground water monitoring locations for the BCV watershed are shown in Figure E-2, as presented in the latest 2015 Remediation Effectiveness Report for the ORR (DOE 2015a). Many of the locations are equipped with weirs/flumes and data loggers to provide continuous data on flow rates and water quality parameters. Results of surface water monitoring at each of the proposed EMDF sites are reviewed in subsequent sections where data are available.

2.10.2 Northern Tributaries of Bear Creek

As shown in Figure E-9, the NTs flowing southward into Bear Creek provide significant local hydrologic and ground water boundaries along the east and west sides of each of the four candidate sites. The lengths and watershed areas of the NTs tend to be roughly similar along the length of BCV, with a few exceptions such ast NT-14 which cuts all the way through Pine Ridge and draining a relatively larger watershed. While stream flow along Bear Creek increases incrementally with flow from each of the NTs, the stream flow conditions along each of the NTs tend to be more similar due to their similarity in length and size. The many springs, seeps, and wetland areas within the NT watersheds at and near the proposed sites reflect the relatively shallow water table that intersects with the ravines and valleys of the NTs, and the lateral flow of shallow ground water discharging along those areas.

2.10.2.1 Springs, Seeps, and Wetland Areas

The USGS inventory identified hundreds of springs and seeps along the NT tributaries and sub tributaries throughout the BCV watershed. These springs and seeps represent the locations of shallow ground water discharge that supports base flow for the NT stream channels. The locations occur where the water table or potentiometric surface intersects the ground surface. Flows at these locations strengthen during the Winter/early Spring nongrowing season when evapotranspiration is lowest and ground water recharge and flux are highest, and weaken during the hotter drier Summer and Fall growing seasons when evapotranspiration is highest and recharge and rainfall are typically lowest. Headwater springs with low flows (<1 gpm) are common near the base of some of the narrow incised valleys heading into the south flank of Pine Ridge. Other springs and seeps commonly occur along or adjacent to lower flatter areas of valley floors further downstream along the NT tributary paths. Many of the seep/spring areas fall within wetland boundaries that have been delineated and mapped during assessments of BCV and during specific projects where wetlands have required disturbance or elimination. Relatively large seep areas can represent zones of significant ground water flux. Seeps at Site 5 have been observed to become dry as the shallow water table seasonally falls below ground surface. Although the ground water may not discharge at the surface, it continues to migrate slowly downgradient at shallow depths not far below the surface. As the wet nongrowing season recurs the water table rises again and intersects the ground surface to discharge into seepage faces, springs, and stream channels.

At the proposed EMDF sites, the springs, seeps, and wetland areas represent locations of ground water discharge that must be addressed during landfill design to ensure the water table surface does not encroach on the geobuffer/liner systems below the waste mass. Underdrain networks composed of highly permeable materials are proposed below and adjacent to the landfill footprints to encourage sustained gravity drainage of shallow ground water that may continue to naturally discharge near these former spring/seep locations and to lower and maintain water table elevations below the landfill footprint. The identification and accurate delineation of all springs and seeps, along with estimates of ground water flux from these locations, is thus important at each of the proposed sites. The detailed site descriptions that follow include the identification of specific springs, seeps, and wetland areas identified at each of the proposed EMDF locations.

2.10.2.2 North Tributaries Stream Flow

Stream flow along the relatively small channels of the NTs varies considerably according to season, to the intensity and duration of precipitation events, and antecedent soil moisture conditions. Hydrographs of continuous monitoring of NT stream flows and rainfall demonstrate that runoff occurs relatively quickly in peak episodes of a few hours or more during and immediately after storm events. The regression phases of the hydrographs show that the rapid peak runoff tapers into a stage of soil drainage and base flow conditions spanning one to several days depending on location within the watershed, antecedent conditions, and other environmental factors. The NT stream channels in the headwater areas at and near the proposed sites are typically relatively small with channels that are on the order of 1-4 ft wide and base flow water depths of a few inches, typically small enough to step across. The adjacent floodplains tend to be relatively small as well but vary according to local topography with some flatter floodplain areas that may be a few tens of feet wide. Stream flow monitoring at Site 5 in 2014/2015 is consistent with previous stream flow monitoring at the EMWMF and elsewhere on the ORR in similar smaller watersheds indicating that channels can be rapidly filled at peak stream flows but decline quickly to base flow levels shortly after significant rainfall events.

The USGS inventory data were used to map reaches of the NTs and Bear Creek that were subject to gaining or losing flow, and intermittent periods of low to zero flow under seasonal base flow conditions represented by the March and September 1994 wet and dry season data, respectively. Figure E.23 summarizes the results of the USGS analysis for the upper half of the BCV watershed between NT-1 and NT-8 (based on data from Robinson and Mitchell 1996, as reported in UCOR 2013a). The bottom portion of the figure illustrates representative dry conditions that commonly prevail across much of the NT stream channels during the warm dry growing season, particularly during the late Summer and Fall seasons. Seasonal site reconnaissance and stream flow monitoring at Site 5 indicates that stream flow along the upper NT-2/NT-3 tributaries is intermittent and all but ceases during summer and fall low base flow conditions between significant storm events. Storm events during the drier growing season may result in short term runoff and stream flow but in the absence of prolonged heavy rainfall, streamflow tapers down relatively quickly to little or no flow between storm events. In contrast, winter/early spring base flow in the upper NTs is continuous during the wet non-growing seasons when evapotranspiration is low, soil moisture conditions are high, and rainfall more common.

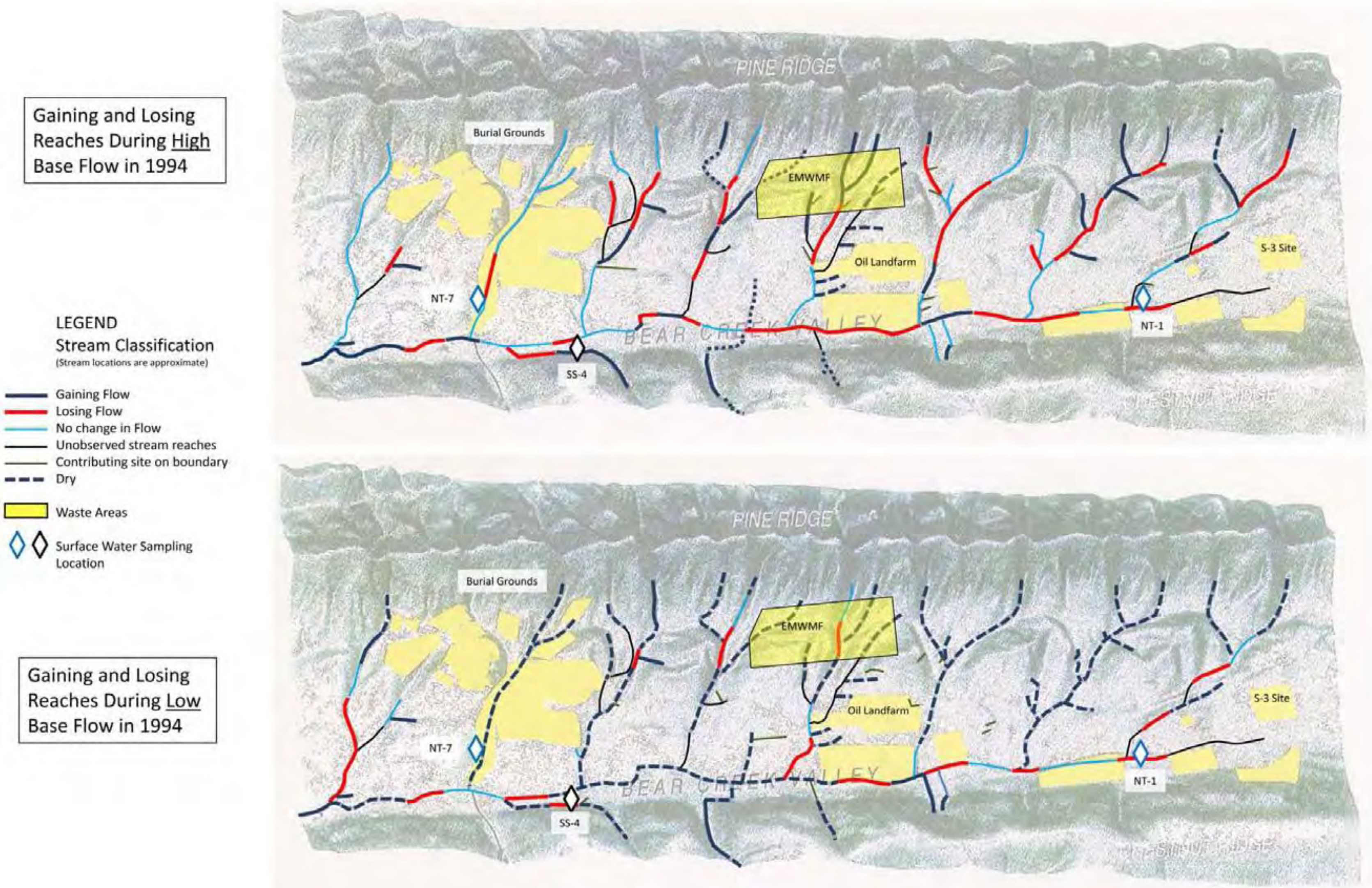

Figure E-23. Base flow conditions for NT streams and Bear Creek measured by the USGS in March 1994 (wet season base flow) and September 1994 (dry season base flow) in the upper half of the BCV watershed

[From UCOR (2013a) based on Robinson and Mitchell (1996); Note that dry indicates flows were at immeasurable rates <0.005 cfs (2.2 gpm), not necessarily completely dry]

The gaining/losing stretches identified in the upper half of Figure E-23 for high base flow conditions should be viewed with some caution. The stretches were determined by taking the differences between flow at widely spaced measurement point locations and applying limited assumptions for streamflow criteria (see Robinson and Mitchell 1996 for details) over the broad spatial scale of the entire BCV watershed. The report did not address the local scale relationships and complex effects among topography, hydrogeology, and water flux between the stream channel and shallow ground water in regolith, alluvium, and bedrock. More detailed analyses would be required to accurately identify and map the spatial and temporal variations in gaining/losing stretches at a local scale similar to that of the proposed EMDF sites. Recent water budget analyses and site reconnaissance conducted for Site 5 suggest that wet season baseflow to the stream channels in the headwater portions of NT-3 at Site 5 is likely to be continuously recharged by ground water during the wet season and are thus mostly gaining flow (See Attachment B). Similar water budget analyses conducted by Golder Associates (1989b) at the WBCV Site 14 area also suggest ground water recharge to the NT stream channels is significant suggesting that the NTs are largely gaining flow from ground water seepage during the wet season.

Intermittent and continuous stream flow monitoring of the NTs has been conducted in BCV in relation to site-specific investigations and for overall monitoring within BCV as a whole. Figure E-2 shows the locations of ongoing stream flow monitoring across the BCV watershed. Stream flow (and water quality) is measured at weir/flume locations at stations along the lowermost sections of NT-1, NT-2, NT-3, NT-7, and NT-8, and at several locations along Bear Creek from Bear Creek Kilometer (BCK) 4.55 near SR 95 upstream to the integration point at BCK 9.2, and further upstream to BCK 12.47 near NT-1. These stations provide longer-term multi-year historical stream flow data useful for assessing flow downstream of the proposed EMDF sites.

Stream flow data are also available along some NTs higher up in the tributary watersheds that is more directly applicable to stream flow conditions anticipated at and near the proposed EMDF sites. Pre-construction flume monitoring was conducted at several locations along upper reaches of NT-3, NT-4, and NT-5 for the EMWMF site adjacent to Site 5. Continuous monitoring was also recently completed in November 2015 over a full year at three Site 5 flume locations in the headwaters of NT-3 (see complete results provided in Attachments A and B), including weekly monitoring data for three intermediate stream locations and three headwater springs. Stream flow hydrographs were developed for four specific storm events in September 1987, and January and April 1988 at four weir locations along the lower reaches of NT-14 and NT-15 and along Bear Creek near Site 14. Little or no data are available for stream flows along the NTs bordering Sites 6b and 7a, but data from the similar sized NT watersheds provides insight into likely flow conditions there. The collective stream flow data from the headwater sections of the upper NT stream channels indicate that flows vary from almost no measurable flow during dry base flow periods to flows of tens to hundreds of gpm or more during peak runoff events. Available data are reviewed in subsequent site-specific sections.

2.10.3 Bear Creek

Bear Creek provides the main surface water drainage pathway for the entire BCV watershed, following the lowest elevation axis of the valley toward the southwest from its head waters near the S-3 Ponds to where the channel makes a sharp turn to the north leaving BCV through a water gap in Pine Ridge near SR 95. Bear Creek follows the outcrop belt of the Maynardville Limestone along the entire length of the valley and is intimately linked with karst conduit ground water flow in the Maynardville. Several relatively larger springs (SS-1 through SS-8; see locations on Figure E-2) also occur at several locations along the lower northern slopes of Chestnut Ridge on the south side of Bear Creek that drain ground water from the carbonate rock formations and regolith mantle of the Knox Group. These springs interact hydraulically with ground water and surface water flow in Bear Creek and the karst conduits of the Maynardville. Ground water from these springs drains mostly from uncontaminated areas along Chestnut

Ridge, although dye tracing and contaminants in some of these springs demonstrate connections with surface/subsurface flow along Bear Creek and ground water in the Maynardville Limestone.

Stream flow increases downstream along Bear Creek as it gains flow from each of the 15 NTs in BCV and the south tributaries and springs draining northward from Chestnut Ridge. Surface and ground water flow from each of the proposed EMDF sites ultimately drains southward toward Bear Creek with the potential to commingle with surface and ground water along Bear Creek.

Except for its uppermost sections near NT-1/NT-2, stream flow along Bear Creek is perennial. However, because of the karst conduit system in bedrock underlying Bear Creek, stream flow disappears along stretches of the channel between NT-3 and NT-8 during low flow periods. The lower half of Figure E-23 illustrates the two main portions of Bear Creek where stream flow is diverted underground into karst conduits. The primary section is approximately 3800 ft long and extends from about 600 ft west of the NT-3 confluence downstream to near SS-4. The second smaller dry section extends for approximately 1500 ft upstream from NT-8. From below NT-8 and BCK 9.47 Bear Creek flow is perennial. Conduit flow continues in bedrock below that point but the subsurface conduits remain saturated preventing complete capture of stream flow from the surface channel. Appendix C and D of the BCV RI Report (DOE 1997) include a much more detailed presentation and analysis of the surface and subsurface flow system along Bear Creek, including supporting data, figures, and references that substantiate the karst flow system and the existing contaminant plumes along Bear Creek.

Stream flow data for the continuous monitoring stations along Bear Creek are available from the DOE web based Oak Ridge Environmental Information System (OREIS). The stations nearest to the proposed sites are shown on Figure E-2. Figures E-24 through E-26 provide examples of the wide range of stream flows at different locations and time scales within the BCV watershed. Figure E-24 illustrates Bear Creek flow rates measured over a full year at the western end of BCV near SR 95 in 1994. Maximum winter season peak flows were recorded around 300 cfs, equivalent to 134,640 gpm, with the lowest flows occurring in September around 0.6 cfs (269 gpm). In contrast, Figures E-25 and E-26 illustrate stream flow data measured along the lowermost and uppermost headwater tributaries of NT-3 at Site 5 representative of locations draining smaller tributary and subtributary watersheds that exist at and near the proposed EMDF sites. The BC-NT3 monitoring gage is located roughly 100 feet upstream from the NT-3 confluence with Bear Creek. The other three flume locations are located within the headwater sub-tributaries of NT-3 at Site 5 (See Attachments A and B for locations and details). The data for BC-NT3 shown in the upper part of Figure E.25 show winter season peak storm flows on the order of 1000 to 4000 gpm over the 15 year period from 2001 to early 2015, with base flow intervals that are near zero even during the wet season. Figure E-25 illustrates stream flow data that reflects the smaller watershed size in the uppermost headwater areas of Site 5 that are typical of the proposed EMDF sites [in Figures E-25 and E-26 watershed areas increase progressively from the smallest at SWG-2, to SWG-3, SWG-1, and BC-NT3 located near the confluence with Bear Creek]. Most of the peak flows shown from the three flumes located at Site 5 are less than 1000 gpm (2.2 cfs) typical of headwater peak flows that are orders of magnitude less than those downstream near the west end of Bear Creek.

2.10.3.1 Bear Creek Water Quality Parameters

Table E-11 summarizes basic water quality parameters measured at several stations along Bear Creek in the eastern part of BCV between the BCBG and S-3 ponds sites. The pH of water in the upper reaches of Bear Creek averages close to 8 standard units (SUs), based on 135 measurements at six stations (BCK 9.47, 11.54, 11.84, 12.34, 12.38, and 12.47) at various times between 1998 and 2009. Specific conductivity, a measure of

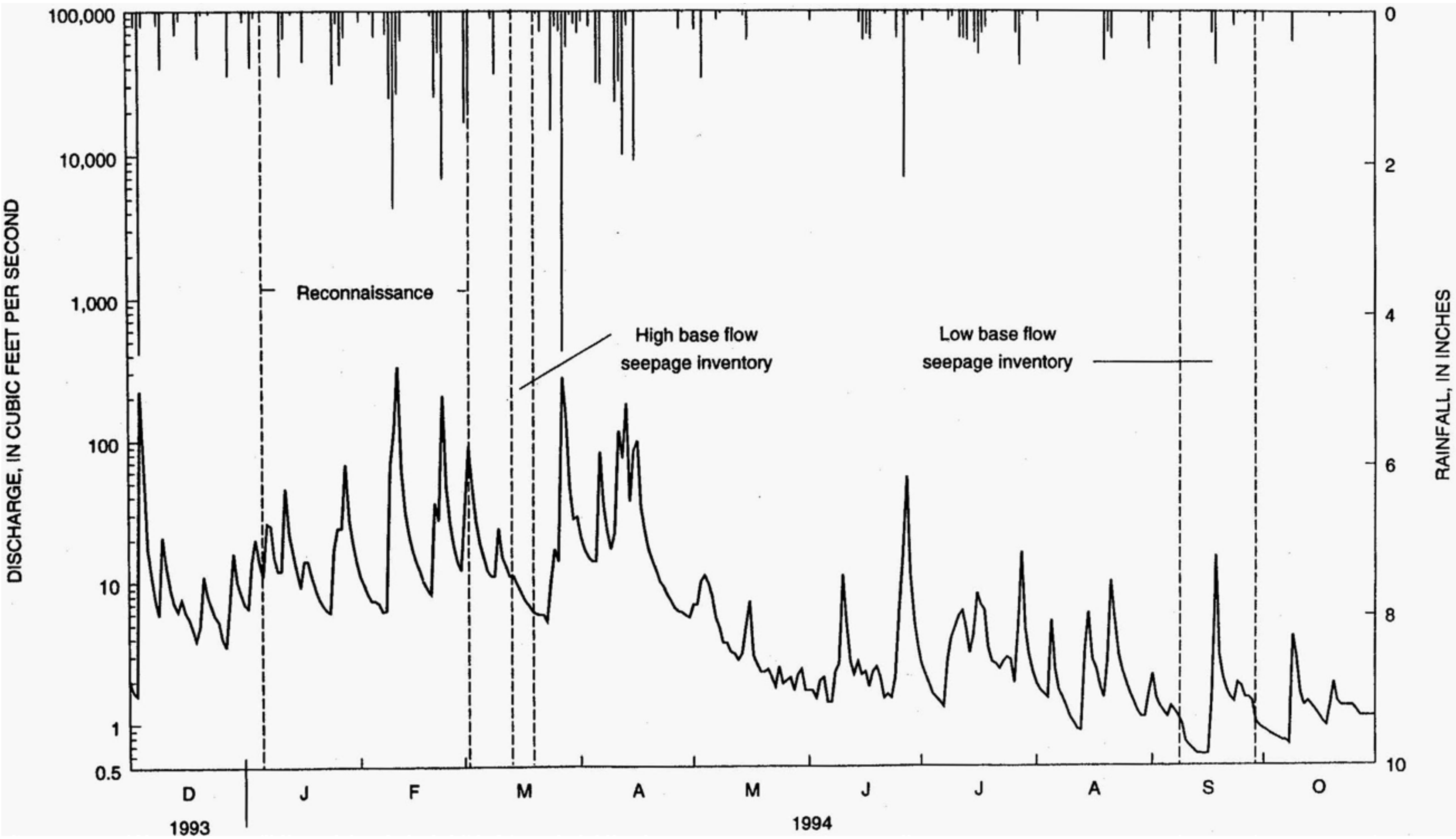

Figure E-24. Typical annual variations in stream flow versus precipitation at the Bear Creek gaging station near SR 95 at the downstream end of BCV

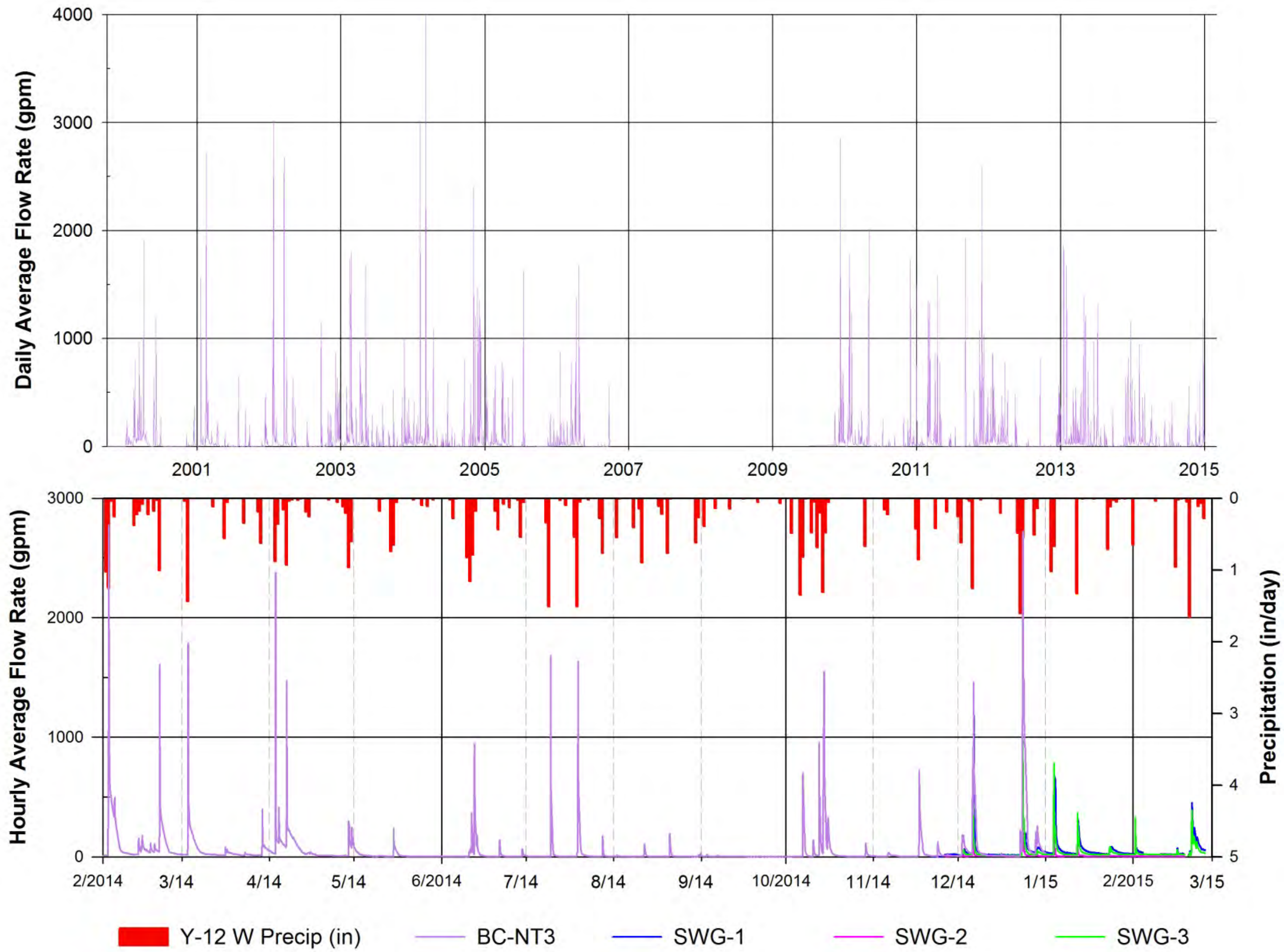

Figure E-25. Flow rates and precipitation records for locations along the headwater tributaries of NT-3 representing ranges typical of upper BCV NT headwaters

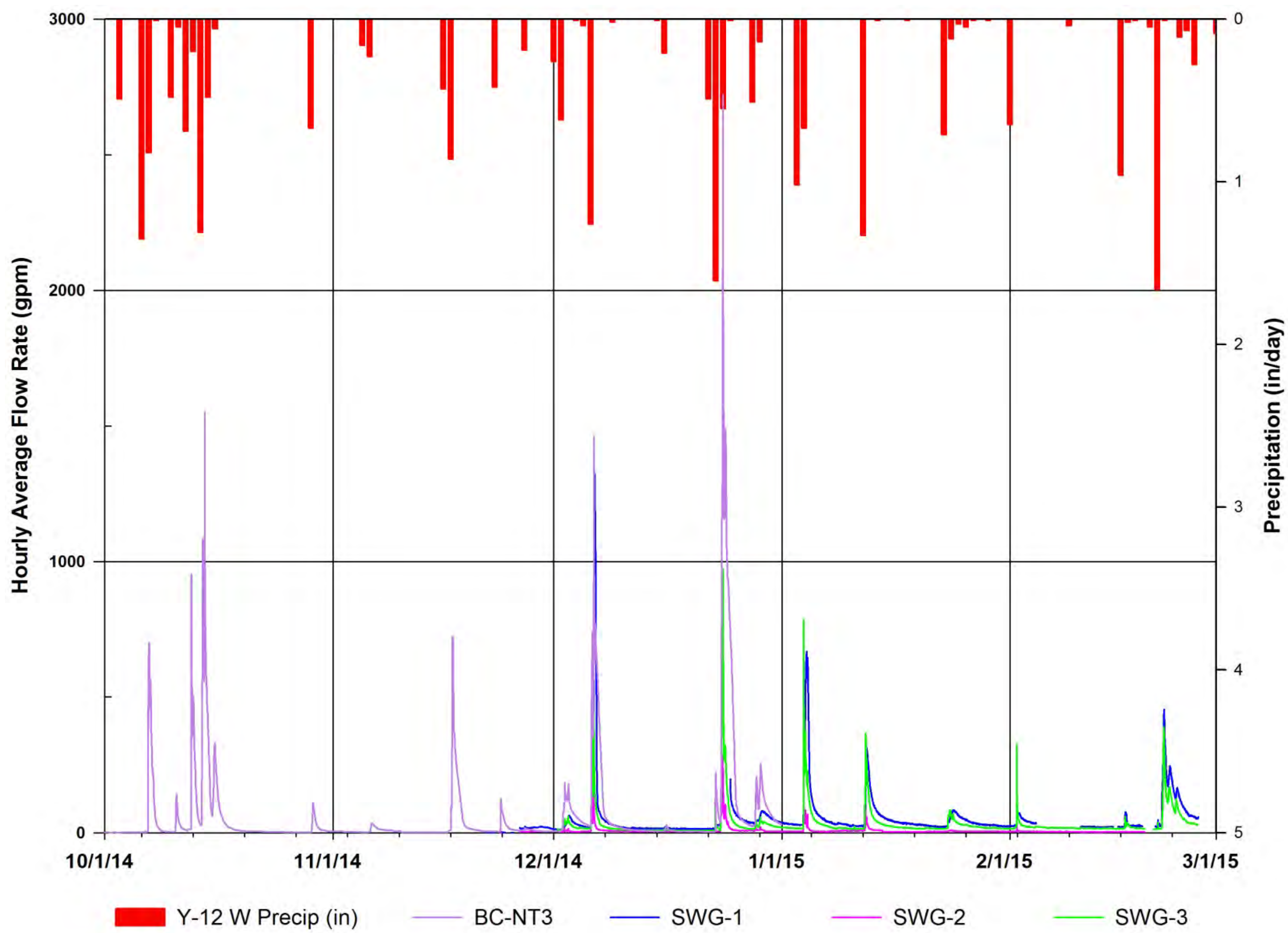

Figure E-26. Stream flow variations proportional to watershed size

[Watershed areas increase from smallest at SWG-2, to larger at SWG-3, to SWG-1, to BC-NT3 located near the confluence with Bear Creek] total dissolved solids, is highly variable, ranging from <1 µS/cm to 2,738 µS/cm in samples taken at the same locations and times. In general, the average specific conductivity by measurement station decreases downstream, and the exception, BCK 12.34, is near the former S-3 Ponds possibly affected by S-3 site contaminants.

Table E-4. Summary of Bear Creek water quality parameters

Station*	N	Period	pH (SU)	Specific Conductivity (µS/cm)	Temperature (°C)	Dissolved Oxygen (ppm)	Redox Potential (mV)
BCK 9.47	21	2/98 – 8/06	8.06	395	15.7	10.2	132.1
BCK 11.54	10	3/02 – 8/06	7.96	552	17.5	8.2	109.1
BCK 11.84	9	3/02 – 8/06	7.98	675	16.2	8.9	106.7
BCK 12.34	66	10/01 – 9/09	7.47	994	16.7	8.4	134.6
BCK 12.47	26	3/98 – 9/03	7.6	653	16.5	8.1	102.7
Upper BCV	21	2/98 – 9/09	7.65	801	16.5	8.6	125.8
Uncontaminated river water**			6.5 – 8.5	50 – 50,000	NA		

* Station 12.38 had only two measurements and was therefore not included in the summary table.
** Hem, 1989; N = number of measurements

2.10.3.2 Bear Creek and Ground Water Contaminants from Waste Sites in EBCV

Eastern reaches of Bear Creek are impacted by contaminants originating in the former S-3 Ponds and the various waste management units in Zone 3 (Figure E-2). The uranium flux goal set by the Phase I ROD is ≤34 kg/year at the integration point (BCK 9.2) and ≤27.2 kg/year at BCK 12.34. The goal for BCK 9.2 was not met during any year since 2000; the goal at BCK 12.34 was achieved during five of the past 10 years, but was not met in 2010 or 2011. Trends in uranium loadings in upper Bear Creek are positively correlated to annual rainfall amounts. A significant portion of the gain in flux appears to be due to inputs from the BCBG. Large increases in uranium flux are observed at BCK 9.2 in response to increased annual precipitation (2004, 2006, 2010); this is apparently due to uranium influx from the BCBG in NT-8. Uranium flux at BCK12.34 also tracks precipitation, but is more subdued.

Nitrate and cadmium contaminants emanating from the former S-3 Ponds have formed two ground water plumes in EBCV, and some of this contaminated ground water is discharged to the upper reaches of Bear Creek (DOE 2012; DOE 1997). Nitrate concentrations are inversely related to rainfall because of dilution. Average annual nitrate concentrations have remained below the industrial use preliminary remediation goal of 160 mg/L, although some measurements from particularly dry periods have exceeded this amount (DOE 2012). Nitrate concentrations decrease downstream from the S-3 Ponds area. Cadmium concentrations significantly exceeded the 0.25 µg/L ambient water quality criteria (AWQC) at BCK12.34 during the years 2001–2010, but meet the AWQC at BCK 9.2 (DOE 2012).

Southworth, et al. (1992) noted that reductions in Bear Creek contaminant loads occurred after waste placement was terminated, and the results of remedial effectiveness sampling since 1999 confirm this trend (DOE 2012). However, uranium continues to exceed the ROD goal.

Figure E-2 illustrates the general areas of existing ground water contaminant plumes in BCV in relation to historical waste sites and the proposed EMDF footprints. The plumes are illustrated for alpha-beta, nitrates, and volatile organic contaminants. As shown, Sites 7a and 14 are located in uncontaminated areas distant from the source areas and contaminant plumes. Site 6b is located in closest proximity to ground water contaminants along the east side of the BCBG, resulting in potential complications to release detection monitoring along the southwest margins of Site 6b. Existing ground water plumes and source areas in the vicinity of Site 5 are located sufficiently far to the south and downgradient of Site 5 that they are not anticipated to complicate release detection monitoring along the margins of Site 5.

2.10.4 Rainfall, Runoff, and Ground Water Relationships

Research in BCV and elsewhere on the ORR has documented the relatively quick response between significant rainfall events and responses in tubes placed within the topsoil stormflow zone, in shallow monitoring wells, and in stream flow. These responses are shown on Figure E-27 (from the BCV RI Report, DOE 1997). Similar responses were documented in research originally reported for the ORR by Solomon et al (1992) and Moore and Toran (1992). In addition, these responses have been documented in Phase I investigation results at EMDF Site 5 (See Attachments A and B to Appendix E). Ground water flux to surface water flow in stream channels via the stormflow zone has been shown to be quite significant during and shortly following rainfall events. With increasing time, however, the stormflow zone discharge diminishes while ground water discharge via the water table continues, providing base flow to stream channels. With further time and sustained periods without rainfall and recharge, the base flow from the water table diminishes even further.

These relationships are known to occur across undisturbed natural areas, including those at each of the proposed EMDF sites, but they will be significantly altered under the scenarios described above where construction dramatically alters the natural landscape across the landfill footprint. Conditions in areas outside of the footprint, however, would remain subject to the influence of storm rainfall events, and related impacts on the water table and stream flow surrounding the footprint.

2.10.5 Water Budgets

A water balance or budget is an estimate of how much water enters and is lost from a defined watershed during a stated period of time. Several investigations have attempted to quantify water budgets for drainage basins on the ORR, and results indicate wide variation in runoff and infiltration values. Runoff has been estimated to vary from about 5% to over 50% of precipitation. Healy, et al. (2007) indicates that, on average in North America, about 31% of precipitation is lost as runoff.

Water input is usually considered to be equal to the amount of precipitation (rain and snow), but may also include surface water and ground water inflow from other subbasins or, because ground water and surface water drainage areas are not always coincident, across surface water divides.

The general equation of state is (Healy, et al. 2007; CCL 2001):

$$\Delta S = P + GW_{in} - GW_{out} - ET - R,$$

where:

ΔS = change in storage (ground water and depression storage)
P = Precipitation
GW_{in} = Ground water inflow
GW_{out} = Ground water outflow
ET = Evapotranspiration
R = Runoff

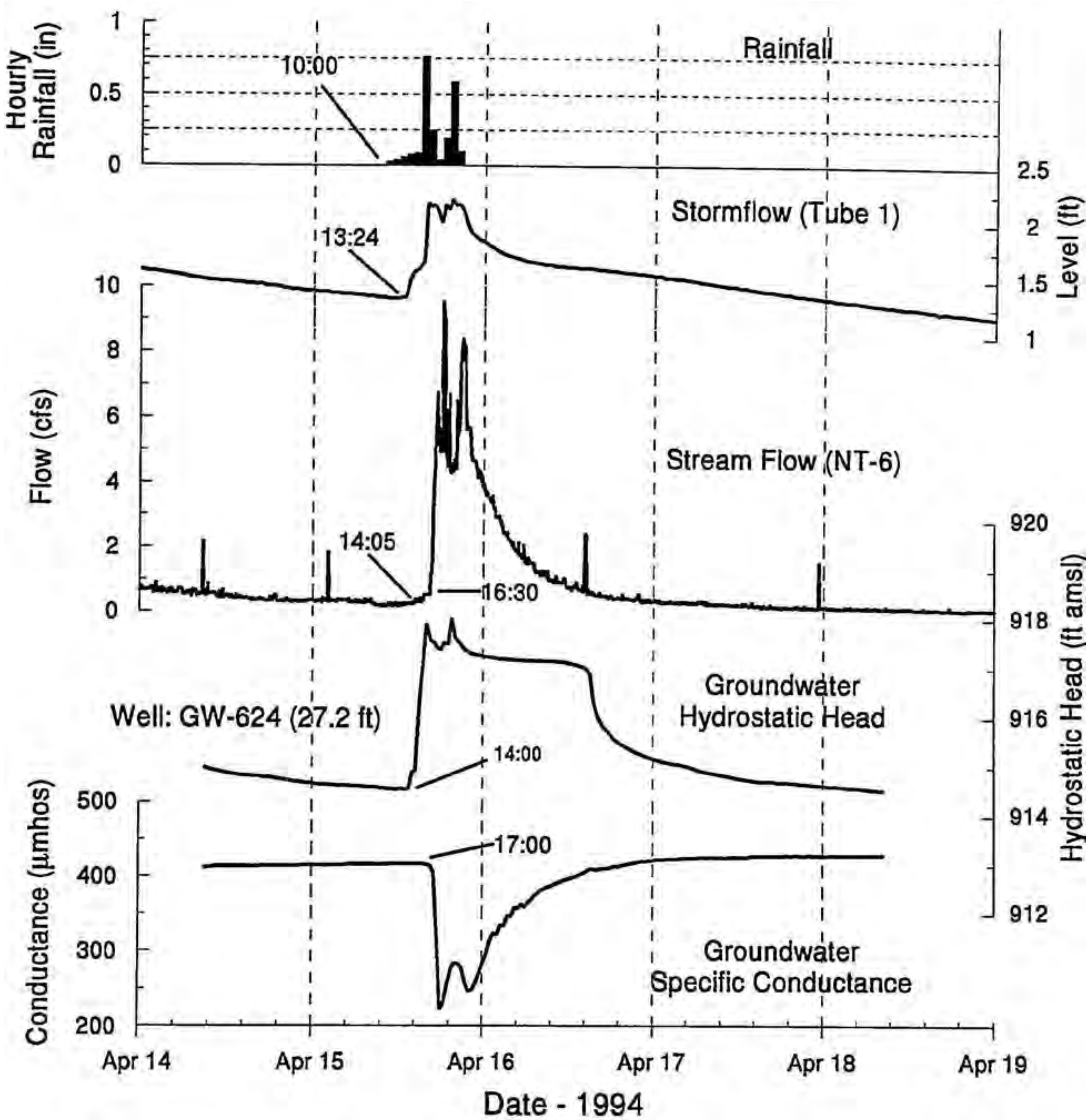

Figure E-27. Transient responses to a storm on April 15, 1994, at the BCBG in the topsoil stormflow zone (Tube 1), stream flow in nearby NT-6, and in a shallow monitoring well (GW-624)

[Figure C.22 from DOE 1997]

When the water budget is estimated on an annual basis, it is common to assume that the change in storage over a year is negligible (i.e., ΔS = 0); therefore, water input and output balance (CCL 2001).

Precipitation and stream flow can be measured with relatively good accuracy. As previously noted, mean annual precipitation is around 52.6 in. water equivalent. Runoff can be measured using a number of different techniques, but the most accurate is by measuring flow through a weir or flume. Evapotranspiration, the total amount of water that is transferred from the earth's surface to the atmosphere by direct evaporation and plant transpiration, is difficult to measure. Potential evapotranspiration is often estimated using mean monthly temperatures, which can result in overestimates of actual water losses. For example, the growing season in the Oak Ridge area is about 220 days long, from early April to early November. During the growing season, calculated evapotranspiration can exceed the rate of precipitation, resulting in soil-moisture deficits. During the winter months, however, precipitation exceeds evaporation, and transpiration is negligible, so that there is a net surplus of water in the system.

Moore (1988) and Borders, et al. (1994) provided an evapotranspiration estimate of 30 in. annually for the Oak Ridge region. This suggests that roughly 55–60% of water that enters the region is lost to the atmosphere. This is in line with the mean evapotranspiration losses for North America noted in Healy, et al. (2007). The remaining 40–45% either flows out of the region in streams, is held in reservoirs, or recharges the ground water system. Evapotranspiration is greatest during the growing season when plants are transpiring and when warm weather increases direct evaporation rates.

Ground water inflow is often assumed to be absent or negligible because surface water drainage divides are usually more or less coincident with ground water drainage divides, and recharge is autogenic. The water budgets estimated for the ORR incorporate this assumption.

Estimates of recharge in BCV range from 3.1 in. (DOE 1997) to 9.55 in. (Golder Associates 1989a, b), as shown in Table E-5. PreWAC model recharge rates range from 7 in./year to 8.75 in./year.

Table E-5. Water budget estimates for Bear Creek Valley

Hydrologic Component	**DOE 1997 (BCV RI)**		**Golder Assoc 1989a, b**	
	Amount	**%**	**Amount**	**%**
Reference Area	East Bear Creek Valley		West Bear Creek Valley	
Period	March 1994 – February 1995		October 1986 – September 1987	
Precipitation	46.4 in. (1,178 mm)	100	43.29 in. (1,100 mm)	100
Surface water flow	15.5 in. (393 mm)	33.3	6.97 in. (177.0 mm)	16.1
Evapotranspiration	27.1 in. (688 mm)	58.3	26.77 in. (680 mm)	61.8
Ground water Recharge	3.1 in. (78.6 mm)	6.7	9.55 in. (242.6 mm)	22.1
Ground water Storage	0.59 in. (15 mm)	1.3		

The BCV RI (DOE 1997) and results of ground water tracer studies (Goldstrand and Haas 1994) suggest that the surface divide between the Bear Creek basin and the Upper East Fork Poplar Creek (UEFPC) basin may not be the same as the ground water divide. Thus, there is a possibility of extra-basin ground water inflow to the Bear Creek watershed.

Ground water outflow is not directly measurable, and therefore must be estimated using flow nets or computer models. Ground water outflow is supported by precipitation infiltrating through soils from the surface (or outside sources). Estimates done for various drainage basins on the ORR range from about 7% to over 45% (Ketelle & Huff 1984; Clapp and Frederick 1989; Rothschild, et al. 1984; Luxmoore 1983; Solomon, et al. 1992). Often, however, the unmeasurable components of a water budget are lumped, rather than estimated, so that:

$$P - R = (ET + GW_{out} + \Delta S),$$

where the parentheses indicate that ET, GW_{out}, ΔS are not discriminated.

Change in ground water storage can be measured in unconfined aquifers as the change in water level in the vadose zone. Over the period of a year, the change in ground water storage can be considered to be a net of zero, because the surplus precipitation from winter is expended during the summer months.

Results differ considerably, reflecting differences in geology, soils, vegetative cover, and hydrology, as well as some of the underlying assumptions used in the calculations. The data and results of the DOE (1997) and Golder Associates (1989a, b) studies are from areas that are most similar to the EMDF candidate site, so that the combined percentage of subsurface flow and change in ground water storage range between 8% and 22% of total precipitation. As noted above, change in ground water storage, on a yearly basis, is essentially zero, therefore the amount of infiltration on a yearly basis can vary from about 22% to about 45% of precipitation.

Water budget analyses conducted using the recent results from the full year of continuous stream flow monitoring stations at Site 5 are presented in Attachment B. Those results provide a water budget analysis focused on and more representative of the water flux within the upper tributaries of the NT watersheds typical of the proposed EMDF sites.

2.11 STRATIGRAPHY

The fractured saprolite and bedrock geology of BCV exert fundamental control over the directions and rates of ground water flow and potential dissolved contaminant transport at and downgradient of the proposed EMDF sites in BCV. The relatively thin mantle of topsoil, colluvium, and alluvium is underlain everywhere by some combination of weathered and fractured saprolite, and variably weathered to unweathered fractured bedrock. The subsurface sequence of geologic formations underlying BCV is shown in the maps and cross sections of Figures E-3, E-4, and E-10. The figures illustrate the general southeasterly structural dip averaging around 45° to the southeast and the relative thicknesses of each formation. The cross section in Figure E-4 illustrates the White Oak Mountain thrust fault outcropping north of Pine Ridge and passing below BCV in the very deep subsurface.

The sequence of geologic formations underlying BCV from Pine Ridge southward to Bear Creek includes the Rome Formation of lower Cambrian age and formations of the Middle Cambrian Conasauga Group. The Conasauga Group is overlain by the Knox Group formations that outcrop below Chestnut Ridge along the southern border of BCV. Within the Conasauga Group, only the Maynardville Limestone consists predominantly of carbonate rocks. The remaining formations of the Conasauga Group are predominantly clastic rocks composed mostly of fine grained shales, mudstones, and siltstones. Limestones are interbedded with fine grained rocks in portions of the Friendship/Rutledge formation and the Dismal Gap/Maryville formation, but the only well documented karst dissolution features in BCV are primarily associated with the Maynardville Limestone and the Copper Ridge Dolomite.

The proposed EMDF site footprints all occur within the outcrop belts of the predominantly clastic formations ranging from the Pumpkin Valley Shale to the Nolichucky Shale. The Site 5 footprint is centered roughly on the Friendship/Rutledge and Rogersville formations, while Site 14 is centered roughly on the Dismal Gap/Maryville formation, with both sites spreading across parts of adjacent formations. The 6b and 7a site footprints are located slightly further south and centered more over the Dismal Gap/Maryville formation and Nolichucky Shale. All of these formations are predominantly clastic, and the Pumpkin Valley and Rogersville are both particularly deficient in carbonate beds. However, limestone beds have been logged in parts of the Friendship/Rutledge, Dismal Gap/Maryville, and Nolichucky formations. While typical karst features such as sinkholes, sinking streams, and resurgent springs have not been documented in BCV in the clastic formations of the Conasauga, the more carbonate rich beds in some of these formations have a higher potential for dissolution that could result in subsurface pathways with relatively higher hydraulic conductivities.

Table E-6 presents the stratigraphic column for BCV and Table E-7 provides more detailed lithologic descriptions for the geologic formations underlying BCV that are relevant to the proposed EMDF sites. The tables and descriptions are adapted from *Geology of the West Bear Creek Site* (Lee and Ketelle, 1989). Detailed descriptions of the geologic formations for the entire ORR are also described by Hatcher et al (1992), but the descriptions and thicknesses from the WBCV report are specific to BCV and the Whiteoak mountain thrust sheet. The descriptions, thickness determinations, and other geologic characteristics described by Lee and Ketelle are based on hundreds of feet of bedrock cores at the WBCV site used to thoroughly define the entire stratigraphic sequence across BCV. An additional report by King and Haase (1987) presents geologic maps and cross sections for BCV that identify the contacts between and thicknesses for each of the individual Conasauga Group formations. That report addresses bedrock geology based on several additional valley wide transects with deep boreholes and extensive bedrock cores located at the east end of BCV near the S-3 Ponds, near the center of BCV at the BCBG site, at the WBCV site, and even further southwest at the former Exxon nuclear site. Each of these three reports along with many others referenced in those reports provide additional details on bedrock geology and geological structures underlying BCV.

The unique bedrock geological and hydrogeological features of the Maynardville Limestone were addressed in a report by Shevenell et al (1992). The report presents the results of borehole drilling, logging, and wells completed along transects or pickets across the geologic strike at five picket locations up and down the length of BCV. Additional geological and hydrogeological descriptions of the Maynardville are provided in the BCV RI Report (DOE 1997).

2.12 REGOLITH AND BEDROCK HYDROGEOLOGY

The regolith includes all unconsolidated materials that overly competent bedrock. Depending on site topography and local conditions, the regolith may include surficial topsoils and clayey residuum, colluvium and alluvium along flanks and floors of the NT tributary valleys, and underlying saprolite. For practical purposes, the depth of the regolith may be considered as auger refusal drilling depth. Subsurface geotechnical sampling and engineering test data used for engineering design of landfills such as the proposed EMDF are focused largely on regolith materials. Numerous previous investigations of waste sites and proposed waste management/disposal sites in BCV provide considerable engineering and hydrogeological data on regolith materials. Characteristics of regolith geology and hydrogeology for BCV are reviewed below followed by a general review of bedrock hydrogeology. Site-specific conditions for the proposed EMDF sites are presented in subsequent sections where data are available.

Table E-6. Stratigraphic column for bedrock formations in BCV
(From Lee & Ketelle 1989a)

Age	Group	Formation/Unit	Description	Thickness (ft)
MIDDLE CAMBRIAN	CONASAUGA (€c)	MAYNARDVILLE Fm.	Upper (Chances Branch Mbr.) – limestone and dolomitic limestone in thick massive beds.	140
			Lower (Low Hollow Mbr.) – dolomitic limestone in thick massive beds. Light gray to buff.	200
		NOLICHUCKY Fm.	Upper – shale and limestone in thin to thick beds. Shale dark gray or maroon. Limestone light gray, oolitic, wavy-bedded, or massive.	60–140
			Lower – shale and limestone in medium to thick beds. Shale dark gray, olive gray or maroon. Limestone light gray, oolitic, glauconitic, wavy-bedded, and intraclastic.	430–450
		MARYVILLE Fm.	Limestone and shale or siltstone in medium beds. Limestone light gray, intraclastic, or wavy-bedded. Shale or siltstone dark gray.	320–410
		ROGERSVILLE Fm.	Shale and argillaceous limestone. Laminated to thin bedded, maroon, dark gray, and light gray.	80–110
		RUTLEDGE Fm.	Limestone and shale in thin beds. Limestone light to olive gray. Shale gray or maroon.	100–120
		PUMPKIN VALLEY Fm.	Upper – shale and calcareous siltstone. Laminated to very thin-bedded. Shale reddish brown, reddish-gray, or gray. Calcareous siltstone light gray or glauconitic.	130–150
			Lower – shale and siltstone or silty sandstone. Thin-bedded. Shale reddish-brown or gray to greenish gray. Siltstone and silty sandstone light gray.	175
LOWER CAMBRIAN		ROME Fm. (€r)	Sandstone with thin shale interbeds. Sandstone fine-grained, light gray or pale maroon. Shale maroon or olive gray.	Unknown

2.12.1 Topsoil, Residuum, and Saprolite

The results from subsurface investigations in BCV at sites along geologic strike with the proposed EMDF sites indicate a typical subsurface profile in undisturbed upland areas of BCV underlain by predominantly clastic rocks of the Conasauga Group. This profile is illustrated in Figure E-28 and is representative of the general subsurface sequence found at the proposed EMDF sites in topographical areas above and beyond the immediate vicinity of the adjacent NT valleys. The profile includes: (1) a thin topsoil layer, (2) a clayey residuum interval, (3) variably weathered bedrock (saprolite), and (4) unweathered bedrock.

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Table E-7. Lithologic descriptions and thicknesses of geologic formations in BCV

Geologic Formations	Downhole Thickness (ft)	Equivalent True Thickness Assuming 45˚ dip to SE (ft)	Lithologic and Contact Descriptions from Lee & Ketelle 1989a (Based on extensive rock cores collected at the proposed LLWDDD site in WBCV)
Maynardville Limestone - Cmn	NR	NR	The Maynardville is divided into lower and upper members - the Low Hollow and Chances Branch members. The Low Hollow member is generally a ribbon-bedded or mottled, fine to medium grained, dolomitic calcarenite with stylolites and irregularly spaced beds of oolitic calcarenite. Thin beds and shaley partings occur commonly within the ribbon-banded lithology. Basal portions include several laterally continuous dark gray shale beds roughly 0.5 to 2 ft thick. The Chances Branch member consists of bioturbated and thin-laminated, fine to medium grained, dolomicrite and dolomitic calcarenite in massive beds.
Cn/Cmn Contact			Abrupt Contact: The contact was located at the base of massive ribbon-bedded or mottled limestone of the Maynardville and uppermost thick (>2ft) shale in the Nolichucky
Nolichucky Shale - Cn	NR	NR	The lower Nolichucky is generally medium bedded shale and limestone or calcareous siltstone resembling the underlying Maryville. The upper part of the lower Nolichucky is thick to very thick bedded maroon or olive gray shale, and oolitic, coarse grained, or intraclastic limestone. The upper Nolichucky is lithologically diverse, consisting dominantly of dark gray shale with planar adn wavy-laminatee or ribbon-bedded micrite in thin beds (<1 to > 2 in thick).
Cmr/Cn Contact			Gradational Contact: The contact was placed above a 6 inch to 2 ft thick intraclastic limestone bed in the upper Maryville and at the base of the first clean dark gray or maroon shale bed > 2ft thick.
Dismal Gap Formation/Maryville Limestone - Cmr	430	304	The Maryville consists of oolitic, intraclastic (flat pebble conglomerate), and thin-bedded limestone interbedded with dark gray shale that typically contains thin, planar, and wavy-laminated, coalesced lenses of light gray limestone and calcareous siltstone. Fine-grained glauconite often occurs at the tops of the thin-laminated limestone lithology. Several isolated dark maroon shale beds typically occur in both the upper and lower Maryville. Although considerable mixing of limestone lithologies is noted, the upper Maryville generally contains greater amounts of intraclastic limestone, while thin-laminated and oolitic limestone is more prevalent in the lower portion. The contact separating these two upper and lower portions is gradational over tens of feet of section. Limestone intraclasts are randomly oriented and roughly 2 to 10 cm in length. In roughly the lower 40 ft of the Maryville, a variable number of prominent, coarse-grained, pinkish limestone beds occur which contain coarser and more abundant glauconite pellets than those higher in the section.
Crg/Cmr Contact			Abrupt Contact: The Rogersville is terminated abruptly by the occurrence of the comparatively thick limestone beds of the overlying Maryville, with the contact placed at the bottom of the first such limestone.
Rogersville Shale - Crg	90 & 150	64 & 106	The lower Rogersville consists dominantly of dark gray shale containing thin- laminated and bioturbated argillaceous limestone lenses less than 1 in thick. When maroon shales occur in the lower portion, they are thinner and more chocolate brown than the maroon shales in the upper portion. Glauconite partings are commonly interlaminated with the limestones but also occur as bioturbated beds several inches thick. The Craig Member, recognized elsewhere in East TN, is not present at the WBCV site. In the approximate position of the member are a few thin limestone beds which may represent the Craig Member at the site. The beds are 4 to 6 in. thick and composed of interlaminated, light gray, silty limestone and dark gray shale. These beds differ from those in the lower Rogersville principally in thickness and may be more appropriately considered the uppermost portion of the lower Rogersville at the site. The upper Rogersville consists dominantly of maroon shale containing thin (less than 1 in. thick), wavy, light gray, calcareous siltstone or argillaceous limestone lenses in varying amounts. Thin glauconitic partings are liberally incorporated within the siltstone and limestone lenses. The interlamination of these variably colored lithologies gives the upper Rogersville an overall thinly laminated appearance. Thicker beds (more than 1 ft thick) of clean, maroon-to-brownish-maroon shale are occasionally interspersed within the thin-laminated lithology.
Crt/Crg Contact			Abrupt Contact: The contact with the Rogersville is abrupt and recognized by the absence of 1-ft-thick limestone beds and the introduction of maroon shale. The contact is placed at the top of the uppermost such limestone bed.
Friendship Formation/Rutledge Limestone - Crt	124 & 126	88 & 89	The Rutledge consists of light gray, bedded limestone, often containing shaley partings interbedded with dark gray or maroon thin-bedded or internally clean shale in beds from 2 to 5 ft thick. Limestones are generally evenly divided between wavy laminated and bioturbated. Horizontal burrows are frequently observed. Maroon shale is more common in the lower Rutledge, and two distinctive beds on the order of 3 ft thick occur at the bottom of the formation, separated by three limestone beds of similar thickness. These limestones are referred to as the "three limestones" of the lower Rutledge, but their lithologic similarity with limestones in the bulk of the Rutledge makes them less distinctive than the two maroon shales. The relatively clean, dark maroon shales in the lower Rutledge give way to dark gray shale with thin calcareous siltstone interbeds. Upper Rutledge interbeds are generally thinner than those below, and more coalescing of lithologies is recognized. Limestone beds are often ribbon or wavy bedded, and some are heavily bioturbated with abundant glauconite pellets. Glauconite stringers also occur commonly within the calcareous siltstone interbeds.
Cpv/Crt Contact			Abrupt Contact: The contact with the overlying Rutledge is abrupt and placed at the top of generally uninterrupted, thin-bedded, reddish-brown shale and below the interbedded limestone and dark maroon shale of the Rutledge.
Pumpkin Valley Shale - Cpv	376 & 398	266 & 281	The Pumpkin Valley Shale is readily divisible into upper and lower units of nearly equal thickness. The lower Pumpkin Valley consists of reddish brown and gray-to-greenish-gray shale with thin interbeds of siltstone and silty, fine-grained sandstone. Shales typically contain thin, wavy laminated siltstone drapes and discrete laminae of fine-grained glauconite. Silty sandstone interbeds are typically wavy laminated to thin bedded but are often heavily bioturbated. High concentrations of large glauconitic pellets occur in the bioturbated lithology. Decreasing silty sandstone content upward within the lower Pumpkin Valley attests to its transitional nature above the Rome. The upper Pumpkin Valley is laminated to thin-bedded, dominantly reddish-brown, reddish-gray, and gray shale with thin, wavy, and planar-laminated siltstone lenses. Shales are generally fissile and may be massive or thin laminated. Thin partings of fine-grained glauconite pellets are ubiquitously interlaminated within the siltstone lenses.
Crm/Cpv Contact			Gradational Contact: The contact with the overlying Pumpkin Valley Shale is gradational and placed at the top of the uppermost thick, clean, planar laminated, 8- to 12-in.-thick, sandstone bed of the Rome.
Rome Formation - Crm	>>195	>>138	The Upper Rome consists of thick beds of gray or pale maroon, fine-grained, arkosic to subarkosic sandstone with occasional interbeds of maroon shale that often contain thin siltstone bands. Sandstones are typically planar to wavy-laminated or current-rippled. Vertical burrows are in great abundance in the interbedded lithology but are also recognized in the sandstone-dominated lithology. Burrows diminish in abundance down section. Upper Rome sandstone/shale interbeds occur nonuniformly at the two site locations from which core was acquired. The common occurrence of such interbeds on the western portion of the site is almost entirely replaced in the center of the site by gray or pale maroon sandstone couplets with a total absence of shale. Such lateral facies changes within roughly 1000 ft suggest the Upper Rome was subject to locally variable clastic influx in a low-relief paleodepositional setting.

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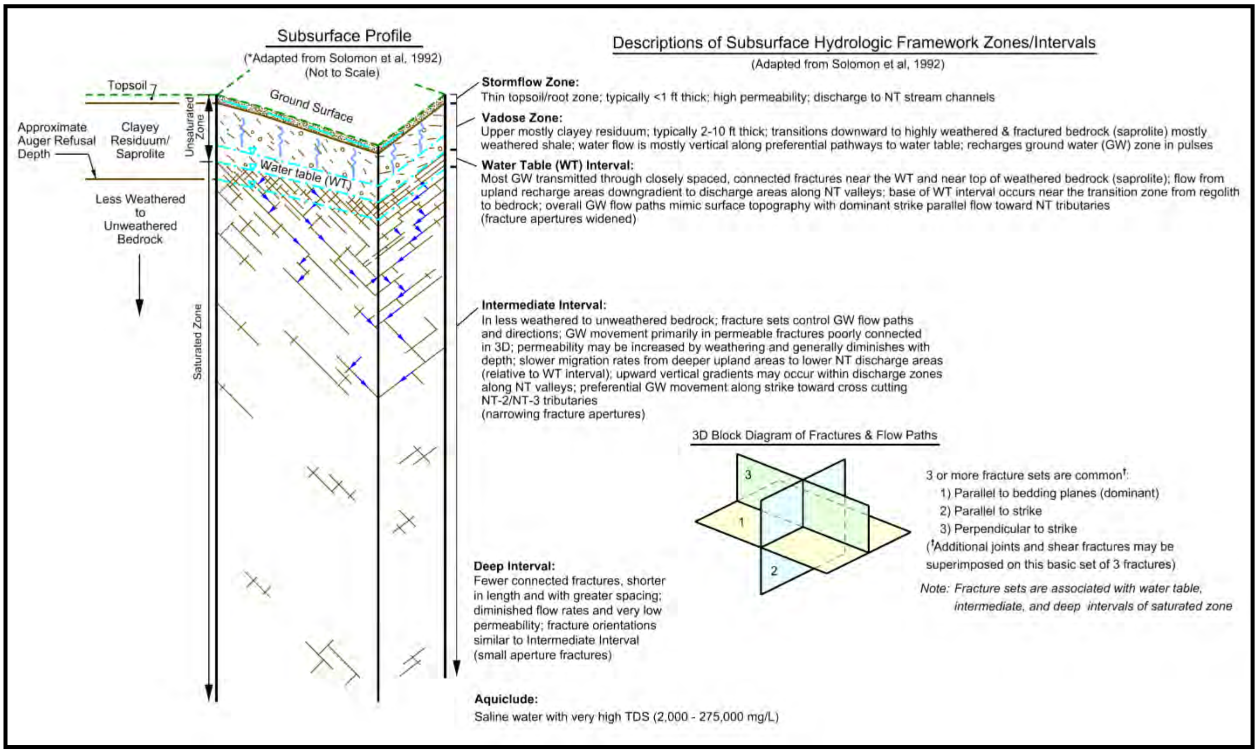


Figure E-28. Typical subsurface profile and conceptual hydrogeological model for upland areas of BCV underlain by clastic rocks

The natural subsurface profile at the EMDF site typically consists of a thin topsoil layer or root zone of organic rich clayey soils from a few inches to <1 ft thick below the ground surface. Below this relatively more porous and permeable topsoil layer is a zone of clayey/silty residuum that typically varies from less than two to ten feet in thickness. Below this is an interval of highly to variably weathered fractured sedimentary rocks (saprolite) that can generally be drilled using a hollow stem auger rig to refusal atop less weathered or unweathered fractured competent bedrock. The thickness of these intervals and downward transition from one to the next may be fairly sharp or gradual depending in part on the degree of chemical weathering and topography. The degree of weathering and fracturing generally decreases with depth with a typical equivalent decrease in effective porosity, permeability, and ground water flux.

It is important to note that the topsoil layer and any portions of the underlying residuum that are loose and unstable would be removed across the footprint areas during initial landfill construction. The hydrogeological characteristics of these uppermost layers are therefore less important than deeper layers in terms of assessing and simulating the potential for future contaminant migration below and laterally away from the EMDF footprints.

2.12.2 Alluvium and Colluvium

Stream channel and floodplain sediments (alluvium) occur along the valley floors of the NT tributaries cross cutting the prospective EMDF footprints. The relationship of the alluvium with underlying and adjacent subsurface materials is illustrated schematically in Figure E-29 and varies in width and thickness. Colluvium also may occur surficially along the lower marginal slopes of these valleys. The nature and extent of alluvium and colluvium are poorly defined at the proposed EMDF sites. Detailed soil mapping was completed at Site 14 (WBCV) in conjunction with investigations for the proposed

LLWDDD site, but the vertical extent of alluvium along the length of the NT valleys is largely undefined. Most of these relatively loose unstable deposits would be removed during landfill construction and as necessary for placement of the proposed underdrain networks (where required) and overlying geobuffer/liner systems. Ancient paleo-colluvial/alluvial deposits may also occur in places outside of the current NT stream valleys, as demonstrated by the detailed LLWDDD site soil surveys (see Figure E-30; adapted from Lietzke et al, 1988). However, these loose deposits are anticipated to be relatively minor in extent and would also be removed prior to landfill construction.

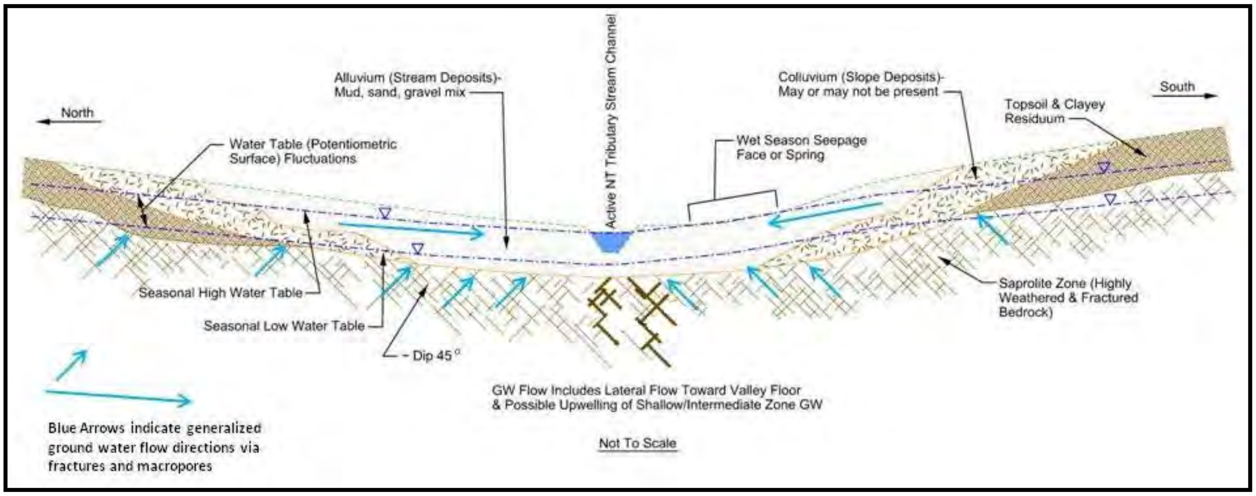
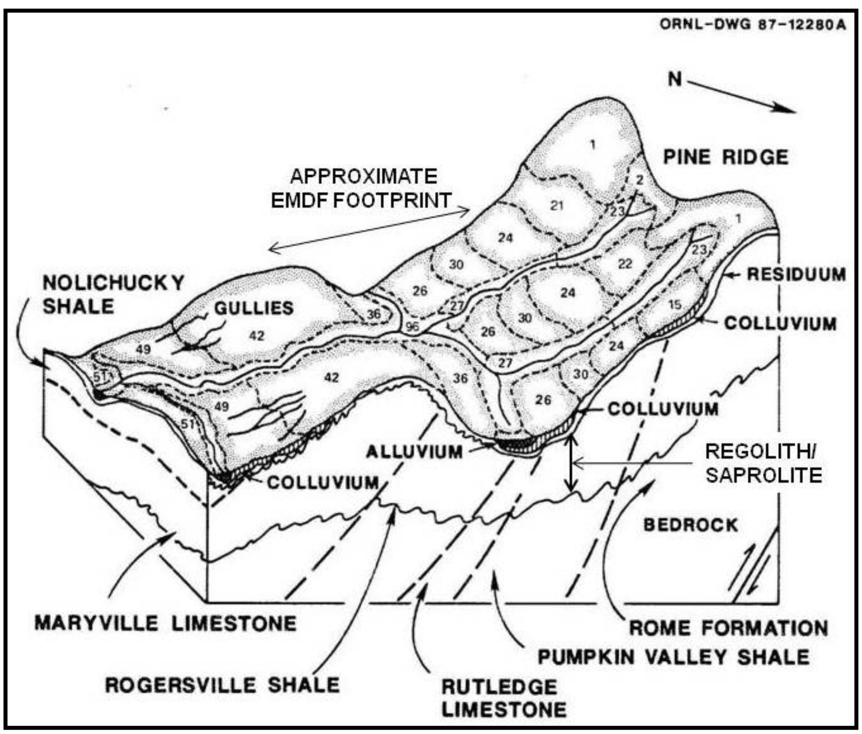


Figure E-29. Typical subsurface profile anticipated across an NT valley underlain by fractured clastic rocks



[Modified from Figure 8a of Lietzke et al 1988 at WBCV LLWDDD Site]

Figure E-30. 3D diagram illustrating relationships between alluvium/colluvium, residuum, saprolite, bedrock, and topography mapped at Site 14 (WBCV) and anticipated at any of the proposed EMDF sites in BCV

2.12.3 Geologic Structures Influencing Ground Water Flow

Geologic structures provide the fundamental pathways for ground water flow and contaminant transport. Structures most relevant to the site conceptual model and fate and transport modeling include: 1) macropores and other preferential pathways within residuum and alluvium/colluvium, 2) macropores and relict fractures within saprolite, and 3) fractures within bedrock associated with bedding planes, orthogonal joint sets oriented perpendicular to bedding, and local scale folds and shearing. Bedrock solution cavities become dominant structural controls on ground water flow within the Maynardville Limestone downgradient of each of the proposed EMDF sites. Localized deformation within bedding parallel zones may influence structures as well by creating fractured shear zones with a greater number of closely spaced and interconnected fractures.

2.12.3.1 Regolith Structures

Specific descriptions of basic structural characteristics for surficial soils, clayey residuum, and saprolite comprising the regolith are sparse beyond general descriptions on boring logs and in summary descriptions of overburden materials. For the predominantly clastic rocks at and near the proposed EMDF sites, structural characteristics of saprolite generally mimic those of bedrock fracture systems, but reflect much greater leaching and weathering that would in general increase pore and aperture size of macropores and fractures. Evidence from near surface exposures in road cuts and root balls at Site 5, and from test pit and boring logs at and along strike with the proposed sites suggests that near surface silty/clayey residuum transitions downward into a mix of silt/clay matrix and weathered rock fragments mostly composed of shale and siltstone. The bulk hydraulic characteristics of the topsoils and silty/clayey residuum resemble those of porous media transitioning with depth into highly weathered and fractured saprolite with relict features that vary according to the lithologies and structures of the underlying less weathered to unweathered fractured bedrock. Loose unconsolidated surficial regolith composed of topsoils and silty/clayey residuum grades progressively downward through increasingly more competent regolith until solid bedrock is reached at auger refusal depths. This transition probably reflects a general decrease in bulk effective porosity and permeability across the regolith, but K measurements typically made from slug tests in shallow monitoring wells commonly screened at and above auger refusal provide average values that reflect the entire screened interval.

Driese, et al. (2001) documented extensive filling in saprolite fractures at the base of the soil zone due to translocated clays. These clays and associated iron and manganese deposits choke the fractures, forming a leaky seal between the storm-flow zone in surficial topsoils and the deeper vadose zone.

2.12.3.2 Bedrock Fractures in Predominantly Clastic Formations of the Conasauga Group

Descriptions and data on bedrock fractures applicable to the proposed EMDF sites are available from site investigations and research reported from clastic Conasauga Group formations at sites in BCV and elsewhere on the ORR. Results from these sources are summarized below. Original reports are recommended for detailed data, graphics, and interpretations.

One of the most important field research efforts to accurately identify permeable fractures in wells and boreholes was conducted by Moore and Young in the early 1990’s using a new electromagnetic borehole flowmeter developed by TVA. Moore and Young (1992) conducted systematic depth discrete and very sensitive flow meter testing (0.05 cm/sec) in 70 wells and open coreholes at Y-12 and ORNL. The tests measured flow rates under natural and induced (mostly by water injection) conditions at vertical spacings of 0.5-1.0 ft across the entire length of screened wells and open boreholes. Their results provided vertical profiles identifying the numbers and depths of permeable fracture intervals. Nearly all of their surveys were run on wells in the Conasauga Group; the same formations underlying or adjacent to the EMDF sites. Most wells installed during site investigations on the ORR do not include flow meter testing to identify and distinguish between individual depths and flow rates for permeable fractures versus intervening relatively impermeable intervals without fractures. Moore and Young (1992) analyzed and interpreted the flowmeter surveys "*to show that about 65% of the permeable intervals are <1.2 m (4 ft) thick and transmit water chiefly toward cross-cutting tributary streams. The other 35% of the permeable intervals are >1.2 m thick; these fractures occur only within 6 m (20 ft) of the water table and transmit water downslope to main-valley streams*." Furthermore they noted that "*Several previous studies have suggested that a large majority of all ground water is transmitted to nearby streams in a thin, permeable zone at the water table. This hypothesis, however, was based only on logical reasoning and indirect evidence. The flowmeter results provide the first direct evidence for a difference in the fracture characteristics of the permeable zone near the water table and the fracture characteristics at deeper levels. Information on fracture spacing and on effective porosity is necessary for the modeling of matrix diffusion and sorption, as well as for calculations of contaminant velocity and concentration. A combination of results from borehole surveys and injection tests show that orthogonal fracture spacing is about 0.15-0.44 m (0.5-1.4 ft) near the water table and 0.44-0.73 m (1.4-2.4 ft) at deeper levels. Average effective fracture porosity is about 1.3 x 10^{-4}*." The ORNL report by Moore and Young (1992) should be referenced for additional details.

Moore and Toran (1992) estimated that a recharge boundary was indicated in about 85% of the injection tests conducted on the ORR, supporting the concept that a relatively small number of fractures may control ground water flux. Sledz and Huff (1981) attempted to use linear regression to find relationships between fracture length, density, lithology, and bed thickness, however, their results indicated little correlation between the parameters evaluated. They found fracture densities in the Pumpkin Valley Shale in BCV as high as 100–200 fractures per meter, a mean range of fracture density in siltstones of 6–45 fractures per meter, and 12–28 fractures per meter in shales. They also noted that Conasauga Group shales exhibit greater fracture densities in thinner lamina, but in siltstones the density of fractures decreased as bed thickness increased.

Fractures may propagate over long distances, particularly along bedding planes or in massively bedded rocks, but are more typically on the order of a few inches to a few feet long (Dreier, et al. 1993; Moore 1988; Sledz and Huff 1981). Sledz and Huff (1981) reported that mean joint length in Pumpkin Valley shales was nearly constant at 4.7 in. (12 cm); in siltstones fracture length varied from 1–30 in. (2–76 cm). Fracture length also increased in thinner beds and lamina of shales, and fracture length increased as bed thickness increased in siltstones. Lemizski (1995) and Dreier, et al. (1993) noted that bedding plane fractures tend to be much longer and wider than orthogonal fractures. Eaton, et al. (2007) noted that "*. . . few if any vertical fractures will propagate across all layer interfaces*" where rock layers are characterized by differences in response to tensile stresses. This tends to increase the tortuosity of ground water flow paths.

Aperture is a critical measure of a fracture's ability to conduct water. Moore and Toran (1992) give a geometric mean fracture aperture of 0.005 in. (0.12 mm) for ORR rock units, and since porosity can be calculated as the ratio of aperture to spacing (35 mm), porosity averages about 0.34%. Bedding plane fractures tend to be wider and more open than the vertical fractures (Lemizski 1995; Solomon, et al. 1992). Sledz and Huff (1981) indicated that, for the Pumpkin Valley Shale, apertures in outcrop and in unweathered bedrock ranged between 0.005 in. and 0.28 in. (0.1 mm and 0.7 mm). They further observed that joints in competent rock were much narrower than those in saprolite. Lemizski (1995) indicated that fracture aperture did not necessarily correlate with other fracture dimensions, such as length.

Fracture width in saprolite is increased relative to bedrock due to weathering (Driese, et al. 2001; Dorsch and Katsube 1996). For example, Driese, et al. (2001) report that fracture apertures in sandstone saprolite range from 0.005–0.5 mm; in shale and siltstone saprolite the range is 0.005–1.5 mm, and in limestone saprolite the range is 0.005–2.0 mm.

The RI Report for BCV (DOE 1997; Appendix C.3.3) also addresses bedrock fractures in BCV applicable to the proposed EMDF sites. Descriptions that follow are largely derived from that report. The RI report notes that because of the large-scale faulting and folding characteristic of ORR geology, all bedrock Iithologic units in BCV are highly fractured. The most pervasive structural features are extensional, hybrid, and shear fractures. Corehole studies of fractures in bedrock along a transect across BCV near the head of Bear Creek (Lutz and Dreier 1988; Dreier and Davidson 1994 – See DOE 1997) demonstrate the existence of several major fracture sets that are dominated by a strike-parallel set. Most fractures in ORR bedrock constitute a single cubic system (three orthogonal sets) of extension fractures (Dreier et al. 1987; Sledz and Huff 1981). One fracture set is formed by bedding planes dipping to the southeast. Two other fracture sets generally parallel strike and dip; at shallow depths, these sets are commonly angled 50˚ to 60˚ below the horizon. These three fracture sets may occur in any locality, and other extension and shear fractures may also be present (DOE 1997). Results of research into fracture systems on the ORR, many based on data from Conasauga Group rocks in BCV, are described in detail by Hatcher et al (1992) and Solomon et al (1992) and not paraphrased here. These reports reference other research addressing fracture systems, and implications of fracture systems on ground water flow and contaminant transport.

The RI Report for BCV provides additional summary information on bedrock fractures, noting that fractures are abundant on rock outcrops (as observed in available shallow outcrops during site reconnaissance at Site 5). In general, fracture spacing is a function of lithology and bed thickness. Fractures in more massively bedded formations tend to have longer trace lengths and are more widely spaced. Dreier et al. (1987) measured an average fracture density of ~200 fractures per meter (60/ft) in saprolite of the Maryville Limestone and Nolichucky Shale. At the other extreme, Sledz and Huff (1981) measured a minimum of five fractures per meter (1.7/ft) in fresh rock. Fewer open fractures occur at deeper levels. As described by Haase et al. (1985), fracture frequency is variable, but most fractures observed in cores occur within limestone or sandstone layers >0.5 m (1.6 ft) thick, and many are filled or partly filled with secondary minerals.

Most fractures are short, a few centimeters to ~1 m (3.3 ft) in length (longest dimension). Sledz and Huff (1981) found that fracture length at outcrop is relatively uniform [~12 cm (5 in.)] in shale but increases with bed thickness in siltstone. Haase et al. (1985) observed numerous fractures ~0.1 to 1.5 m (0.3 to 5 ft) long in limestone and sandstone units of the Conasauga Group and the Rome Formation. In limestone, typical fracture spacings range from <5 cm (2 in.) for very thin beds to >3 m (10 ft) for very thick to massive beds. The size of fracture planes may be only a few square meters for thin to very thin beds, but pervious bedding-plane fractures may be 10^3 to 10^6 square meters for medium to massive beds (Ford and Williams 1989).

Detailed logging of core from wells at the BCBG site (located southwest of the EMWMF and along strike with the proposed EMDF sites) has provided information on the relative changes in densities of open (hydraulically active) fractures in the Nolichucky Shale compared to depth and lithology (Dreier and Davidson 1994). This information was supported by estimates of spacings for hydraulically active fractures from resistivity, temperature, and flow meter logs of the same borings. The resulting estimates ranged from ~0.9 m (3 ft) in the shallow intervals to more than 6 m (20 ft) in the deep intervals. The combination of hydrological data and fracture logging in Dreier and Davidson (1994) also shows that changes in the vertical hydraulic gradient can be correlated to changes in the spacing of hydraulically active fractures. In the Nolichucky Shale, a strong vertical hydraulic gradient exists in well GW-726 over the upper 76 m (250 ft), where fracture spacings are ~0.9 m (3 ft). Below this level, however, fracture spacings increase and the vertical head gradient decreases significantly, becoming flat with increasing fracture spacing.

Moore and Young (1992) used subsurface flow meters to determine fracture density and conductivity in Bethel Valley and BCV. Their data show that fractures >1.2 m long occur mainly within the upper 6.1 m of the saturated zone, whereas fractures <1.2 m long occur both near the water table and at deeper levels.

The shorter fractures (65% of the total) have dips of 45° to 82° and probably transmit water chiefly toward cross-cutting tributary streams. The longer fractures (35% of the total) have dips of >82° and probably transmit ground water downslope toward main-valley streams. The thickness of bedrock matrix intervals in the flow meter surveys show that orthogonal fracture spacing is about 0.15–0.73 m and the steeply dipping fractures apparently have the closest spacing. Further, they corroborate the notion that the most conductive zone is near the water table.

In addition to the fracture sets discussed above, small to larger-scale deformation features such as localized shear fractures and zones of folded crumpled beds may occur that would provide enhanced ground water flow paths may exist in the subsurface and influence ground water flow at the EMDF sites. Analysis of extensive rock cores from the WBCV Site 14, and results from Phase I rock cores at Site 5 suggest that zones of shear deformation and folding may occur at least locally within some bed parallel intervals of the Dismal Gap/Maryville. In addition, field observations of shallow road cuts at Site 5 (EBCV) suggest that contorted bedding may occur locally within thinly bedded shales and siltstones of the Rome and Pumpkin Valley. There is no clear evidence of vertically oriented strike-slip faults in BCV.

Figure E-31 presents a generalized schematic for fracture system complexity in clastic rocks applicable to the proposed EMDF sites. The real world geometry of fracture networks can deviate from this schematic as fractures often may not form continuous planar surfaces for great distances laterally or vertically and may be stratabound (Ketelle and Lee, 1992). In addition, the schematic cannot accurately convey the complex interconnectivity of wider aperture fracture networks that actively transmit ground water and which are critical to fracture flow modeling simulations.

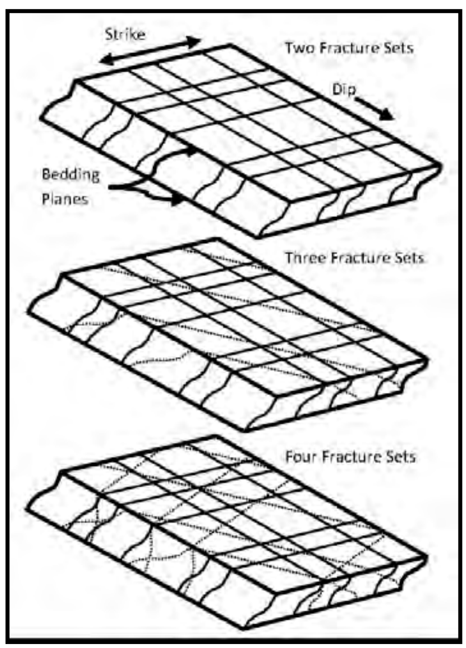


Figure E-31. Schematic of typical orthogonal fracture sets along bedding planes and joints in bedrock of BCV showing potential for increasing number and complexity of fractures

A thorough treatment of bedrock geologic structures for the ORR, including BCV and the Whiteoak Mountain Thrust Sheet is provided in Chapter 5 of the Status Report for the ORR (Hatcher et al., 1992). The several studies noted above addressing geologic structures in Conasauga Group formations in BCV are available and should be referenced for additional details.

Descriptions and detailed systematic analyses of fracture sets are generally not provided in site investigation reports or in boring log or test pit descriptions, so that the nature of fracture systems and the detailed geometry of fracture networks remain nebulus and undefined at most sites. This is true for the EMWMF and for the proposed EMDF sites. It has only been through published research on the ORR that the nature of fracture systems and conceptual models describing those systems have been defined. In addition, most of that effort had been focused on bedrock fracture systems with less emphasis on defining the geometry of preferential pathways via macropores and relict fracture systems within residuum and saprolite materials above bedrock. Boring data is inherently limited by the small diameter of tube and rock core samples limiting the horizontal scale to no more than a few inches. These uncertainties and limitations are necessarily reflected in fate and transport simulations in fractured media on the ORR.

2.12.3.3 Karst Hydrology in the Maynardville Limestone and Copper Ridge Dolomite

As noted in previous sections, conduits resulting from limestone dissolution within the Maynardville subcrop belt are well documented and provide the ultimate drainage path for surface water and ground water leaving BCV. The closer the EMDF footprints are located to Bear Creek and the Maynardville, the greater the potential for future contaminant releases to reach the relatively faster ground water flow paths within the Maynardville. Figures E-7 and E-9 illustrate the relative proximity of the proposed footprints to Bear Creek and the outcrop belt of the Maynardville. Figure E-9 in particular, shows the relationship between the proposed footprints and the approximate contact between the Nolichucky Shale and Maynardville Limestone. Areas south of this contact are where distinctive karst features first begin to appear along the southern margins of BCV. Areas to the north do not include typical limestone karst features such as sinkholes, caves, sinking streams, and karst resurgent springs.

The RI Report for BCV addresses cavity/conduit characteristics in the Maynardville of BCV (DOE 1997). The report notes extensive dissolution in the Maynardville Limestone underlying the valley floor of Bear Creek and in the Knox Group below Chestnut Ridge, and that in BCV, only these formations display highly developed and well connected cavity systems. The report indicates that in BCV, 66% of wells drilled in the Maynardville Limestone and Copper Ridge Dolomite intercepted at least one cavity and 38% intercepted two (Shevenell and Beauchamp 1994). During the drilling of the Maynardville Exit Pathway Picket Wells (Pickets A, B, C, and W; see Fig. C.5 in DOE 1997), numerous cavities and water-bearing fractures were intercepted (Shevenell et al. 1992). Although no obvious correlation was found between stratigraphic zones in the Maynardville (designated informally from top to bottom as Zones 7 through 2, with Zone 1 designated as the uppermost part of the Nolichucky Shale) and the occurrence of water-bearing zones and cavities in general, most water-bearing zones were intercepted in zones 2 and 6 near the bottom and top of the formation, and cavities were more common in zone 6 near the stratigraphic top of the formation (Shevenell et al. 1992; Shevenell and Beauchamp 1994; Goldstrand and Dreier 1993). Regardless of stratigraphic zone, 60% of cavities were encountered at depths of <30m (100 ft) and nearly all were encountered above 90 m (300 ft).

The RI report further notes that cavities encountered in the Maynardville Limestone range in size from <0.3 m (1 ft) to >3 m (10 ft) (Shevenell and Beauchamp 1994). In the Maynardville Limestone, 52% of measurable cavities were between 0.3 and 1.5 m (1 and 5 ft) in height with 12% >1.2 m (4 ft) and 16% <0.3 m (1 ft) (20% were of unknown height). Stratigraphically and physically above the Maynardville, the Copper Ridge Dolomite dips to the southeast under the north flank and crest of Chestnut Ridge. Cavities in the Copper Ridge are generally larger than those in the Maynardville, with 38% between 0.3 and 1.5 m (1 and 5 ft) in height, 23% >1.5 m (5 ft), and 1% <0.3 m (1 ft), with 38% of unknown size. Uncontaminated ground water from the cavity/fracture network below Chestnut Ridge drains northward and discharges to Bear Creek and probably commingles with ground water in the Maynardville karst.

The RI Report for BCV also notes that in addition to creating cavities and solution-enlarged fractures in the carbonate formations, water-rock chemical interaction in the Maynardville Limestone and Copper

Ridge Dolomite has increased the matrix porosity of these formations. Two diagenetic processes, dissolution of evaporite minerals and dedolomitization (Saunders and Toran 1994b), have produced matrix porosities in these formations of between 1.3 and 2.1% in the Copper Ridge Dolomite and zone 6 of the Maynardville Limestone, and between 0.5 and 0.8% in zones 2 to 5 of the Maynardville Limestone (Goldstrand et al. 1995). The RI Report for BCV provides documentation for gaining and losing reaches of Bear Creek that reflect the cavities and conduits developed within the Maynardville and from the adjacent Copper Ridge Dolomite (See Appendix C of DOE 1997 for extensive details). Section 4 below illustrates the losing reaches along Bear Creek that occur south of Site 6b.

A review of available lithologic logs and data summaries (BWXT 2003) for wells and borings in EBCV indicate that cavities are rarely, if ever, encountered in the stratigraphic units that underlie the proposed EMDF sites. An analysis of cavities by geologic formation for 222 wells in BCV numbered between GW-601 and GW-833, based on information provided in data summaries (BWXT 2003), found that the majority of conduits or cavities in BCV occur in the Copper Ridge and Maynardville Formations, especially adjacent to formation boundaries. Of the 58 Nolichucky wells reviewed, only two wells encountered cavities. Forty-nine wells that penetrate the remaining Conasauga formations did not encounter any cavities. While not conclusive, these data suggest that the majority of conduit flow occurs in the Maynardville and Copper Ridge, which is consistent with findings from the previous investigations and research reported in the BCV RI Report (DOE 1997).

2.13 GROUND WATER HYDROLOGY

The components of the hydrologic framework for the ORR (Solomon et al 1992; Moore and Toran 1992) include the stormflow zone, unsaturated (or vadose) zone, and the three intervals of the saturated zone (shallow, intermediate, and deep) as illustrated conceptually in Figure E-28 and summarized above for the site conceptual models for ground water flow in the clastic rocks of the Conasauga Group. The hydrologic framework for the ORR documents the close relationships between surface water and ground water on the ORR and in BCV. The basis for the hydrologic framework is presented in great detail by Solomon et al (1992), and Moore and Toran (1992). Their reports should be referenced for additional details only presented in summary below.

The depth to the water table or unsaturated zone thickness at each of the proposed EMDF sites varies across a relatively wide range from upland to lowland areas. Vadose zone thickness is greatest below upland areas such as those along Pine Ridge and along the subsidiary ridges underlying the Dismal Gap/Maryville outcrop belt. Away from these upland areas of ground water recharge the vadose zone thins into ground water discharge zones along the NT valley floors where the water table is at or near the ground surface. Ground water within the saturated zone converges and discharges slowly into NT stream channels supporting base flow along the valley floors, particularly during the wet non-growing season. During drier periods, ground water may make little or no contributions to stream channel base flow but may continue to slowly migrate southward toward Bear Creek along the NT valley floor areas within alluvium, saprolite, and bedrock fractures below the active stream channels. In addition, a portion of the ground water below the EMDF sites that does not readily discharge along strike to the NT valleys cross cutting the sites, moves southward toward Bear Creek along less dominant fracture pathways oriented perpendicular to geologic strike.

Shallow ground water also discharges to springs at point locations at the base of tight headwater ravines of the NT-3 tributaries and across broader seepage faces along portions of the NT valleys (See site conceptual model figures for the locations of springs, seeps, and wetlands where shallow ground water intersects the surface at and near the proposed EMDF sites). Ground water from these locations also contribute to stream channel base flow, particularly during the wet season. Continuous hourly water level data collected in Site 5 (EBCV) monitoring wells during 2014/2015 indicate that shallow ground water occurs within regolith materials above auger refusal bedrock depths at all Phase I well locations, except at

GW-976(I). At this location on the crest of the Maryville subsidiary ridge, the water table is much deeper and located roughly 20 ft or more below the bedrock/regolith interface at auger refusal. Water level data, boring logs, and well construction diagrams from many other locations in BCV along strike with the proposed EMDF sites illustrate that the water table commonly occurs up within regolith materials above auger refusal depths, except in local areas below topographic highs.

Water table hydrographs with hourly precipitation data indicate that recharge to the water table interval occurs readily in response to significant rainfall events in most wells, but the response may be subdued and delayed in wells below upland areas where the water table is at greater depth and recharge rates are slower. Potentiometric surface contour maps (flow nets) and cross sections for BCV and individual sites within BCV (e.g. - Site 14, Site 5, the BCBG, and the EMWMF) indicate that shallow and intermediate level ground water migrates from upland areas downgradient toward discharge zones along the NT valley floors and Bear Creek. Most of the ground water flux within the saturated zone has been demonstrated to occur via the shallow water table interval with progressively less flux occurring at intermediate and deeper intervals. The flux decreases in proportion to a general decrease in K associated with smaller fracture apertures, and an overall decrease in the number and relative frequency, spacing, and density of interconnected fractures capable of transmitting ground water.

The following subsections address hydraulic characteristics of the unsaturated (vadose) and saturated zone, ground water flow characteristics, ground water geochemical zones, and the results from tracer tests and tracer test modeling. The tracer test results are particularly relevant to the hydrogeological site conceptual models and ground water contaminant fate and transport modeling applied to the proposed EMDF.

2.13.1 Unsaturated Zone Hydraulic Characteristics

The hydraulic characteristics of the unsaturated zone below the landfill footprint contrast greatly with those in natural undisturbed areas surrounding the footprint. Section 2.9 above reviews the progressive changes to the unsaturated zone before, during, and after landfill construction. The drainage layers and low permeability layers of the landfill are engineered to maintain an unsaturated zone from the surface downward through all waste layers, the engineered layers below the waste, and the upper portions of natural materials below those layers. The resulting unsaturated zone after closure is thus quite thick extending from above and through the waste zone down to the post construction water table that occurs mostly within native saprolite materials below the footprint. The maximum thickness of this unsaturated zone between the top of the waste and the post closure water table is in the range of 100-150 ft thick at Site 5 (See conceptual design cross sections in Chapter 6 of the EMDF RI/FS Report).

During initial landfill construction and site grading, loose and unstable topsoil materials, and all alluvium and colluvium, will be completely removed from the site footprint to create a stable platform for construction. Removal of these materials with subsequent placement of geobuffer/liner materials effectively eliminates the former stormflow zone from the footprint area. The characteristics of the stormflow zone (occurring in undisturbed topsoils of the unsaturated zone) are therefore only relevant in undisturbed areas upslope and immediately surrounding the site(s). Because the upgradient French drain/trench system is designed to capture and divert surface runoff and topsoil ground water flow via the stormflow zone, the effects of the stormflow zone on the unsaturated zone are largely eliminated at and near the proposed landfill footprints.

Water infiltrating the landfill surface will initially migrate vertically toward the water table. Some portion of infiltrating water will undergo evapotranspiration within the surficial cover materials. Infiltration varies according to many environmental factors including rainfall intensity and duration, and daily and seasonal variations in temperature, wind speed, and vegetative growth. Flow in the vadose zone is episodic when it occurs, and requires sufficient water to overcome the effects of capillarity and to fill empty pores. The lateral drainage layers of the cover are designed to capture and divert most of the infiltrating water away from the landfill. However, a minor portion of infiltration is assumed to occur. The detailed pathways and rates of ground water flux through the relatively homogeneous engineered layers of the unsaturated zone are difficult to predict and models generally provide the only reasonable method for estimating unsaturated flow. The potential for the long-term development of preferential pathways within the engineered layers of the unsaturated zone cannot be ruled out but are impossible to predict. The increasing confining pressures imposed by the overall mass of the landfill at progressive depths below the landfill surface as well as the insulating effects of depth on variations in termperature and humidity should act to prevent cracking associated with wet/dry cycles that can effect low permeability soil layers in shallow landfill covers.

As described in Section 2.9, the pre-construction water table surface is estimated to be lower by several feet following construction and closure, increasing the thickness of the unsaturated zone below the EMDF site(s). In addition, the vertical range of water table fluctuations is expected to be significantly reduced by the umbrella effect of the cap, and by surface water runoff and stormflow zone diversions, and lowered base level water table elevations in the underdrain trenches.

Potential subsurface contaminants are mobilized through dissolution into water slowly infiltrating through the landfill waste. Contaminant migration is mostly downward through the relatively thick unsaturated zone. The unsaturated zone is vertically comprised of the final, interim, and daily compacted soil covers and waste layers; the low permeability engineered liner and geobuffer materials (15ft thick); structural fill layers where required, and naturally occurring in-situ materials above the water table at the top of the saturated zone. The unsaturated zone also includes relatively thin lateral drainage layers in the cap (2 ft thick biointrusion layer/1ft thick lateral drainage layer) and liner systems (1ft leachate collection layer and 0.3 in. leak detection layer). The hydraulic characteristics of these layers vary according to the material properties of each layer, their relative homogeneity and heterogeneity, and preferential pathways that may exist or develop within each layer. The material and hydraulic properties of the engineered layers are defined in the current EMDF conceptual design and will be ultimately dictated by the construction requirements of engineering specifications and drawings in final design documents. Those requirements must be met during landfill construction, operations, and interim and final capping (e.g. – standards for minimum K, placement, compaction, and grain size). Those standards all greatly limit the potential for heterogeneities and vertical preferential pathways to occur within and across the engineered thickness of the unsaturated zone. The low permeability cover and liner/geobuffer system layers are all designed to three dimensionally encase the waste materials in an unsaturated condition above the water table.

2.13.1.1 Unsaturated Zone Hydraulic Characteristics of the Engineered Landfill Layers

The majority of the unsaturated zone at the EMDF site(s) includes the engineered landfill layers enclosing the waste. The material and hydraulic properties of the engineered layers are described in the EMDF conceptual design (Chapter 6 of the EMDF RI/FS Report). The properties of each layer are further defined in the parameters of the detailed HELP model used to estimate infiltration rates (e.g. – layer type, thickness, soil texture, total porosity, field capacity, and saturated K; see HELP parameter table in Appendix H). The characteristics are based on reasonable assumptions for each type of layered material (e.g. - low permeability soils, plastic geomembranes, etc.) and the construction requirements and specifications that ensure uniformity and proper placement of materials. The K values of the various low permeability layers of the landfill (excluding those highly impermeable layers composed of plastic materials subject to long-term degradation) range from 10^{-8} cm/sec (Layer 6 amended compacted clay layer) to 10^{-6} cm/sec (Layer 17 – soil geobuffer barrier layer).

2.13.1.2 Unsaturated Zone Hydraulic Characteristics of In-situ and Underdrain Materials below the Landfill

While the majority of the unsaturated zone below the EMDF footprint is composed of the engineered landfill layers, the underlying undisturbed in-situ materials comprise the lowest relatively thin layer directly above the water table. The smallest fractional volume of the unsaturated zone below the footprint includes any portions of the underdrain blanket and trench drain network incised into in-situ materials that may occur above the water table (the total plan view area of the underdrain/trench system at Site 5 underlies approximately 10% of the footprint with similar to much lesser percentages likely at Sites 14 and 7a/6b). The underdrain materials have K values several orders of magnitude greater than the adjacent in-situ materials, designed to promote continuous drainage of shallow ground water into the underdrain.

Infiltrating water below the footprint that reaches unsaturated in-situ materials will tend to follow preferential fracture pathways downward to the water table along relict bedding planes and joints in saprolite (or in bedrock in limited areas where deepest cut grades occur). The hydraulic characteristics of those unsaturated in-situ materials will be similar to those described below for the upper portions of the saturated zone in undisturbed areas, except for any additional effects that may be imposed by the overlying landfill mass.

2.13.1.3 Unsaturated Zone Hydraulic Characteristics in Adjacent Undisturbed Areas

Flow in the unsaturated zone in undisturbed natural areas surrounding the capped EMDF footprints will differ markedly from that described above where flow is greatly impeded through the thick engineered sequence of landfill materials. Unsaturated flow in undisturbed areas will migrate to the water table through the typical sequence of topsoil, silty/clayey residuum, and saprolite described in Section 2.12, which may also include veneers of alluvial and colluvial materials along the flanks and floors of the NT valleys. According to the work of Solomon et al (1992), Moore and Toran (1992) and others, most of the water infiltrating the surface during and immediately after storm events travels laterally and relatively quickly through the topsoil stormflow zone to discharge with surface runoff along stream channels. The portion of natural recharge infiltrating below the stormflow zone that reaches the water table in these undisturbed areas will merge with the lowered water table passing below and around the footprint perimeter and influence the underflow of uncontaminated ground water passing below the footprint from upgradient and cross gradient areas. The lowest elevations of the water table surrounding the footprints will continue to be at or in close proximity to the elevations along the NT tributary and sub tributary channels adjacent to the EMDF sites. Thus the thickness of the unsaturated zone in undisturbed areas east and west of NTs adjacent to the EMDF sites will remain largely unaltered. Ground water flow from upland recharge areas to lowland discharge areas along the NT valleys will continue before, during, and after landfill construction and closure.

Research on the ORR (Solomon et al, 1992; Moore and Toran 1992; Clapp 1998) has demonstrated that recharge through the unsaturated zone in undisturbed natural settings is episodic and occurs along discrete permeable features that may become saturated during storm events, even though surrounding macro and micropores remain unsaturated and contain trapped air. During recharge events, flow paths in the unsaturated zone are complex, controlled to a large degree by the nature and orientation of structures such as relict fractures in saprolite (Solomon et al, 1992).

Virtually all field tests to determine K (i.e. – slug tests, packer tests, borehole flow meter tests, and pumping tests) reported from sites in BCV have been those conducted in the saturated zone, or using lab tests on soil samples designed to determine K under saturated conditions. The hydraulic characteristics of unsaturated (and saturated) in-situ materials can be currently estimated based on available data at and near the proposed EMDF sites but most field investigations have not involved any direct measurements of unsaturated zone hydraulic parameters.

Solomon et al (1992) describe the natural hydraulic characteristics of the vadose zone on the ORR. They note that saturated K measurements have been made in the vadose zone using infiltration tests and packer tests and state the data are lognormally distributed with a geometric mean K of 1.9 x 10^{-3} m/d (2.2 x 10^{-6} cm/sec), and a range of 1.74 x 10^{-7} cm/sec to 1 x 10^{-4} cm/s, ± one standard deviation (p. 3-13). They state that the total porosity of the vadose zone is probably the same as in the stormflow zone, ranging from 0.3 to 0.5, but provide no concrete basis for generalizing the porosity of the stormflow zone (which is defined as flow through topsoil/root zone materials) across the entire thickness of the vadose zone. They note a calculated average effective porosity for the vadose zone of 0.0042 (0.42%), determined by Moore (1989), and that this value is nearly the same as the specific yield (S_y) of the ground water zone. [Note that effective porosity is equivalent to S_y in unconfined aquifers and that effective porosity and S_y reflect gravity drainable porosity]. In addition, they note that this S_y is an order of magnitude less than that in the stormflow zone, indicating that vertical percolation through the vadose zone "*occurs in only a few permeable features such as fractures*" (Solomon et al 1992, p. 3-14).

2.13.1.4 Unsaturated Zone Geotechnical Data

Geotechnical engineering data collected from subsurface investigations for design and construction of landfills tends to be focused on vadose zone materials. A considerable amount of geotechnical data from the vadose zone are available from geotechnical investigations conducted in the EMWMF footprint and at an adjacent site east of the EMWMF footprint. Those data are summarized below in Section 5 in relation to EMDF Site 5, but results are applicable to portions of the other proposed EMDF sites in BCV along geologic strike with Site 5. With regard to K measurements in the vadose zone, bulk soil samples from two test pits (TP12 & TP16) excavated in the unsaturated zone at the EMWMF site were submitted for laboratory analysis of permeability (per ASTM Method D5084) from depths of 4 and 8 ft below surface. Permeabilities ranged between 10^{-6} to 10^{-8} cm/sec for four tests conducted on remolded and compacted silty/clayey saprolitic soils (two tests per sample were conducted at 5 and 30 psi confining pressures with lower permeabilities associated with the 30 psi tests). These results, based on a small sample size and remolding and of bulk soil materials, are not representative of bulk K values for natural in-situ soils and saprolite, but they are applicable to soils and saprolite that could be used for engineered fill/geobuffer materials. Detailed site characterization will be needed once a final site is selected. If unsaturated zone characteristics are required to support modeling, engineering design, or other project needs, they can be addressed in future work plans for site characterization.

2.13.2 Saturated Zone Hydraulic Characteristics

Most measurements of subsurface hydraulic characteristics come from the saturated zone. The hydraulic characteristics of the saturated zone influence the rates and directions of ground water flow below and away from the EMDF footprint(s). Hydraulic characteristics of the saturated zone in BCV have been determined by a variety of field and laboratory methods applied during numerous investigations and field research at many sites in BCV. The following subsections review the findings from site investigations and research in BCV most relevant to the hydraulic characteristics of subsurface materials at and downgradient of the proposed EMDF sites. The detailed and comprehensive reports by Solomon et al (1992), Moore and Toran (1992), and others, describing the hydrogeology of the ORR (including BCV) should be referenced for additional information on hydraulic characteristics and subsurface flow processes relevant to the proposed EMDF sites.

2.13.2.1 Field and Laboratory Methods for Determining General Hydraulic Characteristics of the Saturated Zone

The most common field methods for determining hydraulic characteristics of the saturated zone in BCV include: 1) slug tests, 2) packer tests, 3) pumping tests, and 4) tracer tests. The most common hydraulic parameter measured in the saturated zone of BCV sites is K, which is most often determined from slug tests and packer tests conducted in wells and open boreholes. A limited number of pumping tests in BCV also provide K data, as well as values for transmissivity (T), S_y, and storativity (S), and anisotropy. Pumping tests generally provide a better indication of bulk hydraulic characteristics by influencing a much larger volume of the saturated zone relative to the localized zone around individual wells or isolated zones within individual boreholes. Detailed results of pumping tests conducted at the WBCV Site 14 are presented below in Section 5 where previous investigations at Site 14 are summarized. Results of several tracer tests relevant to the EMDF sites are presented below in Section 2.13.4. The methods for conducting, interpreting, and modeling tracer test results are complex and varied relative to the more standardized methods applied to single and multi-well tests for determining K and other parameters.

Hydraulic characteristics can also be determined from laboratory methods using bulk and tube samples collected from unconsolidated regolith materials (soil residuum and saprolite). However, as noted above, these methods (commonly standardized ASTM methods) are generally focused on unsaturated zone soils (including saprolite in BCV) and on engineering design needs that may differ from those required for fate and transport modeling and risk assessment. It is important to evaluate results according to the type and depths of subsurface materials tested and in the context of the complex fractured subsurface media in BCV. Researchers on the ORR have also used less conventional analytical and laboratory methods to determine aquifer characteristics as summarized in subsequent sections (Dorsch et al 1996, Moore and Toran 1992, and others).

2.13.2.2 Porosity, Effective Porosity, and Storativity of the Saturated Zone

Estimates of porosity and effective porosity reported for BCV vary and have often been generalized for subsurface materials in BCV. Storativity values for the semi-confined conditions within the intermediate and deeper portions of the saturated zone have been determined primarily from pumping tests. The effective porosity (equivalent to S_y in unconfined aquifers) of the saturated zone represents the gravity drainable porosity and is a fraction of the total porosity. While total porosity may be high in fine grained porous materials such as the silty clay in the regolith of the EMDF sites, the effective porosity is typically quite low as the small pore size and high capillarity of the fine grained materials prevent water from freely passing through the bulk of the material. In the natural subsurface materials at the proposed EMDF sites, the relatively thin silty clayey soil residuum layer above saprolite (typically less than a few feet in thickness) has a relatively low effective porosity associated with the porous but fine-grained silt and clay comprising the residuum. Of greater importance, is the porosity and effective porosity of the much thicker saprolite and bedrock which comprise the majority of in-situ materials through which ground water (and contaminants) migrates below and downgradient of the proposed EMDF sites. The highly weathered and fractured condition typical of saprolite equates to a higher porosity and effective porosity relative to the deeper less weathered to unweathered fractured bedrock with fewer widely spaced fractures and smaller apertures. These general features and downward transitions are evident in tube samples and test pits of soils and saprolite, and in bedrock cores. The general relationship between relatively porous and permeable fractures and adjacent fragments and blocks of relatively impermeable unweathered bedrock is illustrated schematically in Figure E-32. The figure illustrates the porosity and micro-porosity inherent to the fracture surfaces and adjacent macro- and micro-pores of weathered rock (darker areas) in contrast with the relatively impermeable and unweathered host rock indicated as “matrix” (white areas). The figure also illustrates the relative decrease in fracture porosity and effective porosity with depth transitioning from shallow saprolite above and near the water table to deeper weathered and unweathered bedrock. The term aquitard in the figure (from Solomon et al 1992) refers to the predominantly clastic (non carbonate) rock formations within the Conasauga Group (i.e. – the Rome formation through the Nolichucky Shale underlying the proposed EMDF sites).

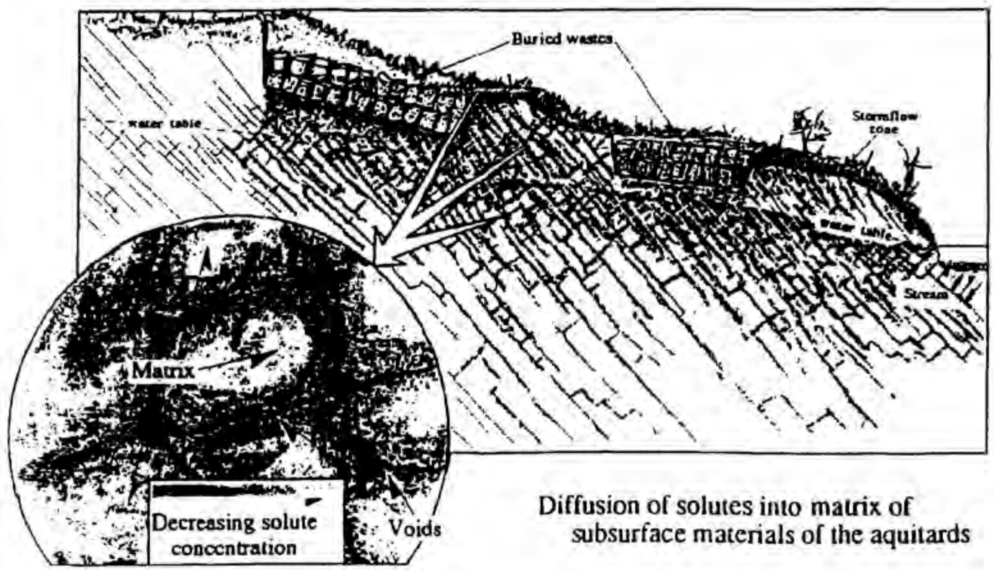


Figure E-32. Differences between relatively permeable and porous fractures and relatively impermeable host rock (matrix) [from Solomon et al 1992]

Total porosity values have been rarely presented in the ORR literature. Moore and Toran (1992) cite a mean porosity of 0.50 for shaley saprolite in trench walls at ORNL Waste Area Grouping (WAG) 6 based on bulk density calculations (p. 15). The majority of porosity related data from the ORR are associated with effective porosity (or S_y) and storativity, which are more significant in terms of determining ground water flow rates than total porosity. Table E-8 summarizes effective porosity, storativity, and matrix porosity data from various reports and research conducted on the ORR and in BCV. The values for effective porosity range widely over several orders of magnitude depending on the methods, assumptions, and calculations applied for their determination. The values reported by Dorsch et al (1996) and Dorsch and Katsube (1996) are based on laboratory analysis of cores from the saturated zone of bedrock and saprolite, respectively. Their values are at least one to two or more orders of magnitude higher than those reported by Solomon et al (1992) and Moore and Toran (1992) for the saturated zone, which were partly derived from analysis of ground water level recession curves, and based on analyses of data derived from several ORR studies. Their methods and analysis differ greatly from the strict laboratory methods applied by Dorsch et al. (1996). The values shown in Table E-8 used by Lee et al (1992), McKay et al (1997), and in the ORNL performance assessment for the WBCV site (ORNL 1997) are all estimates assumed for the purposes of ground water modeling, but generally reference specific investigations on the ORR as a foundation for the assumed values.

The mean storativity value reported by Moore and Toran (1992) and shown in Table E-8, is based on 26 storativity values calculated from observation wells in aquifer tests on the ORR. They note that "*under confined conditions, as occur at deeper levels (Moore 1988, p. 48), storativity may represent chiefly the elasticity of fracture walls. Nevertheless, the water yield produced by changes in fracture aperture may be nearly the same as the yield produced by drainage.*"

Because topsoil materials of the stormflow zone will be removed during landfill construction, the hydraulic characteristics of this zone have little influence on ground water flow and simulated fate and transport modeling below and downgradient of the EMDF sites. Effective porosity values reported for the stormflow zone are generally an order of magnitude or more higher than those of the ground water zone

Table E-8, Effective porosity, storativity, and matrix porosity values from various ORR sources

Paper/Report Source	Mean Effective Porosity (%)	Range - Effective Porosity (%)	Notes
Dorsch et al 1996 - ORNL/GWPO-021	9.9	4.58-13.00%	Bedrock Cores - GW-132, 133, 134 EBCV transect shales from various Conasauga Group Formations in BCV; cores from 40 -1156 ft bgs
Dorsch & Katsube 1996 - ORNL/GWPO-025 - GW-821, 822, 833 WBCV transect; Mudrock saprolite from Nolichucky Shale	39.0		Saprolite groundmass
	16.1		Less weathered saprolite mudrock fragments
		26.2 - 51.3	Calculated interval effective porosities - larger volumes of saprolite - integrate mudrock fragmens and groundmass
Moore as repored by Solomon et al 1992	3.2	3.2 - 3.6	Stormflow Zone (topsoil/near surface)
	0.23		Ground water zone (shallow water table interval)
Solomon et al 1992 (ORR Hydro Framework)	4.0		Stormflow Zone
	0.42		Vadose Zone
		0.25-0.33	Ground water zone (shallow water table interval)
		0.1-0.001	Groundwater zone - appears to include entire saturated zone from shallow water table interval through intermediate to deep intervals
	Mean Storativity (%)	**Range - Effective Porosity (%)**	
	0.084	0.58 to 0.0048	Storativity from aquifer tests (10^{-3} to 10^{-5})
Moore and Toran 1992 - Supplement to Hydrologic Framework for the ORR (See their descriptions and their Table 1, p. 38-39)	**Mean Effective Porosity (%)**		
	3.5		Stormflow Zone
	0.23		Groundwater Zone
	Effective Fracture Porosity (%)		
	0.035		Groundwater Zone
	Total Matrix Porosity (%)		
	0.96		Groundwater Zone
	Fracture Porosity (%)		
	0.05		Groundwater Zone
	Storativity (%)		
	0.076		Groundwater Zone
	Mean Effective Porosity (%)	**Range - Effective Porosity (%)**	
Lee et al 1992 - Tracer test/modeling at WBCV site	3 (See Notes)	1-10	Wells screened in regolith (saprolite) and unweathered bedrock of Dismal Gap/(Maryville
	Calculated Effective Porosity (%)	**Estimated Matrix Porosity (%)**	
McKay et al 1997 - EPM Modeling/Tritium Tracer Test	9	8-40	ORNL Burial Ground 4 in saturated fractured weathered shale saprolite of Pumpkin Valley Shale similar to EMDF/BCV but in different fault block
	Mean Effective Porosity (%)		
ORNL 1997 Performance Assessment for WBCV Site	5		Values based on aquifer tests at Eng Test Facility in similar geology at ORNL/Melton Valley
Law Engineering 1993	0.3		OLF/BCBG pumping test
Lozier et al 1987	0.06		OLF/BCBG pumping test
Geraghty & Miller 1985	0.05		BCBG pumping test
Geraghty & Miller 1986	0.01 - 0.04		S-3 Ponds site pumping test
Golder Associates 1988	0.01		WBCV Site (near EMDF Site 14)

Table Notes:

Green shading – vadose zone
Light blue shading – shallow ground water zone mostly in weathered fractured saprolite and shallow bedrock ~<100 ft bgs
Dark blue shading – deeper ground water zones with discrete fracture zone flow
No color – results unclear with respect to saturated zone intervals
Lee et al (1992) used 3% in their model noting a range of 1-10% based on aquifer studies on the ORR.
See references cited for additional details

(excluding the values reported by Dorsch). The results are consistent with the rapid lateral water flux in the stormflow zone documented by ORR research (Moore 1988, Moore 1989, Solomon et al 1992).

2.13.2.3 Matrix Diffusion and Effective Porosity

Dorsch et al (1996) provide a summary of relationships between matrix diffusion and effective porosity in relation to the clastic "mudrock" saprolite and bedrock of BCV that dominates the subsurface environments at the proposed EMDF sites. Figure E-33 from Dorsch et al (1996) conceptually illustrates the partitioning of contaminants by matrix diffusion from ground water fracture flow paths into the adjacent pores and micropores of the surrounding host rock "matrix". As illustrated in the preceding Figure E-32, the nature and thickness of the porous "skin" of the relatively impermeable host rock adjacent to the fracture (and/or macropores in the more highly weathered portions of saprolite) will vary primarily upon the extent of weathering and dissolution, which generally decreases with depth below the water table in the clastic rocks of BCV. The effective porosity values described above reflect the decimal fraction of the rock volume that permits fluid flow (Moore and Toran 1992), as shown by the open part of the fracture in Figure E-33 that transmits water. As discussed in the review of tracer tests below, matrix diffusion is thought to play a critical role in attenuating the migration rates and concentrations of contaminants from source areas to downgradient locations. Diffusion of dissolved contaminants from the more transmissive fractures into the adjacent less mobile micropores and microfractures is believed to result in considerable attenuation along flow paths. This has obvious important implications for the contaminant fate and transport modeling presented in Appendix H. See Dorsch et al (1996) for additional details regarding matrix diffusion and effective porosity.

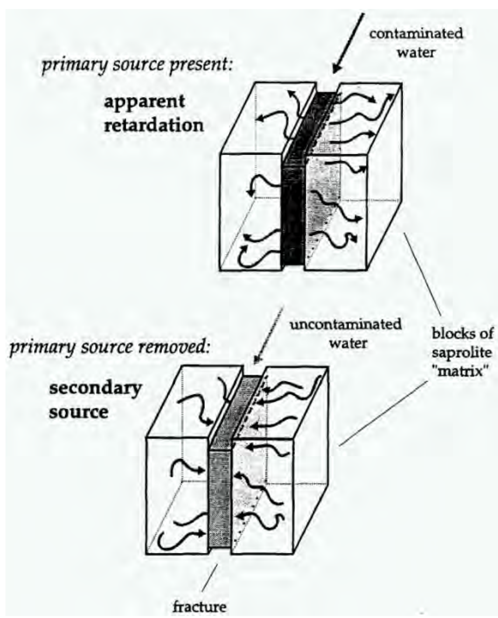


Figure E-33. Schematic diagrams illustrating the diffusion of contaminants from a single fracture into the surrounding skin of the rock "matrix" in saprolite or bedrock.

[Fig. 3 from Dorsch et al (1996)]

2.13.2.4 Hydraulic Conductivity of the Saturated Zone

Among the hydraulic parameters determined during subsurface characterization studies, K is the most commonly measured and is one of the most significant parameters employed in the fate and transport modeling used to calculate PreWAC for the EMDF (see Appendix H to the current RI/FS). The most recent compilation of K values reported for BCV by Jacobs (1997) span seven orders of magnitude ranging from a minimum of 0.000009 ft/day (3.0 x 10^{-9} cm/sec) to a maximum of 99.0 ft/day (3.5 x 10^{-2} cm/sec). The values range from low K values determined from packer tests in deep coreholes to relatively high values measured in wells completed in karst conduits in the Maynardville Limestone. K varies by lithology, degree of weathering and fracturing, and depth. K values are influenced by the test method; borehole or well completion interval tested; the number and vertical spacing among permeable fractures/fracture intervals and intervening relatively impermeable rock matrix intervals; and other factors.

Early Compilation and Analysis of K Data in BCV by Connell and Bailey (1989)

The volume of K measurements in BCV is substantial. One of the earliest compilations and statistical analyses of K data was reported by Connell and Bailey (1989). They evaluated pre-1985 K data from ten investigation reports with 338 single-well aquifer tests from BCV and from Melton Valley at ORNL Results were segregated and evaluated by regolith and bedrock tests and by geologic formations. In BCV, they selected 232 tests from 153 wells for statistical analysis; 63 in regolith, 164 in bedrock, and 5 in deep bedrock. Within BCV, the tested wells were located at the BCBG, Oil Landfarm, and S-3 Ponds waste sites in EBCV, and from the proposed Exxon Nuclear site southwest of SR 95 between SR 95 and the Clinch River. While none of this early well data included wells at the proposed EMDF sites, the results included wells completed in the same geologic formations underlying and downgradient of the EMDF sites, and are therefore representative of the range of K values that may be expected at and near the EMDF sites.

Figure E-34 summarizes the results of their evaluation of BCV data in terms of the distribution ranges for K among the geologic formations spanning the width of BCV and the proposed EMDF sites. Table E-9 summarizes their results with respect to the ranges of K used in the EMDF PreWAC ground water flow modeling. Figure E-34 illustrates that although the overall range of K values may overlap among the formations, the median K values for the clastic rock formations underlying the predominantly clastic geologic formations underlying the EMDF sites (i.e. – Pumpkin Valley through Nolichucky Shale) are roughly an order of magnitude lower than the median K value of the Maynardville Limestone. The data are reasonably consistent with relatively higher K values reported in the subsurface karst flow system of the Maynardville. The original report by Connell and Bailey (1989) should be referenced for additional details, analysis, and data summary tables.

Compilation and Analysis of K Data at the WBCV Site by Golder (1989b)

Golder Associates (Golder 1989B) analyzed K data from a total of 120 packer tests, 66 slug tests, and four pumping tests across a broad area of WBCV in support of the planning for the proposed (but never constructed) "Tumulus" disposal facility around EMDF Site 14 (See Section 3 below for figures illustrating the many Golder well locations in WBCV at and near Site 14). Golder plotted and analyzed the K results by test method, by geologic formation, and by depth. Golder provided log K plots versus depth by test method and by geologic formation. They subdivided the K data into three depth horizons, 0-50 ft, 50-300 ft, and >300 ft and provided frequency distribution plots of log K data according to these three depth levels. They concluded that, "*there does not appear to be a strong relationship between K and geologic formation. However, K is clearly depth dependent*."

The 0-50 ft interval was considered the most permeable and most representative of saprolite or shallow bedrock, with progressive decreases in K with depth for the lower horizons. From shallow to deep, they assigned geometric mean K values for the three horizons of 10^{-4} cm/sec, 10^{-5} cm/sec, and 10^{-7} cm/sec.

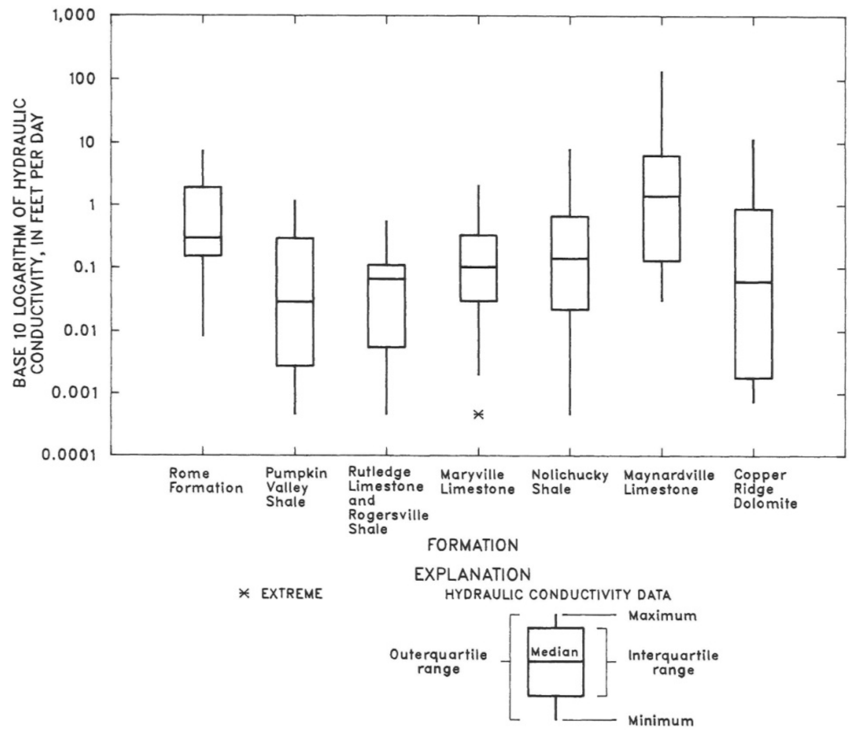


Figure E-34. Results of statistical analysis of hydraulic conductivity of 232 tests in BCV wells

[Fig. 3 from Connell and Bailey (1989) based on pre-1985 wells]

Golder also performed a linear regression analysis of the K data with depth as the independent variable and K as the dependent variable. Results are shown in Figure E-35, with a correlation coefficient of 0.46. Golder considered their data set too limited to conduct multivariant analyses to assess the effects of test type, test scale, and geologic formations. They also noted that a "significant emphasis" was placed on testing the Nolichucky Shale and Maryville Limestone as these two formations are found below a majority of the tumulus site. While the Golder results are most directly applicable to EMDF Site 14, they are also applicable to the other proposed EMDF sites that are located along strike with the WBCV site wells. The Golder Task 6 Report (Golder 1989b) should be referenced for additional figures, details, and interpretations.

<u>Hydraulic Conductivity Data Used in the Performance Assessment Modeling in WBCV</u>

Table E-10 illustrates K data used by ORNL (1997) in the PA modeling completed for the proposed Tumulus disposal facility in WBCV at EMDF Site 14. The data were obtained from slug tests conducted by Golder from 39 wells in WBCV (described more completely in Section 3 below). The table illustrates the depths of the completed interval and geologic formation for each well. The wells were all completed at relatively shallow depths no greater than 72 ft bgs; most as well pairs completed at the shallow water table interval in regolith and at slightly lower intervals within the upper sections of bedrock. Appendix E to the PA reviews geostatistical analyses used in conjunction with the ground water modeling. The results from deeper wells were excluded from their data set as their PA modeling only considered the upper tens of meters of the subsurface (see p. E-11 of ORNL 1997). As noted above, these data are applicable to EMDF Site 14, and to the other EMDF sites in BCV. See Section 6 below for additional details on the various K tests conducted in WBCV at and near Site 14.

Table E-9. Range of hydraulic conductivity values reported by Connell and Bailey (1989) in BCV compared to EMDF PreWAC model input data

Stratigraphic Unit	Statistical Analysis of Hydraulic Conductivity for Bear Creek Valley [Connell and Bailey 1989] — Range of Hydraulic Conductivity(ft/day) in Bear Creek Valley Monitoring Wells				Summary Data Used in PreWAC Model (See Appendix H) — Range of Hydraulic Conductivity (ft/day) Shallow to Deep Model Layers 1-11	
	No. Tests	Regolith	No. Tests	Bedrock	Dip & Vertical Directions (K_x & K_z)	Strike Direction (K_y)
Maynardville Limestone	5	6.3E-02 – 1.36E+02	13	3.1E-02 – 7.03E+01	4.80E-04 – 2.13E-00	4.80E-03 – 1.07E+01
Nolichucky Shale	24	3.7E-02 – 3.25E+00	45	4.6E-04 – 7.94E+00	5.00E-05 – 1.50E-01	5.00E-04 – 7.50E-01
Dismal Gap/Maryville Formation	15	3.0E-02 – 2.08E+00	33	4.5E-04 – 2.08E+00	4.50E-05 – 4.95E-02	4.50E-04 – 2.48E-01
Rogersville Shale & Friendship/Rutledge Formation	5	5.2E-02 – 2.8E-01	20	4.6E-04 – 5.5E-01		
Pumpkin Valley Shale	4	4.4E-02 – 1.17E+00	26	4.6E-04 – 8.4E-01	5.60E-05 – 3.00EE-02	5.60E-04 – 1.50E-01
Rome Formation	0	—	13	8.5E-03 – 7.37E+00	8.00E-05 – 8.00E-02	8.00E-04 – 4.00E-01
Deep Bedrock, undifferentiated		—	5	2.0E-05 – 1.4E-04	—	—

Table Notes:

The results shown from Connell and Bailey represent ranges from 232 K tests in 153 wells drilled before 1985 from various sites in BCV from Y-12 to the former Exxon Nuclear site in BCV west of SR 95.

The ranges used in the PreWAC model were based on an evaluation of wells across BCV during preparation of the model for BCV used in the BCV RI Report (DOE 1997) and also for the EMWMF. The BCV model incorporated wells in BCV installed after the analysis of pre 1985 wells by Connell and Bailey.

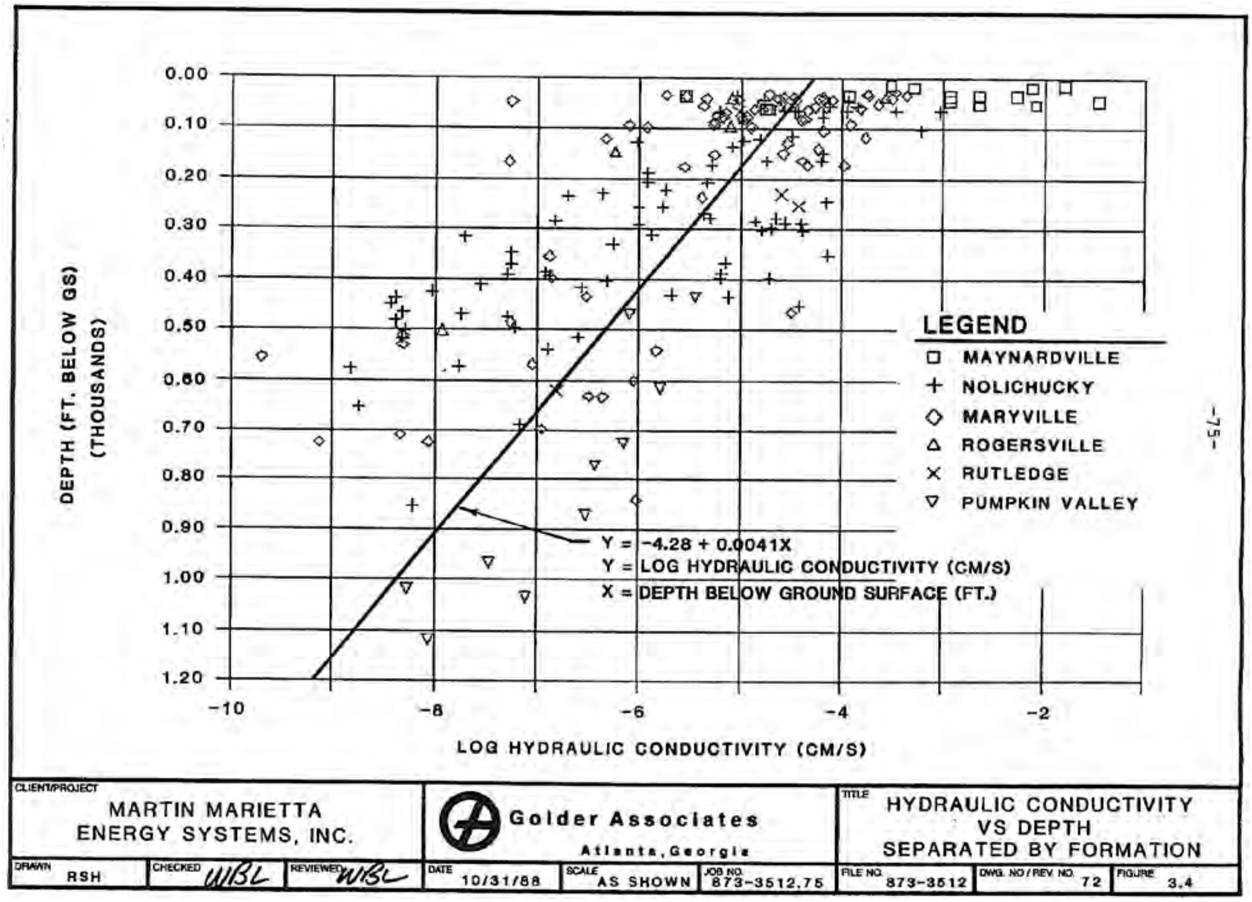


Figure E-35. Linear regression plot of hydraulic conductivity versus depth at the WBCV (Site 14) area.
[From Golder 1989b]

Compilation and Analysis of K Data in BCV by Jacobs (1997)

A more recent comprehensive compilation, summary, and analysis of K data from multiple sites in BCV (including other ground water hydraulic characteristics) were presented in the FS Report for BCV (Jacobs 1997). Chapter 3.5 of Appendix F to the FS Report includes over 200 test results from wells completed in BCV up through 1997 (See 15 pages of their Table F.10 in Attachment F.1 for the individual test results organized by aquifer test types, well, test interval, completed zone, etc., and summary descriptions of the results). The locations and source reports for the aquifer test data in BCV are illustrated in Figure E-36 from the Jacobs report for comparison to the proposed EMDF sites. The data were derived from slug tests/bailer recovery tests, packer tests, and pumping tests, including packer test intervals conducted in deep coreholes between depths of approximately 250 to 950 ft. The results were used in support of the construction and calibration of the original 3D regional ground water flow model for BCV used for evaluating remedial actions at the hazardous waste sites and contaminant plumes in EBCV.

Table E-10. Hydraulic conductivity data from the WBCV Site 14 area listed by geologic formation and used in the PA ground water modeling at the LLWDDD site in WBCV (ORNL 1997)

Well ID	Well location		Open interval		Unit sampled[b]	Hydraulic conductivity		
	Northing (ft)	Easting (ft)	Top (TOC ft)[a]	Bottom (TOC ft)		K (cm/s)	K (ft/d)	log(K) (ft/d)
GW-405	30323.58	28253.06	25.5	36.7	MAR	1.77E-4	5.02E-1	-0.2995
GW-407	30434.65	28828.24	33.5	42.7	ROG	8.12E-6	2.30E-2	-1.6379
GW-409	30289.30	28916.54	48.3	60.5	MAR	4.24E-6	1.20E-2	-1.9201
GW-412	30629.78	29868.86	29.2	42.1	RUT/PV	2.47E-5	7.00E-2	-1.1548
GW-414	30199.96	29585.74	45.5	57.6	MAR	1.57E-5	4.45E-2	-1.3516
GW-415	30099.66	30018.45	26.6	30.0	MAR	3.35E-4	9.50E-1	-0.0225
GW-416	30096.84	30022.85	49.9	63.2	MAR	5.42E-5	1.54E-1	-0.8135
GW-417	29758.11	29655.75	36.5	50.9	NOL	1.16E-4	3.29E-1	-0.4830
GW-419	29473.36	29425.25	38.5	50.6	NOL	1.65E-5	4.68E-2	-1.3300
GW-421	28850.04	28843.60	28.9	40.4	MAY	4.33E-4	1.23E+0	0.0890
GW-422	28849.53	28855.92	4.1	9.4	MAY-SAP	1.25E-3	3.54E+0	0.5494
GW-423	28762.24	29314.19	29.1	41.1	MAY	2.81E-6	7.97E-3	-2.0988
GW-425	29037.15	29867.41	49.7	61.7	NOL	1.40E-4	3.97E-1	-0.4014
GW-427	28682.11	30210.83	38.8	49.8	MAY	1.16E-3	3.29E+0	0.5170
GW-428	28678.78	30217.99	11.3	15.9	MAY	3.05E-4	8.65E-1	-0.0632
GW-430	29522.24	30463.95	27.4	40.2	NOL	9.11E-6	2.58E-2	-1.5880
GW-432	30283.78	30821.16	34.3	46.1	MAR	5.94E-5	1.68E-1	-0.7737
GW-433	30390.62	31191.70	7.1	15.5	MAR/MAR-SAP	8.54E-5	2.42E-1	-0.6160
GW-434	30397.54	31195.83	30.2	42.2	ROG	2.70E-4	7.65E-1	-0.1161
GW-436	30250.71	31291.04	34.9	47.3	MAR	4.53E-6	1.28E-2	-1.8914
GW-437	29960.52	31457.62	53.3	65.1	MAR	1.52E-4	4.31E-1	-0.3657
GW-439	29582.44	31447.29	47.4	61.8	NOL	7.60E-5	2.15E-1	-0.6667
GW-440	29580.31	31453.12	23.1	28.7	NOL-SAP	7.08E-5	2.01E-1	-0.6975
GW-441	28967.71	31214.63	44.6	56.6	NOL	1.67E-5	4.73E-2	-1.3248
GW-448	29885.05	31738.31	32.6	46.1	MAR	6.49E-5	1.84E-1	-0.7353
GW-450	30430.33	31726.04	45.8	57.6	ROG	2.37E-5	6.72E-2	-1.1728
GW-452	29767.95	32590.72	10.6	21.1	NOL-SAP/NOL	2.08E-5	5.90E-2	-1.2294
GW-456	29621.30	29259.87	59.6	72.1	NOL	3.64E-5	1.03E-1	-0.9864
GW-457	29621.30	29259.87	18.3	28.1	NOL/NOL-SAP	1.92E-5	5.44E-2	-1.2642
GW-458	29581.22	29621.56	59.5	72.0	NOL	3.46E-5	9.81E-2	-1.0084
GW-459	29581.22	29621.56	19.5	29.0	NOL/NOL-SAP	1.41E-5	4.00E-2	-1.3983
GW-460	29601.91	29210.49	58.9	71.9	NOL	2.66E-5	7.54E-2	-1.1226
GW-461	29601.91	29210.49	16.9	27.8	NOL-SAP/NOL	1.85E-5	5.24E-2	-1.2803
GW-462	29601.15	29260.50	17.5	70.4	NOL/NOL-SAP	3.53E-6	1.00E-2	-1.9997
GW-463	28679.66	30111.11	45.4	58.2	MAY	2.21E-3	6.26E+0	0.7969
GW-464	28688.53	30111.26	11.8	24.0	MAY	5.17E-4	1.47E+0	0.1660
GW-465	28708.36	30154.55	29.5	42.3	MAY	1.17E-4	3.32E-1	-0.4793
GW-466	28650.90	30161.30	31.1	40.7	MAY	1.17E-3	3.32E+0	0.5207
GW-467	28678.88	30159.43	19.2	64.7	MAY/MAY-SAP	6.74E-3	1.91E+1	1.2812

[a]TOC = top of casing.

[b] Rock unit codes: MAY = Maynardville, MAR = Maryville, NOL = Nolichucky, PV = Pumpkin Valley, RUT = Rutledge, ROG = Rogersville, SAP = saprolite

Source: Data from Golder Associates (1988).

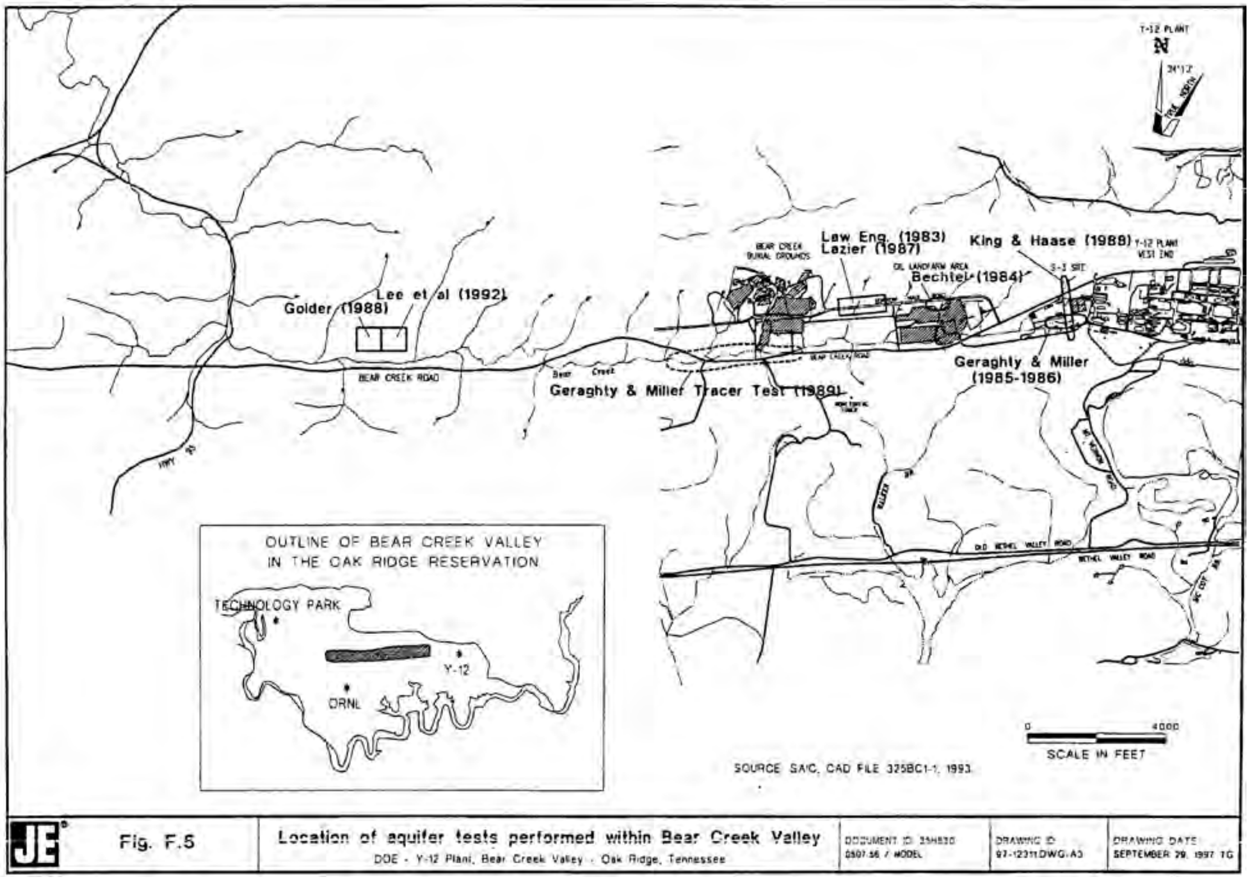


Figure E-36. Areas and report references for aquifer test data compiled and presented in the FS Report for BCV (from Jacobs 1997)

Table E-11 and Figures E-37 and E-38 summarize the results of the K tests presented by Jacobs (1997). Table E-11 presents K statistics by individual geologic formations and by groups of formations with similar hydrogeological characteristics. Figure E-37 illustrates the relationship between log K values and depths for the predominantly clastic (shaley) formations in BCV from the Rome through the Nolichucky Shale, while Figure E-38 illustrates results for the carbonate formations of the Maynardville and Knox Group along the south side of BCV. The plots illustrate the larger number of wells and test results available for relatively shallow wells (<~100 ft) versus results available for intermediate and deep levels of the saturated zone (>~100 ft). The plots and regression lines also illustrate that while there is considerable scatter in the range of K values by depth, the data suggest an overall general tendency toward reduced K values with depth that is consistent with less weathering and fracturing evident in subsurface samples/rock cores, and a general reduction in transmissive fractures with depth.

Table E-11. Summary statistics compiled by Jacobs (1997) for K data in BCV

Hydrogeologic unit	K (min) ft/day	K (max) ft/day	K (avg) ft/day	Count
Knox	0.0002	3.67	0.511	27
Maynardville Limestone	0.000027	99.0	8.132	41
Nolichucky Shale	0.000009	7.1	0.723	109
Dismal Gap/Friendship/Rogersville	0.00003	2.08	0.192	33
Pumpkin Valley/Rome	0.00086	1.156	0.223	18

avg = average
ft = foot
K = hydraulic conductivity
min = minimum
max = maximum

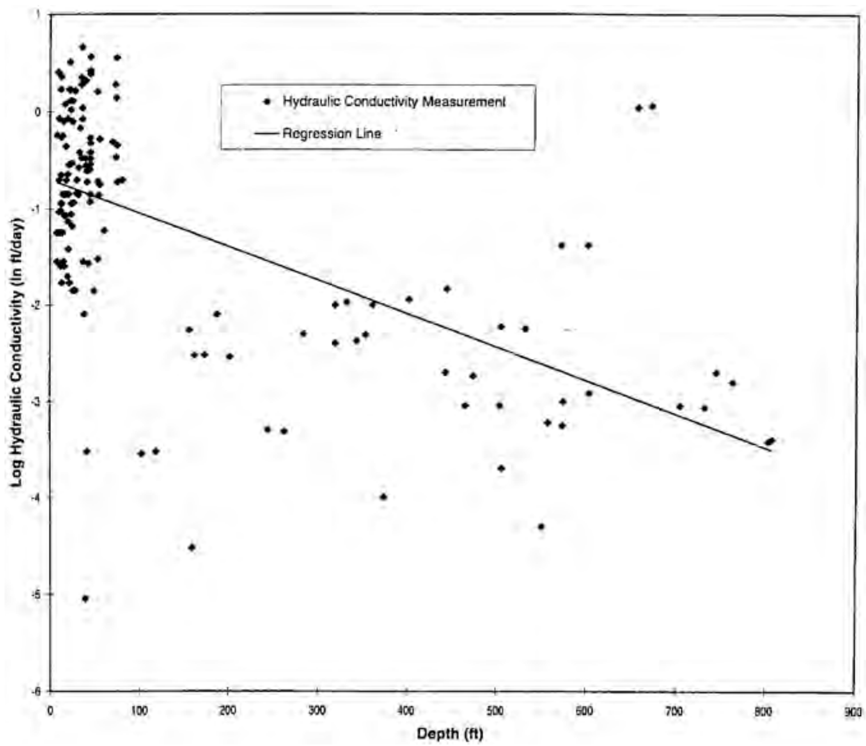


Figure E-37. Relationship between log K and depth in the clastic (shaley) formations underlying BCV
[i.e. Rome through Nolichucky Shale formations; Fig. F.20 from Jacobs (1997)]

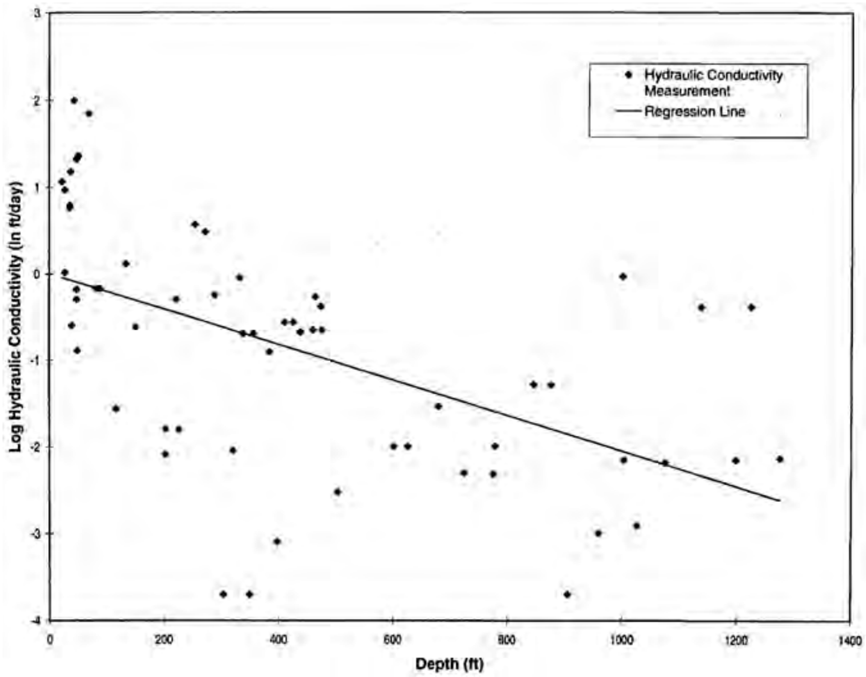


Figure E-38. Relationship between log K and depth in predominantly carbonate formations underlying BCV
[i.e. the Maynardville Limestone and Knox Group carbonates along the south side of BCV; Fig. F.19 from Jacobs (1997)]

Summary of Hydraulic Conductivity Results from Phase I Investigation at EMDF Site 5 (EBCV)

Hydraulic conductivity data were obtained during the recent limited Phase I investigation at Site 5 in EBCV. Results are summarized here but complete details are provided in Attachment A. Slug tests were conducted in the four shallow wells at Site 5 screened in silty, shaley saprolite within the upper portion of the saturated zone near the water table. The slug test results ranged from 1.2×10^{-7} cm/sec to 1.5×10^{-6} cm/sec with an average of 6.7×10^{-7} cm/sec. While the number of tests is quite limited, the range and average K values at Site 5 are relatively low compared with those from similar shallow wells and formations shown in Table E-10 and Figure E-35 from the WBCV site, where most of the K values reported from shallow depths in the predominantly clastic rock formations of BCV were in the range of 10^{-4} to 10^{-6} cm/sec. Reasons for this disparity are unclear but may be associated in part with interpretations of the time/recovery data curves and/or the analytical methods used to calculate K values. The relatively lower K values from the Phase I effort were not used in the Site 5 ground water modeling to remain more conservative, and more consistent with the larger body of data for BCV applied to the original construction of the model.

Laboratory tests were conducted using ASTM Method D5084 for determining saturated K using Shelby tube samples of shallow regolith soils/saprolite from depths ranging from approximately 2 to 10 ft. Values for K from those tests ranged from 3.9×10^{-7} cm/sec to 6.5×10^{-6} cm/sec with an average K of 3.2×10^{-6} cm/sec. These results are similar to those from the EMWMF site, but as noted elsewhere, are based on a very small sample size of a few inches in length and diameter that is much less likely to represent the broader segment of the subsurface encompassing relatively larger fractures and macropores.with higher K values.

Nine packer tests were performed within the open uncased bedrock holes of the deeper Phase I well pairs, each drilled to depths of 100 ft and isolated from regolith materials with surface casing. Each test was conducted with a 10 ft spacing between upper and lower packers. Due to cost limitations for the project, intervals were not tested in a systematic way across the entire bedrock interval; instead selected intervals were chosen based on the results of borehole geophysical logs and rock core analysis and targeted to evaluate the most likely fractured intervals. Some of the most obvious fracture zones identified in the televiewer logs and heat pulse flow meter tests could not be packer tested due to the physical constraints of the equipment and borehole conditions. In addition, a major equipment limitation was imposed by the very limited range of low flow rates that could be sustained and accurately measured. This limited the determination of K values to only those in the range of 10^{-5} cm/sec or higher. The average K values from the tested intervals ranged from 1.2×10^{-5} cm/sec to 1.5×10^{-4} cm/sec among the six tests with reliable data. The packer tests results are limited in extent and range. The deep boreholes remain uncased in four of the five holes. See Attachment A for additional details regarding the Phase I K tests conducted at Site 5.

Hydraulic Conductivity in Relation to Equivalent Porous Media Modeling

Use of single point K data to characterize fracture flow systems and karstic aquifers has certain limitations. Sara (1994, p. 6-4 to 6-5) notes that:

"The hydraulic conductivity of the fracture system of the rock mass as a whole is almost always of more interest than the ability of a single fracture to transmit water, for the typical scale of a facility assessment. The hydraulic conductivity cannot be estimated, of course, unless the mass of rock is sufficiently large. The hydraulic conductivity of the mass as a whole depends on the collective hydraulic conductivity of each of the fractures of an interconnecting system. . ."

In other words, it is not the hydraulic conductivities measured in individual wells or stratigraphic zones, but the average K of the whole-rock mass, or continuum that determines ground water flux at larger scales on the order of large sites or facilities. Freeze and Cherry (1979, p. 73) state that this continuum approach is *". . valid as long as fracture spacing is sufficiently dense that the fractured medium acts in a hydraulically similar fashion to granular porous media."* Freeze and Cherry (1979) further state that flow in an elementary representative volume of fractured rock can be analyzed using standard Darcian porous-media methods with anisotropy. Shapiro (2003) agrees, stating that the bulk rock properties control flow at large and small scales, and that highly conductive fractures exert influence primarily at smaller scales. Worthington (2003, p. 30), in reference to modeling, states that *"The simplest and most commonly-used approach has been to assume that fractures may be locally important, but that fracture density is great enough that the aquifer can be treated as an equivalent porous medium, and modeled using a package such as MODFLOW."* This is the approach taken in PreWAC modeling for the EMDF presented in Appendix H, as well as other historical and current efforts to model ground water flow on the ORR. The MODFLOW-USG code was recently selected for ground water modeling on the ORR (UCOR 2014). The trial basis for this ORR model which is set within the BCV and UEFPC valley of Y-12 is fundamentally structured similar to the EMDF PreWAC modeling and is based on an assumption of EPM conditions with anisotropy applied to K values in the strike direction. The data currently available for the proposed EMDF sites is inadequate for the application of a discrete fracture network (DFN) model.

2.13.2.5 Anisotropy

Anisotropy is the result of differences in fracture orientation, propagation, and development. Hydraulic conductivity tends to be anisotropic in BCV with higher K associated with bedding planes and joints in the strike-parallel direction relative to joint sets oriented at right angles to geologic strike. Expressed in general terms of the relationship of strike-parallel, dip-parallel, and cross-strata fracture flow pathways, $K_{strike} >> K_{dip} > K_{cross\text{-}strata}$ on a whole-rock basis. Anisotropy has been observed and estimated in BCV and elsewhere on the ORR by the tendency of tracers and contaminant plumes to elongate in the direction of strike, and by elongations in the cone of depression during pumping tests. Some estimates of the degree of anisotropy in BCV and in UEFPC along strike with BCV, presented in Table E-12, range from 1:1 to 38:1, but most fall between 2:1 and 10:1.

Bailey and Lee (1991) conducted a sensitivity analysis of anisotropy by varying K values for strike and dip flow and comparing the actual ground water head at numerous wells with that predicted by their model. They found that anisotropy of 1.1 to 1.25:1 provided the best matches between modeled and actual ground water head. They stated that preferential flow along strike is not indicated in BCV, except in the Maynardville Limestone. However, results of tracer tests conducted in the predominantly clastic formations of the Conasauga Group also exhibit anisotropy. Evans, et al. (1996) used a particle tracking model to investigate anisotropy in BCV. They found empirically that particle tracks best mimic the S-3 Ponds contaminant plume at an anisotropy ratio of 10:1. Sensitivity analysis indicated that anisotropy ratios lower than 10:1 provided better fits to the contaminant plume than did ratios higher than 10:1.

2.13.3 Ground Water Flow

As described and illustrated in the site conceptual models in Section 2.8, ground water in BCV flows from upland recharge areas below Pine Ridge, Chestnut Ridge, and the upland areas between the NTs, to lowland discharge areas along the NT valley floors and floodplain areas along and adjacent to Bear Creek. The shallow ground water flux through the highly weathered and fractured regolith and shallow bedrock is much greater than the flux through deeper levels of the saturated zone and supports base flow along the NT streams and Bear Creek. The following subsections review hydraulic head data and potentiometric surface maps and cross sections based on the many wells installed in BCV. Similar more detailed information from the proposed EMDF sites is reviewed below for EMDF Sites 14 and 5 where site-specific maps and data are available.

2.13.3.1 Ground Water Level Fluctuations

Continuous data log monitoring and intermittent measurements of ground water levels in monitoring wells in BCV demonstrate cyclical variations related to: 1) storm rainfall events in any season, and 2) annual trends related to the nongrowing typically wetter winter/spring season and the typically warmer and drier summer/fall growing season. Section 2.10.4 reviews the quick response of ground water levels to rainfall events and the relationships between runoff and ground water recharge as shown in Figure E-27, and in the water level hydrographs provided in Attachment B based on Phase I surface water and ground water monitoring at Site 5. The direct response of ground water levels to precipitation events have been documented in BCV/ORR monitoring wells over several decades of site investigations, and demonstrate the close relationships between surface water and ground water, and the interrelationships among rainfall, runoff, and ground water recharge. Continuous monitoring data from Site 5 Phase I wells indicate that ground water levels may rise abruptly in response to rainfall events on the order of 4 to 9 ft depending on the intensity and duration of the rainfall event and antecedent soil moisture conditions.

Water level hydrographs that illustrate seasonal cycles from 2000 to 2014 are available for many of the EMWMF monitoring wells and well clusters (see representative hydrographs in the attached Exhibit A.18 of Attachment A). These hydrographs show seasonal high water levels that occur consistently in the winter and early spring when recharge and runoff tend to be higher, and evapotranspiration is lowest. Similar annual trends were observed in the Phase I hydrographs shown in Attachment B which illustrate the annual seasonal highest and lowest ground water levels occurring respectively in April and November 2015. The prompt water level fluctuations in response to storm rainfall events are superimposed on the broader annual nongrowing and growing season trends. The Site 5 Phase I results for the full year of monitoring in the five well clusters across the footprint indicate differences between annual high and low water levels ranging from approximately 4.5 to 13 feet. The greatest range in annual fluctuations occurred in the well clusters located within the most topographically elevated parts of the Site 5 footprint below the

Table E-12. Hydraulic anisotropy ratios determined for predominantly clastic formations of the Conasauga Group

Ratio of Strike-Parallel versus Dip-Parallel Hydraulic Conductivity	Test Method	Analytic Method	Reference
1:1	Ground water flow model calibrated to actual conditions in portions of EBCV	Finite-difference model	Bailey and Lee, 1991
2:1	Pumping tests at depths of 3 m and 33 m in Maryville Limestone, BCV	Gringarten & Witherspoon Fractured Aquifer Solution	Lee et al. 1992
38:1	Pumping tests at depths of 3 m and 33 m in Maryville Limestone, BCV	Papadopulos Infinite Aquifer Solution	Lee et al. 1992
4:1	Pump test in Conasauga Group, Melton and BCV	Gringarten & Witherspoon Fractured Aquifer Solution	Davis et al. 1984*
8:1	Pump test	Various analytical methods developed for use with pumping tests – See Golder for details and Section 6.2.1 below	Golder Associates (1989c) as reported by Schreiber (1995)
10:1	Ground water flow model calibrated to actual conditions in EBCV	MODFLOW	Evans, et al. 1996
5:1	Pump test in Conasauga Group	Gringarten & Witherspoon Fractured Aquifer Solution	Smith and Vaughn 1985*
3:1	Model Calibration; Conasauga Group, UEFPC	Numerical model	Geraghty and Miller 1990*
30:1	NaCl tracer test in BCV	Papadopulos Infinite Aquifer Solution	Lozier et al. 1986*
5:1	Nitrate plume and head modeling, Conasauga Group, BCV	Numerical model	Tang, et al. 2010

* Sources cited by Lee et al. 1992. Full bibliographic citations for Lee et al. 1992 and Tang et al. 2010 are provided in the References to this Appendix.

spur ridge extending south of Pine Ridge. Along that spur ridge, the difference between the annual highest and lowest water levels was approximately 13 feet in GW-971(S) and 12.5 ft in GW-976(I). GW-976(I) is located on the crest of the ridge along the south side of the Site 5 waste footprint; GW-971(S) is located further north closer to Pine Ridge but in an upland area above adjacent valleys. Annual seasonal water level fluctuations were notably less in other areas of the Site 5 footprint where the water table is closer to the surface. See Section 3 below and Attachments A and B for figures showing these well locations and additional details regarding the cyclical variations in ground water levels at Site 5 and the EMWMF.

2.13.3.2 Potentiometric Surface Contour Maps and Horizontal Gradients

Figure E-39 illustrates potentiometric surface contour maps showing horizontal hydraulic gradients and generalized ground water flow paths across the upper part of BCV. The upper half of the figure illustrates the shallow water table interval in regolith materials, and the lower half illustrates the shallow and intermediate bedrock interval. Hydraulic head patterns show convergent flow to the Maynardville Limestone in the valley floor aligned with the southwesterly flow along Bear Creek and indicating that it serves as the hydraulic drain for BCV. Site-specific water table contour maps that reflect the details of local topography and the constraints of stream valley elevations are provided below in Section 3 for EMDF Site 5 and in Section 6 for EMDF Site 14. Data are too limited at Sites 7a and 6b to develop reliable water table contour maps.

While Figure E-39 is useful for illustrating generalized flow directions and hydraulic gradients on a broad scale across the upper 2-3 miles of BCV, the figure does not illustrate the localized and more detailed flow directions and hydraulic gradients at the scale of the EMDF sites needed for site-specific evaluaton. Nor does Figure E-39 illustrate or convey site-specific flow paths that are aligned with complex orthogonal fracture networks in saprolite and bedrock. As presented below in Section 2.13.4, tracer test results show that ground water and dissolved contaminants tend to follow dominant strike-parallel fracture pathways where hydraulic gradients are locally parallel or subparallel to the geologic strike. Where hydraulic gradients are perpendicular to strike, ground water flow and contaminant transport tends to be less pronounced along geologic strike. At the local scale of the proposed EMDF sites, the local ground water flow directions and gradients tend to result in strike dominant flow paths toward the adjacent NT streams that trend generally north-south on either side of the proposed sites.

Horizontal gradients tend to vary in proportion to the local topography so that steeper gradients occur along the steeper south flanks of Pine Ridge and adjacent to the subsidiary ridges underlain by the Dismal Gap/Maryville formation. Moore and Toran (1992) reported an average horizontal gradient of 0.05 for the ORR aquitards (i.e. – the predominantly clastic rock formations of the Conasauga Group). Horizontal gradients calculated at Site 5 based on Phase I data range and water table contour maps range from 0.33 to <0.05.

2.13.3.3 Potentiometric Surface Cross Sections and Vertical Gradients

Figures E-40 and E-41 illustrate measured and model-simulated hydraulic heads and gradients in cross sectional views across EBCV. Figure E-40 from Dreier et al. (1993) presents hydraulic head data along a north-south transect obtained from discrete multiport well intervals completed in a series of deep coreholes near the S-3 ponds site near the eastern headwater end of EBCV (See Figure E-2 for the S-3 ponds site location). The multiport depths where head data were obtained are shown as black squares down the length of each borehole in Figure E-40. The figure illustrates horizontal gradients from north to south with a degree of upward vertical gradients extending across the formations of the Conasauga Group toward the Maynardville Limestone. The figure also illustrates mostly downward and lateral gradients below Chestnut Ridge from south to north converging toward the Maynardville. An isolated high pressure zone in the Nolichucky Shale appears to be a relic of higher density fluids flowing down dip from the S-3 Ponds. The lowest hydraulic heads around 990 ft converge within the Maynardville Limestone from

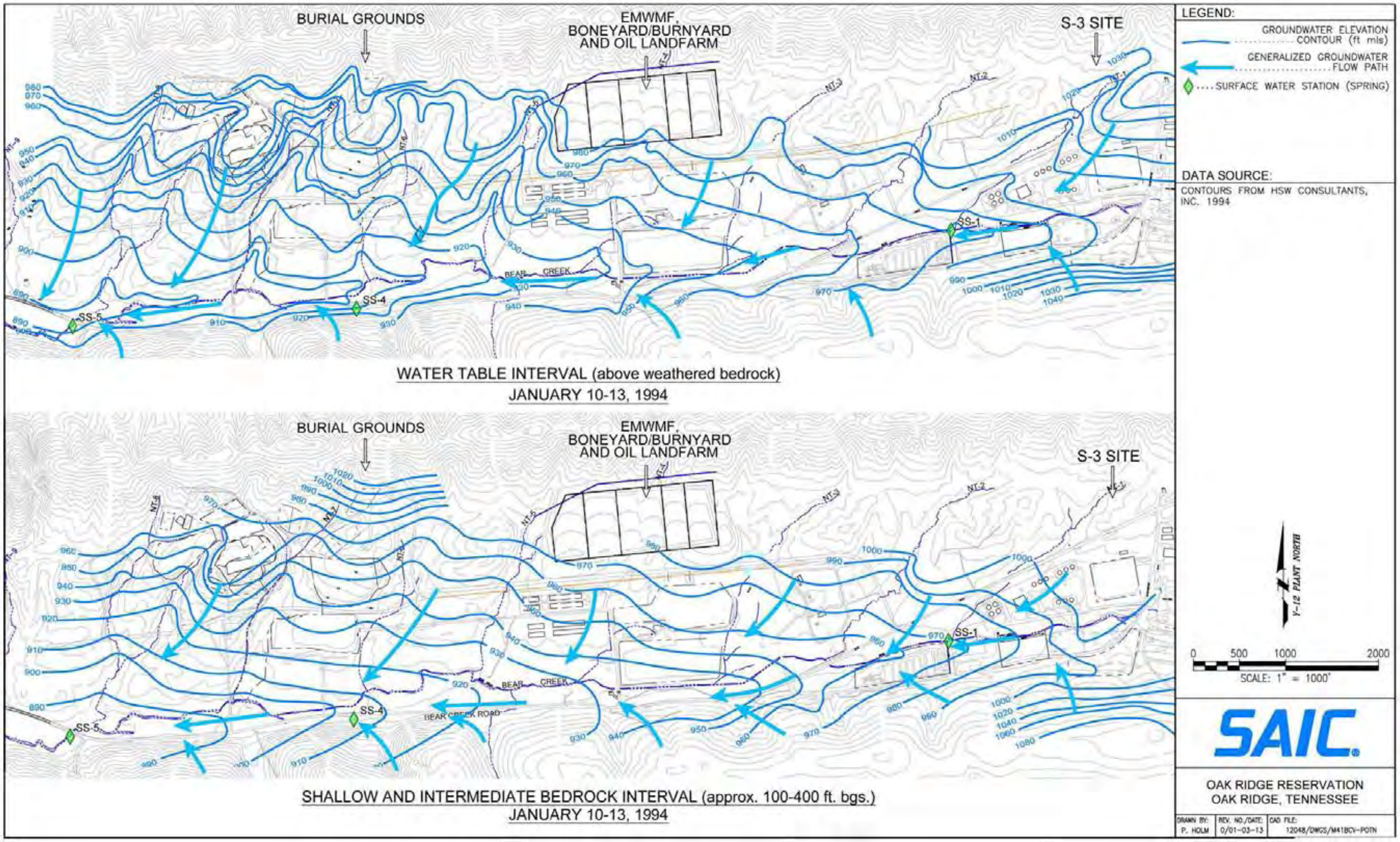


Figure E-39. Potentiometric surface contour maps and generalized ground water flow directions for upper BCV

[From UCOR 2013a]

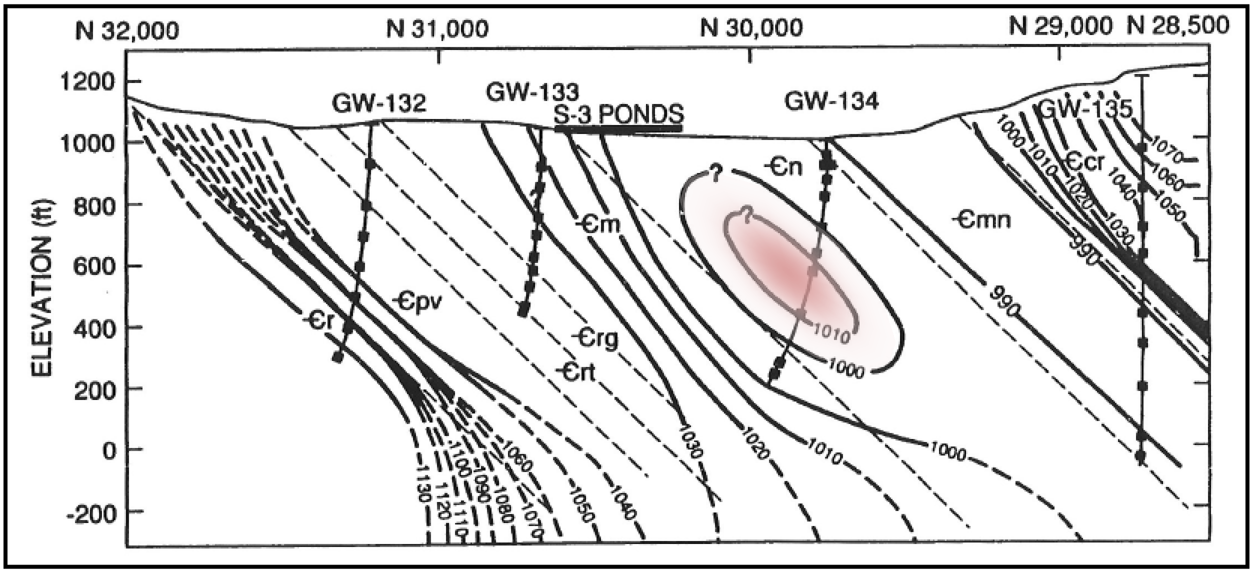


Figure E-40. Hydraulic head distribution across EBCV along a deep transect near the S-3 Ponds

[Adapted from Dreier, et al. (1993). In the cross section, ground water flow directions are perpendicular to the equipotential contours. The high pressure area (rose color) in the Nolichucky Shale is likely related to higher densities of the contaminated leachate from the S-3 Ponds.]

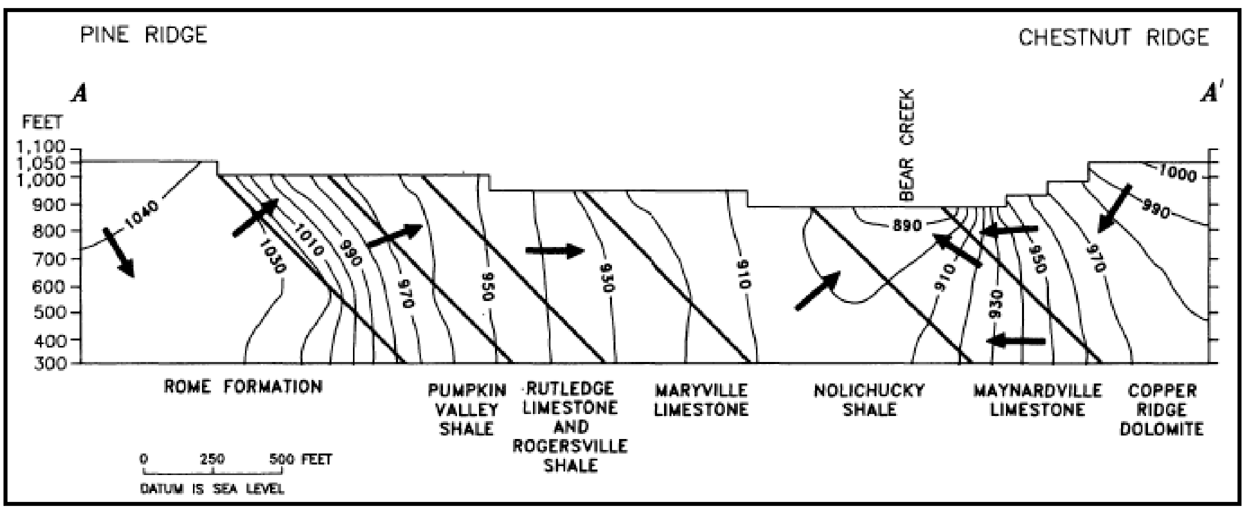


Figure E-41. Cross sectional representation from a computer model of ground water hydraulic head and flow patterns in EBCV

[Source: Bailey and Lee, 1991. Numbered contours indicate head distribution and arrows indicate flow directions. Cross-section is near the BCBG.]

higher heads below Chestnut Ridge and southward from Pine Ridge supporting the concept that the Maynardville, along with Bear Creek, serves as the principal drain for BCV as a whole (Dreier et al 1993). Bailey and Lee (1991) modeled flow in BCV and found a similar head distribution, as shown in Figure E-41.

The discrete interval pressures measured from multiport wells provide the best indication of vertical gradients, but cluster wells in BCV also provide data for calculating vertical gradients at various locations in BCV. An analysis of vertical gradients based on limited Site 5 Phase I well cluster data is presented in Attachment A (p.71-73). Results calculated for synoptic data on January 12, 2015, indicated upward vertical gradients ranging from 0.15 to 2.69 at Site 5, but the results were based on bedrock wells in each cluster completed as open holes to depths of 100 ft. The water level hydrographs developed from the Site 5 Phase I continuous monitoring suggest that hydraulic heads vary with storm precipitation/recharge events when hydraulic heads can be equivalent among shallow/intermediate well clusters (See Attachments A and B for details). During extended periods with little or no recharge and declining water levels, the data indicate consistent upward gradients among the Phase I well clusters with water level differences as much as 2-3 ft between shallow and intermediate well pairs (See Attachment A for additional details and hydrographs). Upward vertical gradients calculated by Pro2Serve using synoptic water level data from water level hydrographs spanning several years of measurements from four shallow/intermediate depth well clusters at the EMWMF range between 0.01 to 0.15 [GW-921/925 – 0.02 to 0.04; GW-917/927 – 0.075 to 0.15; GW-924/926 – 0.01 to 0.02; GW-964/965 – 0.02 to 0.04].

The nitrate plume from the S-3 Ponds (DOE 1997) and VOC contaminant plumes from the Boneyard/Burnyard (BY/BY) and BCBG areas (DOE 1997; Bechtel National, Inc. [BNI] 1984) have been reported to extend down-dip at depth within the Maynardville and Nolichucky formations. These plumes would suggest that upward gradients may not have a strong influence on contaminant migration. However, the nitrate plume is apparently a density-driven plume less influenced by vertical gradients (DOE 1997), and the depth of the VOC plumes may be related in part to deep migration of dense non-aqueous phase liquids below and downgradient of the source areas. BNI (1984) conducted surveys of vertical and horizontal flow in Conasauga Group rocks in the BCBG and BY/BY areas and found that flow orientation and sense (upward or downward) were variable and depended on depth, lithology, and fractures and cavities.

The tracer plume originating from dye released at the water table and mapped for a period over more than a year at the WBCV tracer test site was found to remain within the water table interval throughout its length. Upward vertical gradients measured at the site were identified as the most probable factor preventing the tracer plume from deeper migration along its downgradient flow path (See Section 2.13.5 below for additional details).

As illustrated in the conceptual design cross sections through each of the proposed EMDF sites (see Chapter 6 of the RI/FS), the base elevations proposed for the landfill sites do not extend far into the subsurface below the sites. The effects of upward gradients on the water table below the sites are therefore minimal because the base level grades below the landfill do not intersect the deeper zones where strong upward gradients occur. The conceptual designs also avoid any cuts into the lowest elevation ravine and valley areas along the south flanks of Pine Ridge. Upward vertical gradients would thus not impinge on the geologic buffer or liner system, and the proposed underdrain networks would preclude the build up of upward hydraulic pressure gradients below the footprints by allowing the water table to naturally drain from the former valleys and ravines below the footprints.

2.13.4 Ground Water Geochemical Zones

The boundaries between the shallow, intermediate, and deep ground water zones defined in the hydrologic framework for the ORR and BCV (Solomon et al 1992) are transitional and not precisely defined. The boundaries vary with changes in local topography, vadose zone thickness, the degree and depth of regolith and bedrock weathering, and bedrock stratigraphy. The zones occur at different levels in different parts of the ORR (Moore and Toran 1992) and their placement is commonly based on vertical changes in ground water chemistry. Hydrogeochemical processes involving exchange of cations on clays and other minerals result in a change from calcium bicarbonate (Ca-HCO_3) to sodium bicarbonate (Na-HCO_3) and ultimately to a sodium chloride (Na-Cl) type water at depth. These geochemical zones reflect ground water residence times and reduction of water flux with depth.

The top of the intermediate zone is marked by a change in the dominant cations from Ca, Mg, Na-HCO_3 to predominantly Na-HCO_3, and extends from approximately 100 ft to over 275 ft, where the transition to the deep zone is marked by a gradual increase in Na-Cl (Haase, et al. 1987; Bailey and Lee 1991). The intermediate and deep aquifer zones are distinguished from the shallow zone by a change from a Ca, Mg-HCO_3 chemistry to a chemistry dominated by Na-HCO_3 (Moore and Toran 1992). The transition from Ca-Mg-HCO_3 to Na-HCO_3-dominant water is abrupt, occurring between depths of 80 ft (26 m) to 200 ft (67 m) in the Nolichucky Shale underlying BCV (Haase 1991), which suggests a well defined flow boundary (Haase 1991). Dreier, et al. (1997) noted that this water type is common to all Conasauga Group formations at intermediate and deep depths except in the Maynardville Limestone, and appears to be unrelated to stratigraphic changes. The Maynardville Limestone and adjacent Copper Ridge Dolomite exhibit both a Na-HCO_3 water type with distinct zones of Ca-Mg-Na-sulfate (SO_4) water. These sulfate-rich water zones appear to be related to the presence of gypsum beds in the carbonate units. Table E-13 summarizes this geochemistry information for the Conasauga Group.

Table E-13. Geochemical ground water zones in the predominantly clastic rock formations of the Conasauga

Interval or Zone	Bear Creek Valley (Haase 1991)			Bear Creek Valley (Bailey and Lee 1991)		Melton Valley (Haase, et al. 1987; Nativ, et al. 1997)		
	Depth (ft)	Type	pH	Depth (ft)	Type	Depth (ft)	Type	pH
Shallow	75 ft	Ca, Mg-HCO_3	NA	< 50	Ca, Mg-HCO_3 or SO_4	< 75	Ca, Mg-HCO_3 or SO_4	6.5 – 7.5
Intermediate	NA	NA	NA	50 – 500	Na-HCO_3 (with some Na-Cl and Na-SO_4)	75 - 275	Na-HCO_3	6.0 – 8.5
Deep	NA	NA	NA			75 - 530	Na-HCO_3 to Na-Cl	8.0 – 10.0
Brine (aquiclude)	>530	Na-Cl	NA	NA	NA	590 (GW-121)	Ca-Na-Mg-Cl + SO_4	11.6

This change in ground water chemistry is interpreted to be the result of rock-water interactions and diagenesis of minerals. The rate at which the ground water reaches chemical equilibrium with source minerals is important in the diagenetic evolution of Na-HCO_3, indicating that the ground water is reaching equilibrium with the host rock. If clay alteration is an important control on ground water geochemistry, then Na-HCO_3 type water may mark the transition between the actively circulating shallow zone and stagnating ground water in deeper zones (Solomon et al. 1992).

Studies performed by Dreier, et al. (1993) in deep boreholes in the Conasauga Group and the Copper Creek Dolomite of the Knox Group in EBCV indicate that deep ground water chemistry trends from Na-HCO^3-dominated water to increasing Na-Cl content between 550 ft below grade near Pine Ridge to over 1,150 ft below grade in the Maynardville Limestone on the south side of BCV. This trend is associated with an increase in total dissolved solids and pH that appears to be related to long-term rock-water reactions. Haase (1991) states that these deep transitional waters are saturated with respect to calcite and dolomite.

The aquiclude zone is so named because the extremely high salinity of this water indicates that little or no ground water movement occurs. The aquiclude is well defined in the Conasauga Group of Melton Valley, but is less well documented in BCV.

Dreier, et al. (1993) and Haase (1991) provided detailed water chemistry data for four wells positioned across strike in EBCV and drilled to depths between 557 ft and 1,196 ft below grade. Both reports noted an abrupt increase in total dissolved solids to about 28,000 ppm, increase in pH to the 8.5–10.0 range, and change from Na-HCO_3 as the dominant ion pair to dominance of Na-Cl below 1,150 ft. This increase occurred just below a major fracture zone. Haase (1991) noted that the deep Na-Cl ground water in four deep wells sampled for this study was saturated with respect to Ca and Mg, and contained Ba at near-saturation concentrations, which is indicative of long residence time and little or no recharge by fresher water.

A report by Nativ et al. (1997) indicates that the presence of tritium[3] and modern carbon-14 in some deep brine samples from the Conasauga of Melton Valley suggests that some meteoric water commingles with the brine at depths. They also report that ground water flow has been measured by down-hole flow meter in various deep boreholes below 750 ft (250 m). Based on these considerations, Nativ (1997) postulates that flow occurs in the deep brine, and that at least some meteoritic water is transported to depth. Moline, et al. (1998) refute this interpretation, noting that the persistence of brine over geologic time provides a strong indication that deep ground water circulation is minimal, and that deep rocks exhibit very low K values, on the order of 10^{-7} to 10^{-9} cm/s, which suggests either an absence of or minimal number of numerous permeable fractures.

Observed responses to seasonal and storm-driven changes in the water table measured in some deep wells could be responses to pressure pulse, rather than actual flow. Further, the presence of shallow water signatures (comparatively low total dissolved solids, tritium, and relatively high percentages of modern carbon) may be induced by drilling, well installation and development, open bore hole circulation, or purging prior to sampling. Development and purging of deep wells is hampered by extremely low flow rates and long recovery times (Moline, et al. 1998).

While some ground water exchange may occur between the halocline and shallower ground water zones, it is volumetrically very minor and does not appear to play a significant role in regional flow patterns. As noted above there is a significant difference in density between the shallow ground water and the brine. The density of uncontaminated water, or water contaminated at low concentrations by dissolved constituents, is around 1.01 g/cc; the density of sea water is 1.022 g/cc, and brine is over 1.20 g/cc. A great deal of hydraulic head would be required to drive fresh water into the brine zone. The S-3 Ponds nitrate plume, which extends to depths of more than 400 ft is acknowledged as a density-driven plume,

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[3] Although some tritium is produced in the atmosphere by cosmic rays, it is mostly the result of atomic testing, and its presence in deep ground water suggests that there have been recent additions of shallow water. Tritium has a half-life of 12.3 years and it would therefore be expected to have decayed to undetectable concentrations if ground water migration times were very long.

with a density range between 1.06 and 1.12 g/cc (DOE 1997). This is sufficient to drive the plume below the fresh water aquifer, but above the brine zone. Thus, density differences prevent downward penetration of shallow ground water. This is analogous to the fresh water sea water boundary that develops in coastal aquifers.

2.13.5 Tracer Tests

Tracer tests are conducted by introducing a unique tracer (dye, chemical, radionuclide, or particulates) into an aquifer and monitoring possible flow paths or discharge points to determine if and when the tracer first arrives, when the peak concentration occurs, and how long it takes the tracer to recede. Tracer tests are commonly used in fractured and karst aquifers because they are often strongly anisotropic, heterogeneous, and have complex flow paths and travel times that may be difficult to determine. Tracer tests conducted in BCV and/or in similar geologic formations elsewhere on the ORR are reviewed below along with key findings from the tests most relevant to the proposed EMDF sites. Most of the tracer test publications are from peer reviewed journals and some are from ORNL research publications or contractor reports. The Tennessee Department of Envrionment and Conservation (TDEC) tracer test results are from an informal unpublished document provided by TDEC to DOE. Many of the publications include modeling simulations of the field conditions and calibrations and refinements of the models to match field observations. Reviewers are encouraged to read the original publications for complete details and interpretations by the original authors (Section 7).

2.13.5.1 Tracer Tests in Predominantly Clastic Rocks of the Conasauga Group

Tracer tests have been conducted at field sites in WBCV, and at field sites in Melton Valley at ORNL near burial ground (BG) Sites 4 and 6, and WAG 5. The tests were all conducted in shallow ground water in areas underlain by predominantly clastic formations of the Conasauga Group (i.e. – formations north of and stratigraphically below the Maynardville). The tracers were all introduced at or near the water table in highly weathered and fractured shaley saprolite. The monitored plume areas were all relatively small in areal extent (less than ~20 to 100-200 ft in any direction) and involved a variety of tracers: 1) fluorescent dyes, 2) tritiated water, 3) noble gases (helium, neon, bromide), and 4) colloids. Among all the tracer tests conducted on the ORR, the field site illustrated in Figure E-42 just southwest of the EMDF Site 14 footprint is the most intensively studied with the largest network of downgradient monitoring wells. The longest duration tests were those conducted at the BG4 and BG6 sites. The other tests vary in terms of monitoring duration and/or the configuration of the 3D network of wells used for monitoring.

It should be noted that each of these tests were conducted under natural gradients in undisturbed watershed conditions, whereas the proposed EMDF sites will be dramatically altered with contaminant sources enclosed in low permeability materials. Contaminants potentially released from below the EMDF footprint would migrate vertically through at least 20 ft or more of low permeability layers in the unsaturated zone before reaching the water table and then migrating laterally along flow paths similar to those described at the tracer sites.

Tests at the WBCV Tracer Site near EMDF Site 14

The most intensively tested tracer site within predominantly clastic rock formations on the ORR is located just southwest of the proposed EMDF Site 14 footprint in WBCV (Figure E-42). The test site is located along the contact between the Dismal Gap/Maryville formation and the Nolichucky Shale so subsurface conditions are similar to those that occur below a portion of the proposed EMDF sites, except for the Site 5 footprint which does not span the upper Dismal Gap or Nolichucky outcrop belts. The first tracer tests were conducted there in 1998 by Golder Associates (Golder). Seventy-two monitoring wells (single and nested) were installed at 45 locations along several transects roughly perpendicular to surface topography and hydraulic gradients and general shallow ground water flow directions toward the southwest and the nearby valley of NT-15.

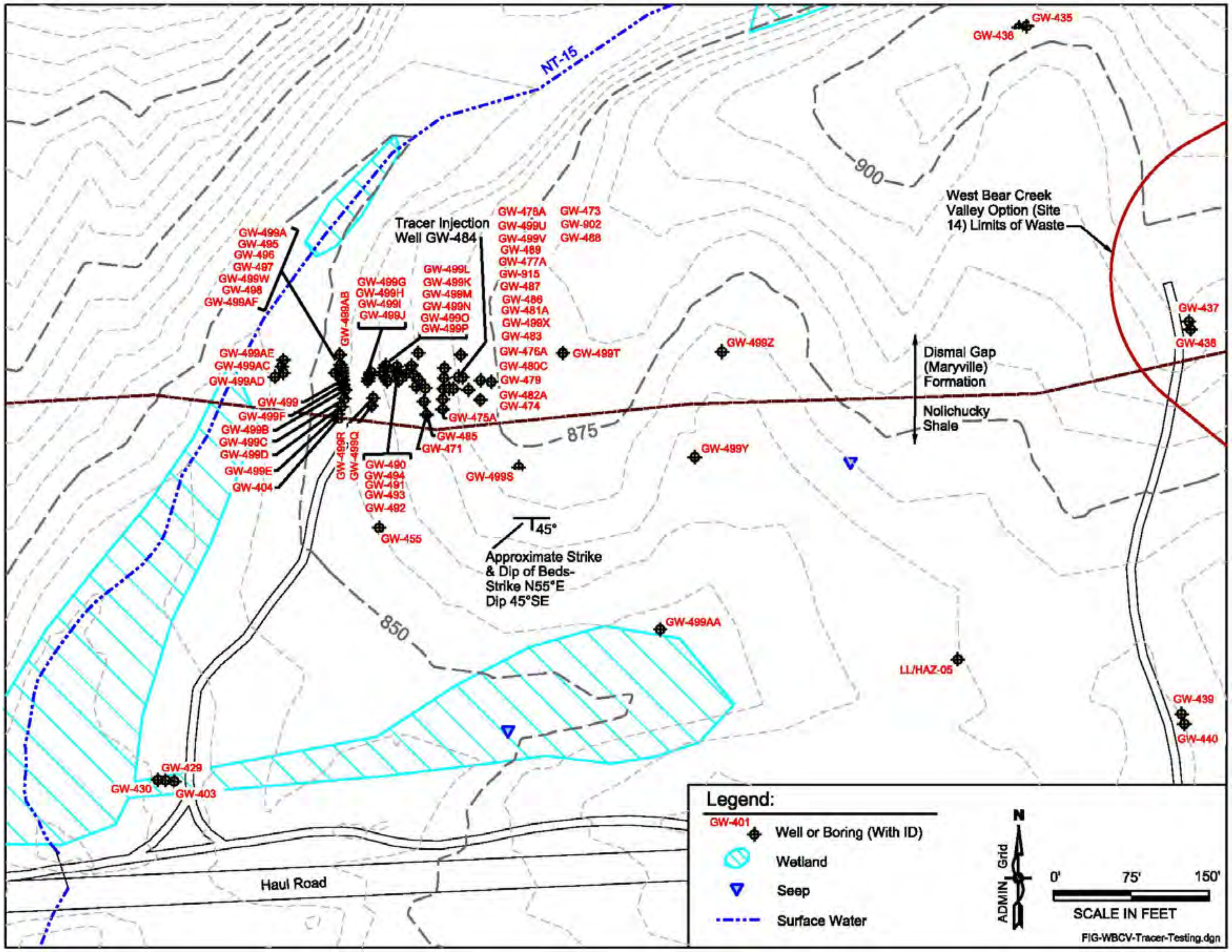

Figure E-42. Well location map for the WBCV tracer test site near proposed EMDF Site 14

The tracer study area is approximately 150 ft long by 70 ft wide trending east-west along the Y-12 administrative grid (i.e – southwest-northeast relative to true north). The Golder scope of work also included drilling and logging of regolith materials and rock cores, packer tests, slug tests, pumping tests, and ground water solute transport modeling. The collective data were used to calibrate and refine model results. Figure E-42 illustrates the layout of the test site wells, local topography, the path of the nearest NT tributary (NT-15) and the proximity to the west edge of the Site 14 waste footprint (see Figure E-9 for the test site in relation to Site 14 and the BCV watershed).

The results of the initial tracer tests, in-situ hydraulic tests, and preliminary modeling were presented by Golder in a Task 5 report for the WBCV site (Golder 1988d). The results of subsequent tracer work and modeling at the same site were published in an ORNL report (Lee et al 1989b) and journal article (Lee et al 1992) authored by an ORNL and university research team. Findings from the 1992 summary article are summarized below. The results provide insight into the complexities associated with characterization, monitoring, and modeling contaminant releases in areas of BCV underlain by predominantly clastic rock formations (i.e. – the Conasauga Group formations north of the Maynardville).

Figures E-43 and E-44 illustrate the tracer plume configuration at three and 12 month time periods after the initial dye injection on April 20, 1988 (10 liters of 40% Rhodamine-WT dye solution). The dye was introduced at the water table in GW-484. Tracer analysis at 1 part per billion (ppb) resolution was performed using fluorimetric techniques. Figure E-45 illustrates a longitudinal cross section through the tracer test site illustrating some of the main subsurface conditions: the water table within regolith saprolite, the southeasterly dipping bedrock of interbedded shale, siltstone, and limestone of the Dismal Gap/Maryville formation, and upward vertical gradients across the site measured among nested monitoring wells.

As shown in Figure E-42, the surface topography at the test site slopes to the southwest toward the NT-15 stream channel. Water table contours shown in Figure E-43 similarly indicate overall horizontal ground water flow directions toward the southwest to the local discharge zone along the valley floor of NT-15. The topographic slope and water table gradient generally trend parallel to subparallel with the geologic strike direction which is shown on Figures E-42, E-43, and E-44 (strike - N55°E; dip - 45° SE). Tracer movement at the WBCV site was found to be predominantly strike-parallel, however at local scales on the order of that among test site wells (i.e. 10-30m), plume migration was not necessarily always consistent with the local direction of maximum horizontal hydraulic gradients measured in the test wells (See Figure E-43).

The authors describe the evolution of the plume configuration over time. *Early time (one month) tracer migrated in a plume less than 2.5m wide which reached a maximum width of 6m after 12 months and a length:width ration of 7.5:1. Monitoring wells positioned across the plume axis, and sometimes less than 1m apart, often showed two order-of-magnitude differences in tracer concentration. The tracer boundary was clearly defined; at peripheral locations, repeated concentrations of 10 ppb and less were outside the plume boundary.*

In the first two weeks, a high concentration plume migrated as rapidly as 1.0m/day (3.3 ft/day) *for about 14m* (46 ft)*in the near-field, but another 9m* (30 ft) *of migration in the mid-field required an additional 230 days (0.04m/day* (0.13 ft/day)*). Total migration distance of 33m* (108 ft) *(the far-field) for the 100 ppb front required 370 days (0.09m/day average* (0.3 ft/day)*). Data analysis could not attribute the erratic rate of migration to the presence of a concentration gradient induced by the slug dye injection, and no consistent correlation could be found with changes in the water table gradient profile or with precipitation. Rather, the migration rate, narrow overall plume shape, and slightly meandering and fingering plume all suggested the presence of lithologic and/or fracture-related pathways of preferred flow.*

The general upward vertical gradient observed at the site explains the observation of tracer only in the water table zone of the aquifer. Tracer was never detected at depth despite long-term monitoring at various depths in bedrock within the tracer pathway and in stratigraphically correlative core holes downdip and downslope of the tracer injection zone. Tracer detection and observed vertical gradients at the site demonstrate that neutral density solutes introduced at the water table mix in a thin zone below the water table and migrate through the bedding plane dominated fracture system. This thin mixing zone which is recharged by local precipitation infiltration from above and by upward leakage from below approximates a two-dimensional solute mixing domain. (Lee et al 1992).

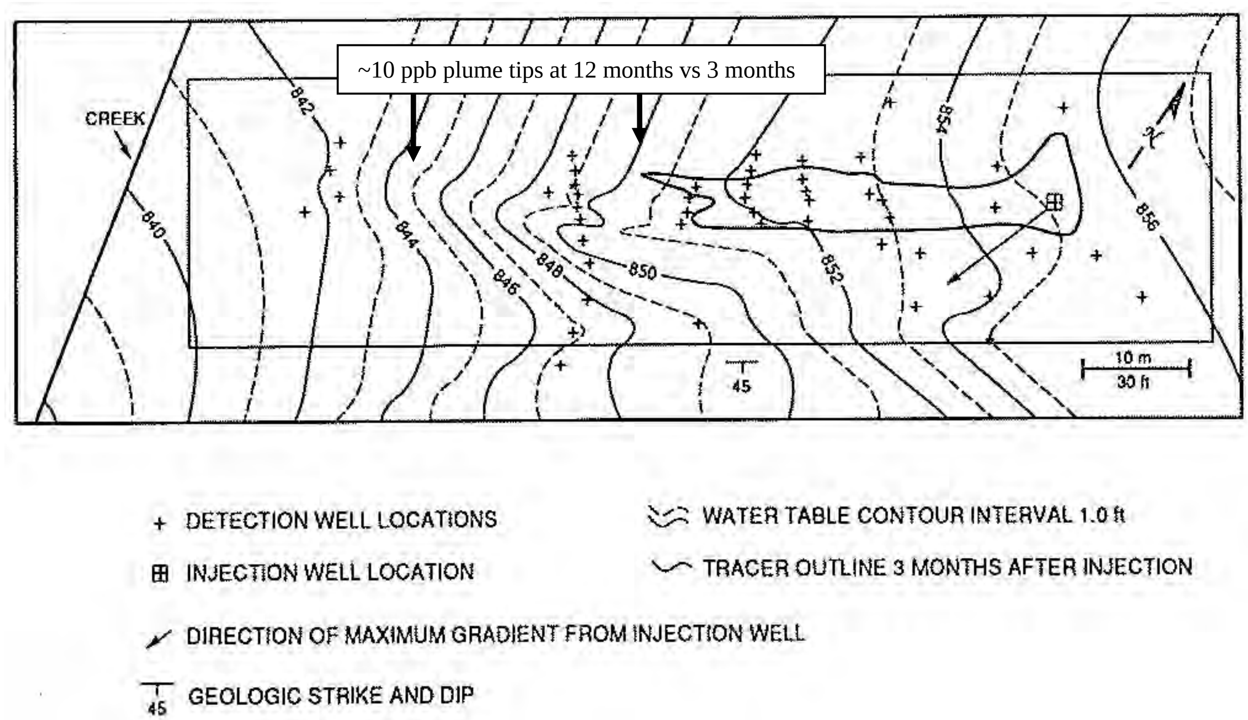

Figure E-43. Dye tracer plume map outlined by 10 ppb concentration contour (~40m or 131 ft long) three months after injection on April 20, 1988 (adapted from Lee et al 1992)

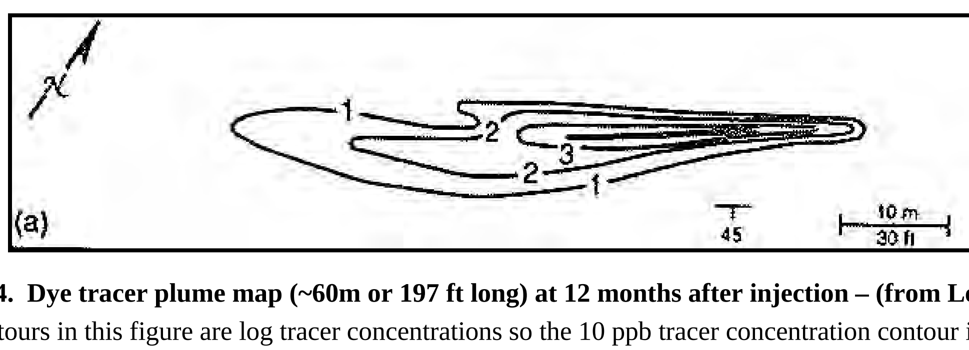

Figure E-44. Dye tracer plume map (~60m or 197 ft long) at 12 months after injection – (from Lee et al 1992)

[**Note:** Contours in this figure are log tracer concentrations so the 10 ppb tracer concentration contour is represented by the “1” contour]

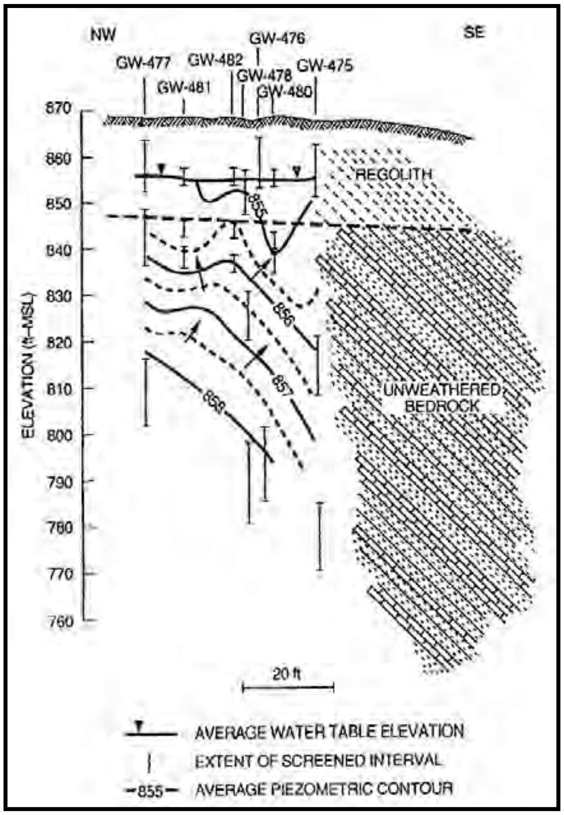

Figure E-45. Northwest-southeast cross section through the WBCV dye tracer site (from Lee et al 1992)

[**Note:** the dye tracer was never detected at depths below the water table interval – the water table is shown by the line with the triangle symbols]

Analysis of "Broad" and "Narrow" Tracer Test Plumes at BG4 and the WBCV Site

In conjunction with simulations of fracture flow using a dual permeability model (Stafford et al 1998) and a 2D equivalent porous medium (EPM) model (McKay et al 1997), researchers at ORNL and the University of Tennessee contrasted the broad plume from a tracer test at the burial ground (BG) 4 site at ORNL, with the narrow tracer test plume at the WBCV site described above. They note that the orientation of shallow horizontal ground water gradients with respect to geologic strike strongly influences the rate and direction of ground water flow and contaminant transport. Broad plumes develop where the average water table gradient is perpendicular to the geologic strike (Figure E-46). Narrow ground water contaminant plumes in the water table interval develop where the average water table gradient is roughly parallel with geologic strike (Figure E-47).

As described by Stafford et al (1998), the BG4 plume "*exhibited an unusually large transverse spreading, with the width of the plume approximately equal to its length. The experiment is unique due to the high levels of tritium injected (50 curies) and the long monitoring period (16 years to date). The water table gradient from the injection well to monitoring well 7 (directly downslope) averages 0.15. The migration of the plume is characterized by a fast moving, low concentration front (10's of cm/day), a slower moving center of mass (<1cm/day), a very long (up to 16 years) low concentration tail, and an unusually large degree of transverse spreading.*"

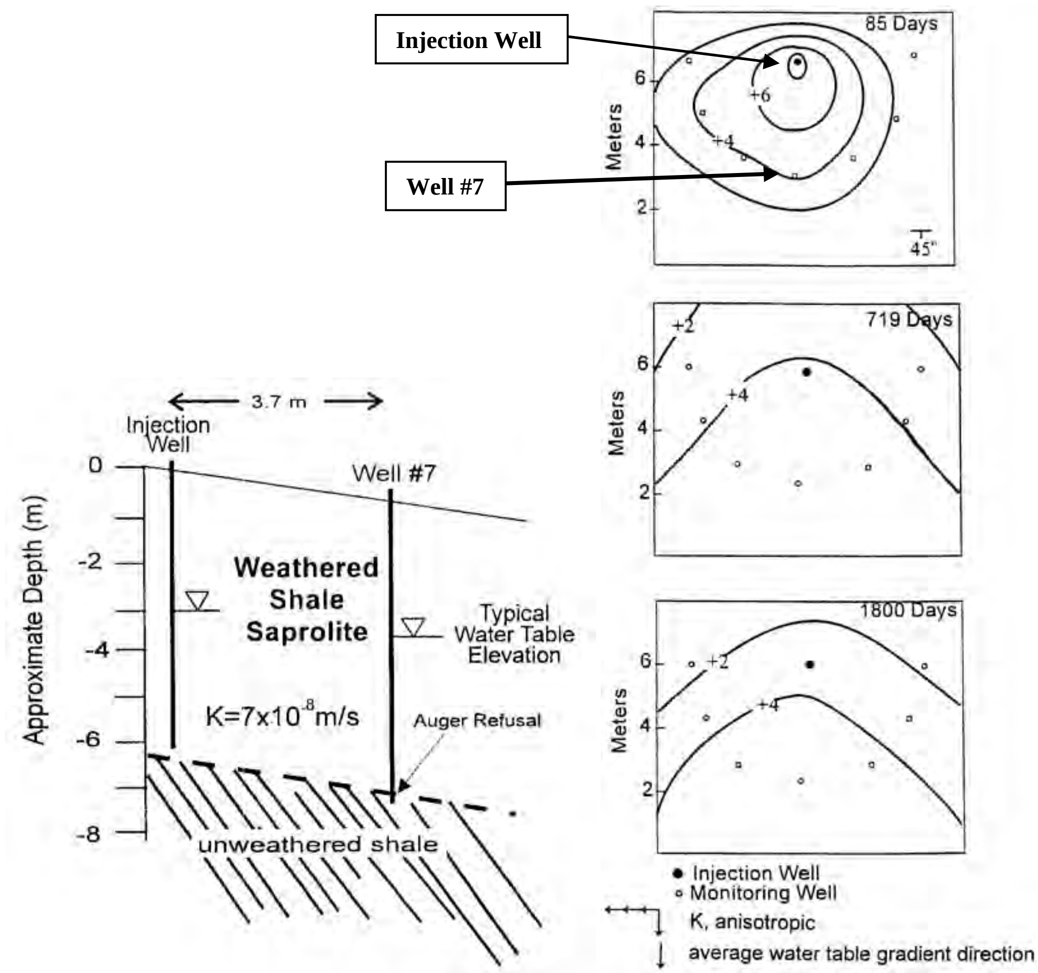

Figure E-46. Longitudinal cross sections and contours of tritium concentrations in log scale of pCi/ml over time for the "broad" plume at the BG4 tracer test site (from Stafford et al 1998 & Mckay et al 1997)

At the WBCV site, Stafford et al (1998) continue – "*The geologic material at this site is similar to that at the BG4 site in terms of porosity, hydraulic conductivity, and fracture spacing and orientation. However, the shape of the plume was very narrow* (Fig. E-47) *as compared to the wide shape of the BG4 plume* (Fig. E-46). *The major difference between the two sites is that the average water table gradient direction at the WBCV site is approximately parallel to strike of the bedding plane, and at the BG4 site it is nearly perpendicular to strike. The orientation of the water table gradient with respect to the fracture planes likely contributed to the difference in plume shapes. The hydraulic conductivity is expected to be higher in the direction of strike at both locations due to bedding plane partings or fractures (Solomon et al., 1992). With this in mind, transverse spreading at the WBCV site, where there is a strike-parallel gradient, would not be strongly influenced by fluctuating water table direction and secondary fractures perpendicular to strike because of the lower hydraulic conductivity in the transverse direction. Conversely, at the BG4 site, where the average hydraulic gradient is in the direction of the lower hydraulic conductivity (perpendicular to strike) fluctuating water table direction and fractures perpendicular to bedding are expected to have more of an influence on transverse spreading. It is likely that at other locations, where water table slope is neither parallel nor perpendicular to bedding strike, the shape of the plumes would be intermediate between these two extremes.*"

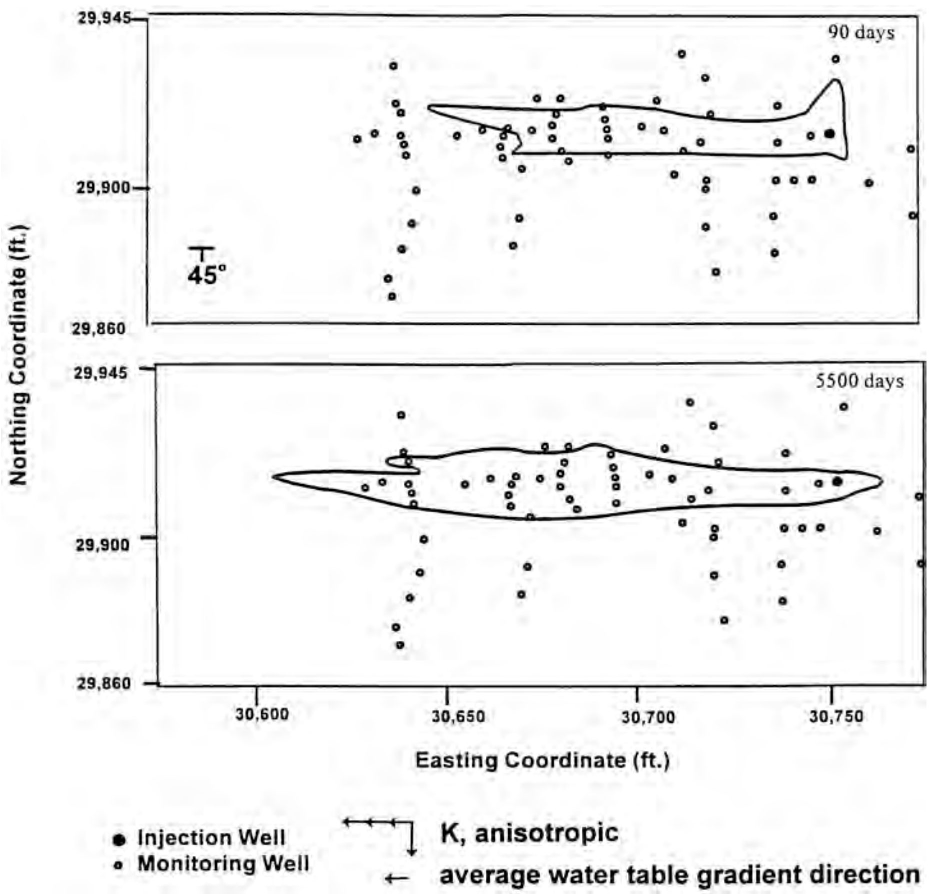

Figure E-47. Contours of 10 ppb rhodamine dye over time for the "narrow" plume at the WBCV tracer test site (from Stafford et al 1998)

[**Note:** the 5500 day (15 year) test period shown in the lower map appears to be incorrect as the test began in 1988 and the paper was published in 1998 (10 years); actual duration shown is unclear but the scale indicates a total plume length of ~160 ft, less than the ~197 ft illustrated above at 12 months by Lee et al 1992]

In the dual permeability model, the discrete fracture approach was combined with the EPM approach to investigate the influence of a few widely-spaced larger-aperture fractures in a highly fractured matrix (such as that found in saprolite and shallow bedrock in the clastic rock formations of BCV). The simulations by Stafford et al (1998) demonstrated that a limited number of truncated fractures within a permeable matrix can create nearly circular plumes, with about the same degree of spreading in the direction transverse to the average hydraulic gradient as in the longitudinal direction. By comparison, continuous fractures in the direction of flow tend to produce elongated plumes, similar to those typically seen in granular materials.

Of particular relevance to the EPM modeling used for developing the EMDF PreWAC, Stafford et al (1998) also noted the following conclusions: "*The combined discrete-fracture/equivalent porous media (DF-EPM) approach is useful for looking at possible causes of features such as the observed transverse spreading, but in the absence of detailed data on the fracture network, it is likely that it would be no more effective than the EPM approach in predicting future behavior of the plume.*"

Several conclusions and implications from the 2D EPM modeling of the BG4 site (McKay et al 1997) are also important in relation to the EMDF PreWAC modeling. The main conclusions quoted by the authors include: 1) *This study shows that a relatively simple EPM modeling approach can be successfully applied to a complex, highly fractured system, for describing general plume behavior and future concentration trends,* ***provided that*** (bold added) *there is sufficient monitoring data available for calibration of the model. This indicates that, at least for this type of fractured clay-rich material, the time span over which monitoring data are collected is a critical factor in model calibration and may even be more important than the number of monitoring wells or the frequency of sampling.* 2) *The study also illustrates the importance of using tracers that are measureable over a wide concentration range…. where the regulatory limit for the contaminant of interest is many orders of magnitude below the source concentration.* 3) *The model calibration may be very site- or direction-specific, as indicated by the large difference in transverse dispersivity values or ratios of longitudinal and transverse dispersivity, observed between the BG4 site and another experiment in similar materials in West Bear Creek Valley. This could strongly influence application of models calibrated to small-scale tracer experiments for simulating behavior at a larger scale, or at different sites.* 4) *Finally, the results of the tracer experiments and the modeling indicate that in cases where extensive contamination has occurred in fractured, porous materials such as shale saprolite, it may take many tens if not hundreds of years of natural flushing to remove dissolved contaminants. Because of the influence of matrix diffusion, attempts to remove dissolved contaminants by pumping would also take a very long time.*

Because the EMDF modeling attempts to simulate a future release and plume that does not currently exist but may occur hundreds of years in the future, no plume monitoring data are available for model calibration. In addition, as demonstrated in the available tests conducted in clastic saprolite, tracer tests typically require a considerable amount of time and resources to implement and the data are typically obtained from and applicable over relatively small areas relative to the much larger areas modeled for the EMDF. The tendency of contaminant plumes to migrate more readily along strike parallel flow directions is addressed in the EMDF modeling primarily by consistently assuming enhanced strike parallel K values relative to those at right angles to geologic strike.

Tracer Plume Evolution at the BG4 Site

D. A. Webster of the USGS presented the original detailed documentation of the BG4 and BG6 tracer tests (Webster 1996). The tests were conducted using tritiated water injected at the water table in shaley saprolite of the regolith in July 1977. Monitoring results were reported for the 5 year period from 1977 through 1982 (but continued after 1982 as reported by Stafford et al 1998 and Mckay et al 1997). The BG4 test site is located in the Pumpkin Valley Shale and the BG6 site is located in the Nolichucky Shale. The BG tracer tests were designed to examine the hypothesis that ground water in regolith can flow transverse to the bedding. The layout of the injection well and downgradient monitoring wells was thus established so that the horizontal gradients and flow directions of the water table interval would be perpendicular to the geologic strike (i.e. – water table/potentiometric contours are parallel with the strike of the beds – in contrast to the WBCV site where the opposite occurs). At the BG4 site seven monitoring wells were installed along a 12 ft radius downgradient of the injection well (with a 30 ft radius at the BG6 site, where plume configurations over time were similar to those at BG4). The wells at site BG4 were numbered clockwise from right to left as 4-4 through 4-10, with similar numbering at the BG6 site.

The wells with the highest tritium concentrations were located directly down-gradient and strike-normal to the injection well. Plots of concentrations over time for several of the BG4 wells are presented in Figures E-48 and E-49 showing variations in the rate of change over the first two years and the longer 5 year time frame (Note the concentration scales change from log to arithmetic scales in the figures).

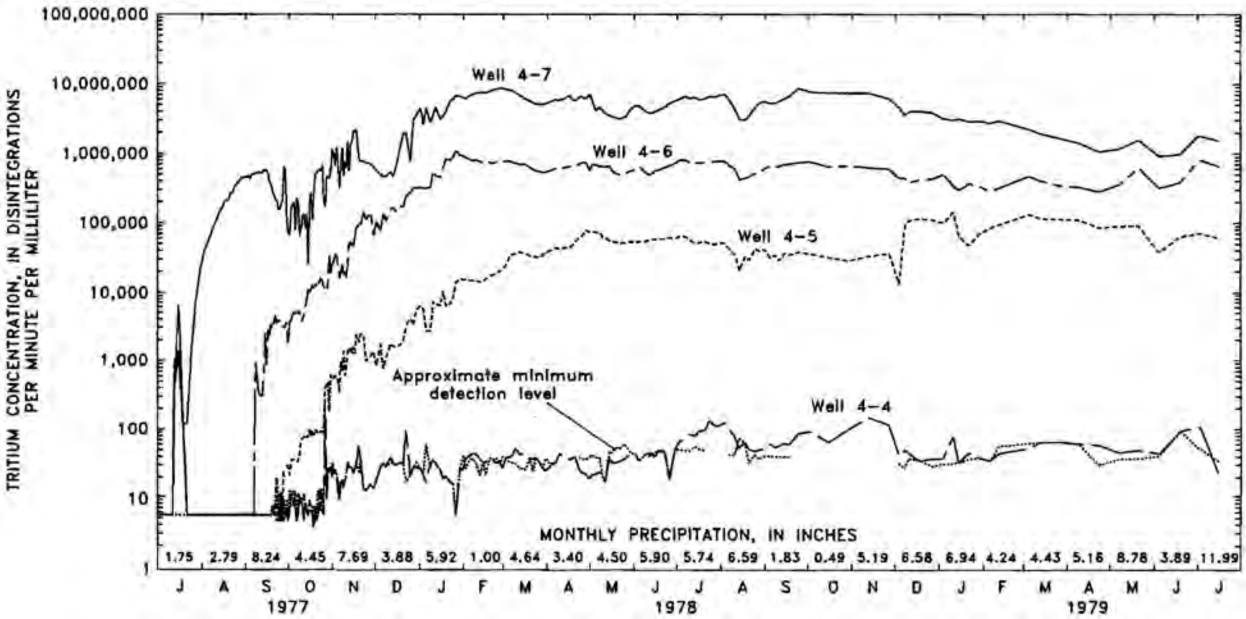

Figure E-48. Tritium concentrations in ground water from observation wells at BG4 tracer test site, 1977-1979 (from Webster 1996)

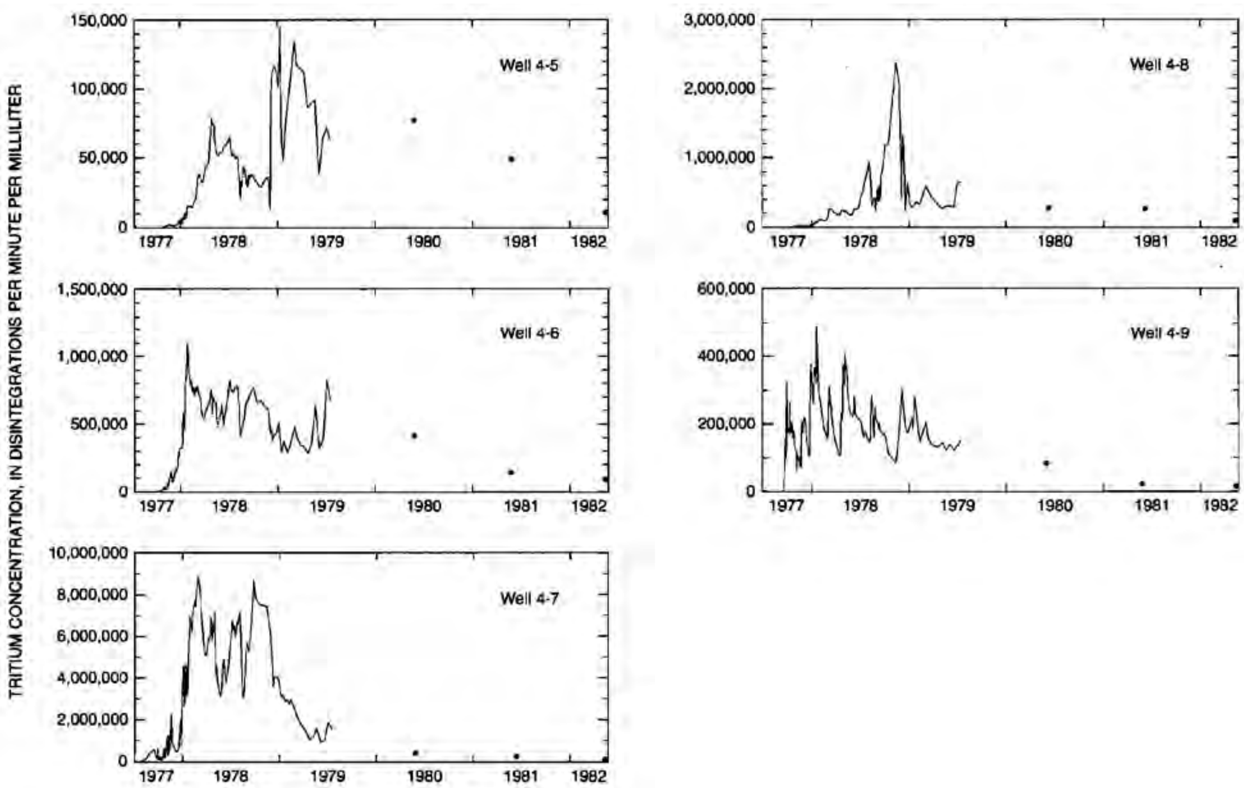

Figure E-49. Tritium concentrations in ground water from selected observation wells at BG4 tracer test site, 1977-1982 (From Webster 1996)

The BG4 plume maps in Figure E-50 and the plots in Figures E-48 and E-49 show that over time, the initial elongate plume expands laterally and downgradient into a more circular plume that widens and decreases in concentration as the center of mass moves slowly downgradient away from the injection well (Similar plume maps and plots are illustrated for the BG6 tracer test site – see Figures 9, 10, & 14 in Webster 1996). The annual point concentrations in 1980, 1981, and 1982 illustrate the long term progressive decline in concentrations in downgradient wells (Figure E-49) over the long term period relative to the WBCV site.

For the BG4 site, Webster states that *"although the leading edge of the plume arrived within 9 days, 5 to 6 months elapsed before concentrations began their rapid increase to maximum values, signaling arrival of the main part of the plume."* For the BG4 test the travel rate for first arrival equates to 1.3 ft/day (12ft in 9days). The peak concentration in well 4-7 occurred 229 days after the test began. The average travel rate to reach peak concentration would therefore be 0.05 ft/day.

For the BG6 site, the fastest first arrival time of 112 days was significantly slower than that at the BG4 site. This equates to a first arrival travel rate of 0.27 ft/day (30 ft/112 days). At the BG6 site, the peak concentration in well 6-7, where the highest concentrations occurred, was reached during the 16th month of the test (~465 days). The average travel rate to reach peak concentration would therefore be 0.06 ft/day.

Webster notes that matrix diffusion may have played an important role in these tests by acting as a mechanism for retarding transport. He lists the following evidence for matrix diffusion:

- the length of time that large tracer concentrations were detected at many observation wells,
- the persistence of residual concentrations at the injection wells and observation wells,
- the relatively rapid movement of the leading edge of the plumes but very slow movement of the centers of mass, and
- the reoccurrence of large concentrations of tritium in water of the BG4 injection well shortly after each of several flushings

At the injection well 4-11, the observed loss in tritium activity during the 5 years was seven orders of magnitude. To examine the possibility of matrix diffusion effects, the concentration data for well 4-11 were incorporated into a simple model simulating matrix diffusion. The observed concentrations were generally found to conform with the model simulations. As with the observations of McKay et al (1998), Webster also noted the implications of matrix diffusion on limiting ground water cleanup. Pumping would quickly remove contaminated water from joints and fractures, but only slowly remove contaminated water from the interstices or pores of the fine-grained saprolite material. This implies that matrix diffusion offers significant potential for retardation and attenuation of contaminants under future EMDF release scenarios. This also suggests that the current ground water modeling at the EMDF is very conservative since matrix diffusion is not incorporated into the models.

<u>Colloidal Tracer Tests at the WBCV Site near EMDF Site 14</u>

McKay, et al. (2000) presented results of tracer tests at the WBCV tracer site (nearest Site 14) using colloidal tracers (latex microspheres and three bacteriophage strains). Colloidal tracers were introduced in GW-484 and samples were collected from the downgradient well field (Figure E-28). All tracers were detected at distances of at least 13.5 m (44 ft), and two of the tracers were found in all downgradient wells. The authors summarize the test results as follows. *"In most wells the colloidal tracers appeared as a "pulse", with rapid first arrival [corresponding to 5 to 200 m/d* (16-656 ft/d) *transport velocity], one to six days of high concentrations, and then a rapid decline to below the detection limit. The colloids were transported at velocities of up to 500 times faster than solute tracers (He, Ne, and rhodamine-WT) from previous tests at the site. This is believed to be largely due to greater diffusion of the solutes into the relatively immobile pore water of the fine-grained matrix between fractures.*

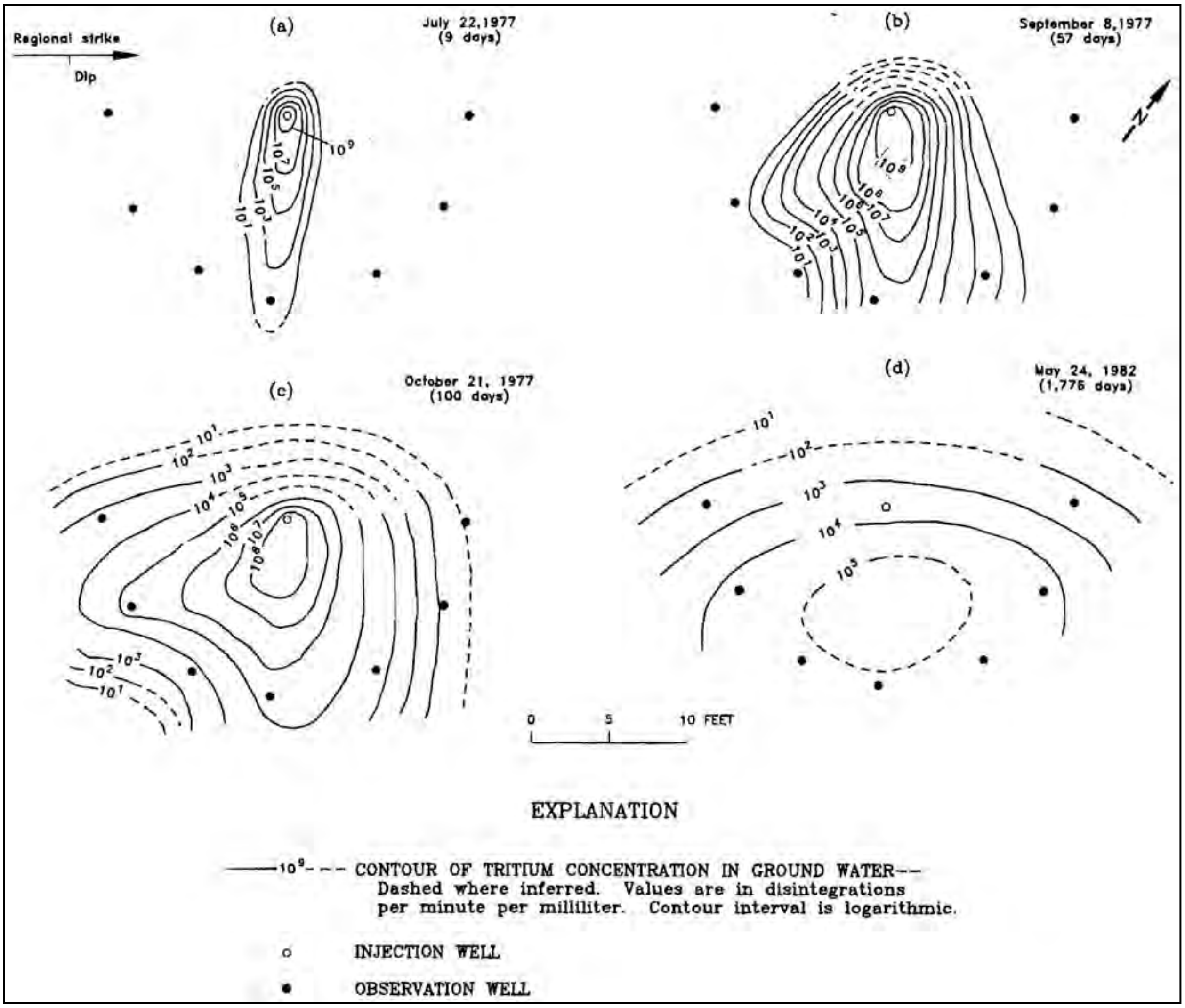

Figure E-50. Contours of tritium ground water concentrations at the BG4 tracer site at 9 days, 57 days, 100 days, and 1776 days (4.9 years) after tracer injection on July 13, 1977 (from Webster 1996)

Peak colloid tracer concentrations in the monitoring wells varied substantially, with the microspheres exhibiting the highest relative concentrations and hence the least retention. Rates of concentration decline with distance also varied, indicating that retention is not a uniform process in this heterogeneous material."

The paper by McKay et al (2000) summarizes key findings from the rhodamine dye tests reported above (Lee et al. 1989b, 1992) and similar tests using dissolved helium and neon (Sanford and Solomon 1998; Sanford et al, 1996). "*Important findings from these two tracer tests include: (1) solute tracer plumes tend to develop that are elongated along strike, with little transverse dispersion; and (2) solute transport rates are strongly influenced by matrix diffusion. In both tracer tests, transport rates (for a given relative concentration contour) decreased with time and distance from the injection well, and the low concentration "front" of the plumes tended to migrate at rates hundreds of times faster than the high concentration region. Both of these types of behavior indicate a high degree of longitudinal dispersion, which is typical of systems in which matrix diffusion is dominant.*" They note that although this difference in transport rates may be "*partly attributable to physical heterogeneity, it is also consistent with greater losses of the tracer pulse with increasing time due to diffusion into the matrix.*"

Dissolved Gas Tracer Tests at WAG 5 (ORNL)

Sanford et al (1996) presented results of dissolved noble gas (helium, neon, and bromide) tracer tests started in October 1994 at WAG 5 in Melton Valley south of the main ORNL campus. The site is described as the shallow aquifer in fractured weathered shale, so similar to conditions at the proposed EMDF footprints. Water table contour maps were not included in the paper, but surface topographic slopes are roughly parallel with the geologic strike (similar to the configuration at the WBCV site nearest Site 14), so shallow ground water flow directions would be anticipated to follow the geologic strike. Unlike the "slug" injections of tracers such as fluorescent dyes, the gases in these tests are injected into the well bore over a sustained period of time at a relatively constant source concentration. Breakthrough curves for the first 155 days of the test, show initial breakthrough occurring at about 15 days at a well located along strike 23 m (75 ft) downgradient of the injection well. This would indicate a ground water flow rate for first arrival of 1.5 m/day (5ft/day). The relatively low concentrations of the tracers in the breakthrough curves were explained by "*diffusion of the tracers into the less mobile matrix.*"

Limited Bromide/Helium Tracer Tests at GW-462 Site in WBCV

Schreiber (1995), Moline and Schreiber (1996), and Schreiber et al (1999) reported on tracer tests using helium and bromide conducted at a location approximately 1500 ft southwest of the intensively studied tracer site described above near EMDF Site 14 (See WBCV Site location map in Section 6 below for tracer well locations relative to Site 14). The work was conducted as part of a Master's thesis by Schreiber and coordinated with environmental researchers on the ORR. The test site is hydraulically separated from the Site 14 tracer test site by the valley of NT-15 and is located approximately 1000 ft west of NT-15, roughly halfway between NT-15 and SR 95 near the center of the outcrop belt of the Nolichucky Shale. Relative to the Site 14 tracer site, the helium/bromide test site covered a small area (~ 50 X 50 ft), and included only three shallow/deep observation well clusters that were not placed along transects perpendicular to the maximum water table gradient toward the southwest. Figure E-51 illustrates the relationships between the injection well (GW-462), the three shallow/deep observation well clusters (GW-456 through GW-461), and the average water table contours suggesting ground water flow in the water table interval would be toward the south/southwest. The three shallow/deep cluster wells were originally placed at right angles up-dip, down-dip and along strike from GW-462 for pumping tests (Schreiber et al 1999). One of the well clusters is located over 30 ft upgradient to the injection well, while the remaining two clusters are located at angles cross gradient to the average maximum water table gradients (the three multi-level discrete interval monitoring wells, GW-821, -822, & -823 were not part of the tracer testing). Relative to the Site 14 tracer site and the BG4 site, water table hydraulic gradients were at intermediate angles with respect to geologic strike/dip directions (See Figure E-51). Detailed topographical maps of the site area show an entrenched ravine located about 300 ft southwest of the test site that apparently influence shallow flow directions and local discharge toward the southwest.

In spite of the serious limitations in the numbers and placement of the tracer test monitoring wells, test results were presented with qualified interpretations. Both tests indicated the highest concentration ratios of helium and bromide in the shallow GW-461 well located southwest and along geologic strike of the injection well (GW-462). A slug of bromide was introduced in GW-462 on April 11, 1994, and monitored for approximately six months in the well pairs. Bromide breakthrough was only consistently detected in the water table well (GW-461) located along strike from the injection well. First arrival of low concentrations occurred on June 15, 1994, indicating a first arrival velocity of 0.23 m/day (0.75 ft/day).

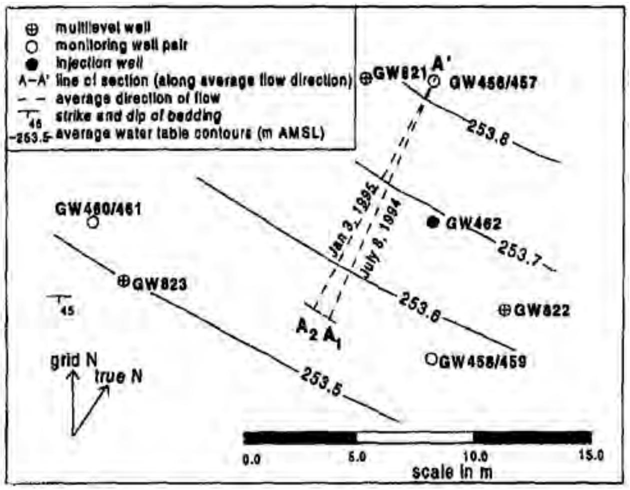

Figure E-51. Limited helium/bromide tracer test site in WBCV approximately 1500 ft west of NT-15

[**Note:** multilevel wells GW-821, -822, and -823 were not used in tracer monitoring]

The helium test involved a helium injection and sampling method described in detail by Sanford et al (1996) and used in the WAG 5 tracer test. The method involved sustained diffusion of helium to saturation levels through injection tubing over a period of several months from March 25 through December 12, 1994. As with the bromide test, the highest concentration ratios were detected in GW-461 along geologic strike. But concentration ratios several orders of magnitude below those in GW-461 were detected in shallow and deep wells up and downgradient of the injection well. The occurrences in upgradient wells were attributed to storm-related changes in flow conditions and to fracture connections with GW-458 in the downgradient direction (Schreiber et al, 1999). First arrivals in the along-strike GW-460(D)/GW-461(S) cluster occurred on May 15, 1994, corresponding to a first arrival velocity of 0.28 m/day (0.9 ft/day), similar to that for bromide.

2.13.5.2 Tracer Tests in the Maynardville Limestone and Copper Ridge Dolomite

Tracer tests in the surface water and karst network of Bear Creek and the Maynardville Limestone and Copper Ridge Dolomite were conducted in 1988 and 2001. Tracer tests in the Maynardville karst in UEFPC watershed along strike with BCV also provide some insight into the rapid ground water flow rates common to the carbonate rocks of BCV. Results are summarized below with references for additional information.

1988 Tracer Tests along Bear Creek

Tracer tests in the Bear Creek/Maynardville Limestone karst system are summarized in the BCV RI Report (DOE 1997; see p. D9-2) as part of an overall description of the hydrogeology of the Maynardville Limestone and Bear Creek. The report notes that "*In 1988 tracers placed in Bear Creek and BCK 10.41* (near NT-6) *were observed to break through in SS-5 ~5.5 d later (Geraghty and Miller 1989). This observation demonstrates that a component of flow at SS-5 comes from BCV surface water flow, which is presumably recharged from a losing reach of Bear Creek into the shallow ground water in the Maynardville. Flow in the shallow Maynardville Limestone interval subsequently transported the tracer to SS-5 ~914m (3000 ft) in 132 h (~6.9m/h or 22.7 ft/h* (545 ft/day)*), demonstrating that contaminants can migrate rapidly along BCV in either surface water or ground water . This study also concludes that, although the tracer was not detected in SS-4 (because the tracer was injected into the creek too far downstream to be captured in SS-4), the similar chemistry of SS-4 and SS-5 suggests that a component of flow at SS-4 might also be derived from shallow ground water and, ultimately, from Bear Creek.*"

Appendix C and D of the BCV RI Report (DOE 1997) should be reviewed for more detailed data and interpretations of the hydrogeology of Bear Creek and Maynardville Limestone. The complex relationships described in the BCV RI Report among Bear Creek surface water flow, the underlying subsurface karst flow network in the Maynardville/Copper Ridge, and contaminant migration from existing sources provides useful insight into the conceptual and predictive models for potential contaminant migration from the proposed EMDF sites.

TDEC 2001 Dye Tracer Tests in BCV

Staff from the TDEC DOE Oversight office conducted dye tracer tests in BCV in 2001 that were reported informally by R. C. Benfield (TDEC 2001 - report provided by S. Jones to DOE and Pro2Serve in 2014 via email). Tracer tests were conducted to assess general subsurface paths and travel times in the Maynardville Limestone, and separate tests were conducted to assess paths and travel times from a collapse feature associated with construction of the Spallation Neutron Source (SNS) facility along the crest of Chestnut Ridge, underlain by the Copper Ridge Dolomite. Figure E-52 illustrates observed surface water and inferred ground water flow paths for the tests.

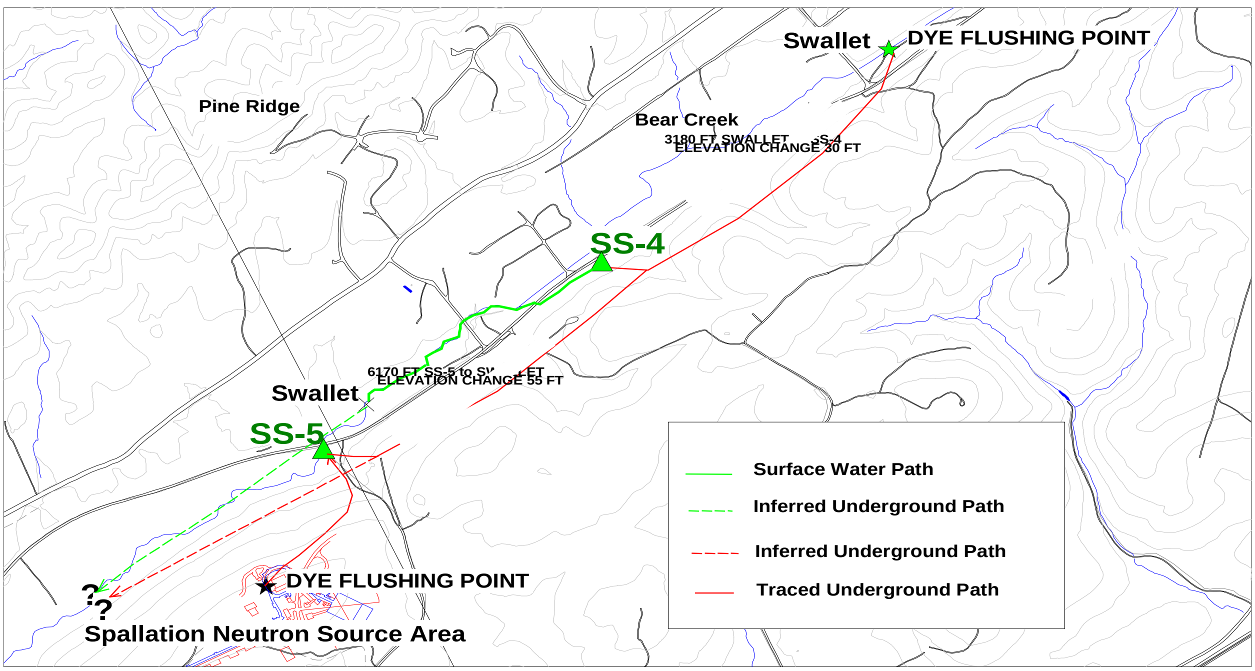

Figure E-52. TDEC 2001 dye trace locations along Bear Creek and Chestnut Ridge (from TDEC 2001)

Tracer tests were initiated by introducing fluorescein dye at a swallet along Bear Creek on May 21, 2001. The swallet is located roughly 200 ft upstream of the EMWMF entrance road crossing Bear Creek. Under low flow conditions Bear Creek stream flow at this swallet is entirely captured and diverted underground. The intervening stream bed of Bear Creek is dry until stream flow is replenished by resurgent flow from the downstream spring at SS-4. TDEC reported that “very visible fluourescein dye was observed” in the SS-4 spring approximately 25 hours after introduction of the dye at the upstream swallet (TDEC 2001). Although not reported by TDEC, the distance between the swallet and SS-4 is approximately 3300 ft, indicating very rapid flow rates of around 132 ft/hr (3168 ft/day) for first arrival of the dye. Plots of relative ppb flourescein versus time indicate peak concentrations at around 1.5 days from the start of the test roughly 12 hours after first arrival. The dye was observed to flow from SS-4 into Bear Creek downstream to a second swallet location along Bear Creek they report as 600 ft below the confluence of

SS-4 and Bear Creek (between NT-6 and NT-7). TDEC results indicated that the flourescein dye was detected in SS-5 (located further downstream near NT-8) with a first arrival time of about 4 days. The distance from the first swallet (farthest upstream) to SS-5 is approximately 5800 ft, indicating average flow rates of around 60 ft/hr (1440 ft/day) for first arrival there. The report states that no other visuals of the fluorescent dye were observed in springs downstream of the SS-5 spring. TDEC states that a second tracer test was conducted on June 26, 2001, to determine if the second swallet was connected to SS-5. Results are not presented other than to indicate that the second swallet did not connect with SS-5.

TDEC also conducted two tracer tests with Rhodamine dye and flourescein dye related to a collapse feature along Chestnut Ridge during SNS construction. They noted muddy turbid water in SS-5 apparently draining north to SS-5 from this feature. Their subsequent dye tracing indicated “a strong visual indication” of dye at SS-5 on August 22, 2001, nine days after initial introduction of Rhodamine dye on August 13, 2001. No travel times were reported to SS-5 or any other springs in BCV, but the data indicate rapid ground water flow rates to the north/northeast from the Copper Ridge Dolomite into the Maynardville Limestone along the south side of Bear Creek. It is clear that surface water and ground water migrating northward from Chestnut Ridge contributes uncontaminated water to Bear Creek and the karst ground water network within the Maynardville underlying the southwesterly flow path of Bear Creek.

The TDEC data are consistent with relatively rapid karst flow conditions reported in the BCV RI Report (DOE 1997) described above. The results are also reasonably consistent with the relatively high flow rates reported by Goldstrand and Haas (1994) for karst flow in the same formations in the UEFPC watershed roughly two miles northeast of and along geologic strike with BCV. Tests were conducted during low-flow and high-flow conditions. Results from the first tracer test indicated first arrival times ranging from 36 to 843 ft/day. Ground water flow velocities from the second test ranged from 14–1,000 ft/day for a Calcofluor White dye and from 47–1,314 ft/day for a Rhodamine WT dye.

2.13.5.3 Key Findings from Tracer Tests

The principal findings from the tracer tests conducted in BCV and at hydrogeologically similar sites on the ORR include:

Tracer Tests in Saprolite of the Predominantly Clastic Rocks of the Conasauga Group

- Ground water tracer flow rates in saprolite and shallow bedrock of the predominantly clastic rock formations of BCV are several orders of magnitude lower than those in the carbonate rocks of BCV.
- The orientation of tracer plumes and average velocities of tracers vary in large part on the orientation of the strike and dip of the beds with respect to the maximum hydraulic gradient
  - relatively narrow elongated plumes develop where shallow ground water flow gradients are parallel to geologic strike (e.g. - WBCV tracer field near EMDF Site 14)
  - broader more diffuse plumes develop more slowly where shallow ground water flow gradients are perpendicular to geologic strike (e.g. - BG4/BG6 sites)
  - plumes intermediate between these extremes appear likely to develop in areas with intermediate flow gradients relative to geologic strike
- Tracer concentration contour maps and breakthrough curves for the WBCV and BG4/BG6 sites illustrate that most of the injected tracer mass lags far behind the advancing low concentration front, indicating significant retardation and attenuation of peak concentrations.
- Tracer flow rates based on first arrival times and distances for very low concentration fronts vary significantly from flow rates based on subsequent arrival times of higher concentration fronts and peak concentrations.

- Ground water tracer flow rates based on first arrival times vary significantly over time and distance from the injection well, and orientation of water table gradients with respect to geologic strike.
  - Dye tracer flow rates based on first arrival times at the WBCV site ranged from 3.3 ft/day in the near field (46 ft in ~14 days), to 0.3 ft/day to reach the far field (108 ft in 370 days) – where flow paths and gradients were parallel to geologic strike.
  - Tritiated water flow rates based on first arrival were 1.3 ft/day (12 ft in ~9 days) at BG4, and 0.27 ft/day (30 ft in ~112 days) – where flow paths and gradients were perpendicular to geologic strike.
- Ground water tracer flow rates based on time to reach peak concentration lag significantly behind first arrival times. At BG4 and BG6 time, flow rates based on time to reach peak concentrations were:
  - 0.05 ft/day (12 ft in ~229 days) at BG4 versus a first arrival rate of 1.3 ft/day, and
  - 0.06 ft/day (30 ft in ~465 days) at BG6 versus a first arrival rate of 0.27 ft/day
- Other flow rates based on first arrival times only and distances from injection well (IW) include:
  - 5 ft/day at 75 ft from IW at WAG 5 for He, Ne, Br;
  - 0.75 ft/day-0.9 ft/day at 49 ft from IW at GW-462 site in WBCV for Br and He, respectively
- Tracer plumes introduced at the water table in saprolite of the predominantly clastic rock formations at the WBCV site remained within the shallow water table interval and did not migrate vertically to greater depths (i.e. – intermediate/deep intervals)
- Matrix diffusion into the pores, micropores, and microfractures of the fine-grained matrix adjacent to the permeable fractures transmitting ground water flow (and contaminants) appears to play a major role in ground water contaminant retardation and attenuation, and in slowing the rate of contaminant mass flux and peak concentration arrival times away from the source injection site.

Tracer Tests in Carbonate Rocks along the south side of BCV

- Ground water tracer flow rates in the conduit flow system of the Maynardville karst along Bear Creek range from 545 to 3168 ft/day.
- Tracer tests indicate ground water can migrate quickly from the Copper Ridge Dolomite below Chestnut Ridge toward the north into the karst conduit flow system of the Maynardville Limestone below Bear Creek. However, as hazardous waste sites do not occur on Chestnut Ridge, the tracer results suggest that rapid ground water flux from the Copper Ridge to the Maynardville and ground water commingling there would serve to dilute and naturally attenuate pre-existing ground water contaminants within the Maynardville.

With regard to the proposed EMDF sites and ground water plume simulations, the results of tracer tests should be viewed in the context of the relatively small scale and relatively short duration of the tests versus the larger scales and longer time frames inherent to the modeling. The test results should also be viewed in the context of footprint locations within and contaminant migration paths across the outcrop belts of the predominantly clastic versu carbonate rock formations of the Conasauga Group.

2.14 GEOTECHNICAL ENGINEERING DATA

Among the proposed EMDF sites in BCV, geotechnical engineering investigations and reports are available for sites directly adjacent to Site 5. The subsurface geotechnical investigations adjacent to Site 5 include:

- Geotechnical engineering investigations of Sites B and C, east and west (respectively) of the Site 5 footprint (Ogden 1993a and b); and
- Pre-construction test pits with geotechnical sampling and analysis of regolith soils/weathered bedrock at the EMWMF (CH2M Hill 2000; WMFS 2000);

Subsurface investigations were completed by Ogden in 1992/1993 at sites on either side of and along geologic strike with Site 5 (Ogden 1993a and b). The Ogden geotechnical investigations were intended to support the design of above ground waste storage facilities that were subsequently never constructed by the DOE. They included subsurface drilling, sampling, and testing at 27 soil boring locations across “Site B”, adjacent to Site 5 on the northeast, and at 52 soil boring locations across “Site C”, now occupied by the EMWMF and directly southwest of Site 5. The Site C results were incorporated into the design for the EMWMF. Pre-construction test pits with geotechnical sampling and laboratory analyses were also conducted at the EMWMF site (circa late 1990s/early 2000s) at locations directly adjacent to and along geologic strike with Site 5 (BJC 1999, CH2M Hill 2000, WMFS 2000).

The geotechnical and hydrogeological data from these investigations is extensive and relevant to Site 5 (and applicable in many respects to likely conditions at the other proposed EMDF sites in BCV). See Attachment A for additional details summarizing these investigations and the types of geotechnical engineering data aquired. The original reports cited above are available with complete details (boring logs, laboratory data, maps, cross sections, etc.) and engineering interpretations. Geotechnical engineering data for the remaining proposed EMDF sites is either limited or non-existent.

2.15 SEISMICITY

There is no evidence of active, seismically capable faults in the Valley and Ridge physiographic province or within the rocks under where the ORR is located (DOE 2011a). The Oak Ridge area lies in Uniform Building Code seismic zones 1 and 2, indicating that minor to moderate damage could typically be expected from an earthquake. Although there are a number of inactive faults passing through the ORR, there are no known or suspected seismically capable faults. As defined in 10 CFR 100, Appendix A, a seismically capable fault is one that has had movement at or near the ground surface at least once within the past 35,000 years, or recurrent movement within the past 500,000 years. The nearest capable faults are approximately 300 miles (480 km) west-northwest of the ORR in the New Madrid (Reelfoot Rift) Fault Zone (DOE 2011). Historical earthquakes occurring in the Valley and Ridge are not attributable to fault structures in underlying sedimentary rocks, but rather occur at depth in basement rock (Powell, et al., 1994).

Oak Ridge lies within the East Tennessee Seismic Zone (ETSZ), a seismically active area lying roughly halfway between the New Madrid Seismic Zone and the Charleston, South Carolina Seismic Zone. The ETSZ extends from central Alabama to southern West Virginia and is roughly coincident with the Valley and Ridge Physiographic Province. The mechanisms and frequency of occurrence of earthquakes in the ETSZ are not well understood. Some investigators believe that earthquake activity in the ETSZ is declining or ephemeral (Powell, et al., 1994), while others believe that the probability of more intense earthquakes in the region remains significant (Petersen, et al. 2008). More recent evaluation using new or revised modeling approaches suggest that earthquake magnitudes and associated ground motions may be greater than earlier models suggest. (Petersen, et al. 2014)

Hatcher, et al. (2012) and Vaughn, et al. (2010) have shown strong field evidence of earthquake-related features, such as fracturing, co-seismic faulting, liquefaction, and similar, that suggests that earthquakes with magnitudes exceeding 6.5 have occurred in the region within the late Quaternary Period, possibly as late as 73,000–100,000 years ago. A recent seismic update for Y-12 was reported by MACTEC (2003).

Historic earthquakes in the ETSZ typically are of small magnitude and mostly go unfelt by people. However, a number of historic earthquakes have had magnitudes greater than 4.0, and were therefore capable of producing at least some surface damage. According to Stover and Coffman (1993), from 1844 to 1989 East Tennessee has historically experienced 26 earthquakes that were widely felt and seven of these caused at least minor damage. An earthquake that shook Knoxville in 1913 was estimated to have moment magnitude of about 5.0. Another earthquake that occurred in 1930, with an epicenter approximately 5 miles from Oak Ridge, had a Mercalli intensity of V to VII (see Table E-14 for a description of scales). The largest recent seismic event was a moment magnitude 4.7 earthquake that had an epicenter near Alcoa, Tennessee, 21.6 miles southeast of Oak Ridge in 1973. The intensity of this earthquake felt in Oak Ridge was estimated to be in the V to VI (light).

Table E-14. Earthquake magnitude and intensity scales

Moment Magnitude Scale	Modified Mercalli Scale	Intensity Descriptor	Peak Ground Acceleration (g)
< 2.0	I	Minor	<0.0017 to 0.039
2.0 – 2.9	I - II		
3.0 – 3.9	II – IV		
4.0 – 4.9	IV - VI	Light	0.039 to 0.092
5.0 – 5.9	VI - VII	Moderate	0.092 to– 0.18
6.0 – 6.9	VII - IX	Strong	0.18 to 0.34
7.0 and up	VIII - XII	Major to Catastrophic	0.34 to >1.24

Source: USGS 2000

The Oak Ridge region continues to be seismically active, with 50 earthquakes recorded within a radius of 100 km (62 miles) of the ORR since 1973. Approximately 60% of the 50 earthquakes within this radius occurred at depths greater than 6 miles (10 km). The closest of those events occurred on June 17, 1998, with an epicenter within ORR near the ETTP, registering a magnitude 3.3 (USGS 2013). Two other earthquakes with epicenters beneath the ORR have been recorded since 1973. These occurred on May 2, 1975 (MMI ≈ 2.6) and April 11, 2013 (MMI ≈ 2.2).

2.16 ECOLOGICAL SETTING AND NATURAL RESOURCES OF BCV

The following subsections review the general ecological conditions and natural resources of BCV in which the proposed EMDF sites occur. Ecological surveys recently completed mostly for the upper NT-3 watershed areas of Site 5 to define stream conditions, accurately delineate wetlands, and to identify threatened or endangered (T&E) species, have not been completed for Sites 14 and 7a. Ecological surveys completed for the EMWMF partially encompassed Site 6b, but would probably need supplemental assessments prior to design and construction at Site 6b. Depending on the final selection of the EMDF site footprint(s), complete or partial surveys will be needed to satisfy applicable regulatory requirements for the protection of natural resources. Final surveys may be needed for Site 5 to address potential impacts of construction on sub-tributaries of NT-2 and NT-3, as the recent ecological surveys did not completely address all of the footprint areas, particularly those at and near NT-2 on the east and southeast sides of the Site 5 footprint.

Baranski (2011) summarizes regulations and policies for protecting ecological and natural resources on the ORR as follows. The DOE is obligated by federal environmental policy and regulations, including the National Environmental Policy Act of 1969 (NEPA) and the Endangered Species Act of 1973 (ESA), Sects. 7 and 9, to protect significant natural resources on the ORR. These two statutes are the primary instruments that protect significant natural areas and federally listed species. Wetlands and surface waters receive specific protection under Sect. 404 of the Clean Water Act and other federal and state statutes and regulations. Other statutes, regulations, and policies also pertain to the protection and management of species, natural areas, and natural resources. As part of the NEPA review process, DOE Oak Ridge Operations' former Office for Project Planning operated under a policy that required surveys of land areas for protected resources prior to initiation of any project that could produce adverse impacts and coordinated land use actions with contractors through a Resource Management Organization; at present, Reservation-related concerns (including land use plans) are the responsibility of the DOE ORR Management Team, led by the DOE ORR Coordinator.

2.16.1 Previous Ecological Investigations, Risk Assessments, and Monitoring in BCV

The earliest most intensive and comprehensive study of ecological conditions in BCV was reported by Southworth et al in 1992 (*Ecological Effects of Contaminants and Remedial Actions in Bear Creek*). The Southworth report presented results of habitat evaluation, toxicity monitoring, and surveys of fish and benthic macroinvertebrates, all within the context of impacts from historical waste sites located in the central and upper parts of BCV. The BCV RI Report (DOE 1997) subsequently presented results of ecological characterization and a baseline ecological risk assessment for BCV in a comprehensive assessment of risks to fish, benthic invertebrates, soil invertebrates, plants, wildlife from chemicals, and terrestrial biota from exposure to radionuclides. Again results were presented in the context of impacts from existing historical waste sites in BCV [grouped into four functional areas (FA): S-3 FA, Oil Landfarm FA, BCBG FA, and Maynardville Limestone and Bear Creek FA]. Results were presented in the main body of the RI report and in greater detail in Appendix G, including remedial goal options for each group of ecological receptors (fish, invertebrates, etc.). In 1996 just before publication of the BCV RI Report, Hinzmann (1996) presented extensive results and analysis of biological monitoring of Bear Creek for the 1989-1994 period. The report presents detailed descriptions of the BC watershed, and results and analyses of toxicity monitoring, bioaccumulation studies, and instream ecological monitoring of fish and benthic macroinvertebrates, continuing the assessment of Bear Creek presented by Southworth et al (1992) for the 1984-1988 monitoring period that continues to the present. The report also includes water quality and steamflow data for Bear Creek. These reports provide extensive details on ecological conditions in BCV prior to and after early remedial actions conducted at some sites in BCV that were designed to reduce the ecological (and human health) impacts from site contaminants along exit pathways via waters coalescing in the Maynardville Limestone and Bear Creek.

Several more recent reports are available documenting ecological conditions and watershed biological monitoring in BCV with potential relevance to the proposed EMDF sites. Among others, the Annual Site Environmental Report for the ORR (DOE 2014), the annual Remediation Effectiveness Report(s) (RER) for the ORR (DOE 2015a), and the Y-12 Biological Monitoring and Abatement Program (BMAP) reports (Peterson et al 2009), address environmental compliance and biological monitoring programs that include the BCV watershed. The ecological monitoring includes surface water and biota sampling and analysis at stations along Bear Creek and several NTs in BCV Land Use Zones 1 through 3. The RER aquatic biomonitoring of streams in BCV includes bioaccumulation (contaminant accumulation in fish) monitoring, fish community surveys, and benthic macroinvertebrate community surveys. The latest ecological surveys were conducted prior to construction of the EMWMF and included areas encompassing Sites 5 and 6b adjacent to the EMWMF. The most recent surveys were conducted at the proposed EMDF Site 5 in EBCV as this site appeared to be a viable location in the "Brownfield" area of Zone 3.

2.16.2 Terrestrial and Aquatic Natural Areas in BCV

Outside of the Zone 3 land use area in EBCV, all of BCV and adjacent DOE properties are designated as part of the Oak Ridge National Environmental Research Park and Oak Ridge Biosphere Reserve (see Figure 11 in Parr and Hughes 2006). In two separate but related reports, Baranski presented an ORR-wide analysis, evaluation, and ranking of terrestrial Natural Areas (NAs; Baranski 2009), and Aquatic Natural Areas (ANAs; Baranski 2011). These reports compiled information from several previous reports into a comprehensive review of natural areas and sensitive habitats for the ORR. The purpose of the Baranski studies "*was to evaluate and rank those specially designated areas on the Reservation that contain sensitive species, special habitats, and natural area value. Natural areas receive special protections through established statutes, regulations, and policies*." As shown in Figure E-53, a swath along almost the entire length of Bear Creek and some tributaries within BCV are designated as ANA2. The ANA2 area extends from near NT-2 downstream through the water gap at SR 95 and Pine Ridge, and along NT-13 and NT-14, and adjacent boundary areas. In areas northwest of Bear Creek in the vicinity of the proposed EMDF sites, two terrestrial natural areas (NA13 and NA28), two Habitat Areas (HA7 and HA2), and four Reference Areas (RA5, RA6, RA7, and RA15) are recognized. Habitat Areas contain known occurrences of commercially exploited state listed species. Reference Areas (RAs) are defined as primarily terrestrial areas that contain special habitats or features and that also may serve as reference or control areas for research, monitoring, remediation, or characterization activities (Baranski 2009). Figure E-53 illustrates the relationships among the proposed EMDF site footprints and the various NAs, ANAs, HAs, and RAs delineated by Baranski (2009/2011). According to Baranski (2011), NAs and RAs are officially recognized for land use planning purposes but receive no additional special status or protections, except as required by NEPA and ESA. Other areas (i.e., Habitat Areas, Potential Habitat Areas, Special Management Zones, CMAs) are identified for planning purposes.

The ANA2 area and NA13 areas coincide with areas given a highest biological significance ranking of BSR-2 – very high significance - in a Nature Conservancy Report of biodiversity on the ORR (see Figure 12 in Parr and Hughes 2006). The HA7 and HA2 areas were similarly given a BSR-3 – high significance rating. Parr and Hughes (2006) also show that the HA7, HA2, NA13, NA28, and RA5 areas are confirmed habitats for rare plant and animal species (state and/or federal candidate and/or listed), and include terrestrially and aquatically sensitive habitats (see Figure 13 in Parr and Hughes 2006).

Along with several other ANAs on the ORR, Baranski (2011) assigned a highest priority rating to ANA2, but he did not identify any T&E species for ANA2. Baranski (2011) describes the Bear Creek ANA2 as follows. Most of this ANA consists of a 3rd-order stream that is a major tributary of EFPC, but three 1st-order tributaries and one 2nd-order tributary are also included. The ANA includes 8.8 stream miles. The headwaters of the system are spring fed. Some withdrawal of water actually or potentially occurs, and some stream reaches naturally dewater during some dry periods. Mature hardwoods compose the dominant vegetation in the riparian zone. Intact 100 ft (30 m) buffer zones are present for 75% of the system. The vegetation is generally undisturbed downstream except for pine plantation logging, but disturbances increase dramatically upstream. There have been major past disturbances, and there are active current disturbances, including nearby sludge application areas and current facilities bordering the ANA (e.g. - EMWMF and its Haul Road, road maintenance complex of buildings and storage areas). The fish species richness (FSR) is lower than expected for the size of the stream, with 22 species having been documented (PFSR = 36). Benthic diversity is high downstream but lowers near the headwaters and is considered to be moderate overall. This stream is reported to have the most dense population of the Tennessee Dace in the state (Ryon and Loar 1988). Life history studies of the dace have been conducted there. The locally rare Blackside Snubnose Darter is present. The Four-toed Salamander has been found in Hembree Marsh (NA24) in the lower section of ANA2. This ANA includes sites (BCK 3.25 to BCK 12.36) for benthics and fish community tasks of Bear Creek remediation activities. The TDEC ratings are OUS—Not Supporting designated uses in 2010, but in 2006 the lower reach was rated Partially Supporting; other 2006 ratings were WQ—Partially Supporting, FAL—Partially Supporting, IM—Not Supporting Due to Habitat Alterations, Natural and Scenic Qualities—Fair. Parts of this ANA are situated within NA4, NA13, NA24, and NA52. It lies within TNC BSR2-10, a large, important landscape complex.

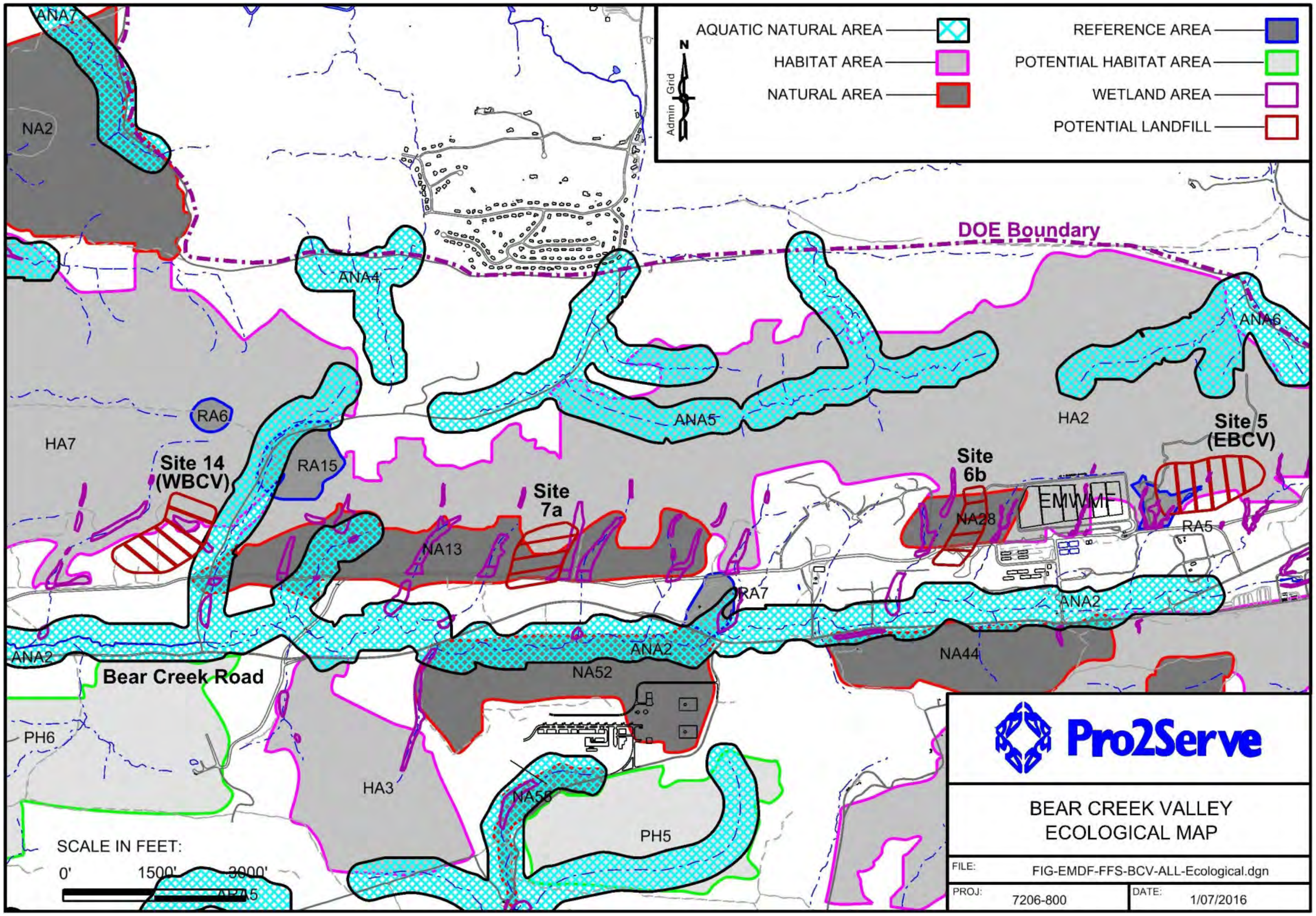

Figure E-53. Wetlands, and officially recognized special and sensitive areas on the ORR at and near the proposed EMDF sites.
[Wetlands from Rosensteel and Trettin (1993); natural areas from Fig. 2 of Baranski (2011)]

Among the terrestrial NAs shown in Figure E-53, NA13, encompassing the lower half of the Site 7a footprint, was identified by Baranski (2009) as having two status taxa, two T&E taxa, and two rare communities (see Table 1 in Baranski 2009 for additional details). NA28, encompassing much of Site 6b and its adjacent NT valleys, was reported to include one status taxa, one T&E taxa, and one rare community. However, no status taxa, T&E taxa, or rare communities were noted for RA5, located within the southwest part of the Site 5 footprint. RA15, located northeast and upslope of Site 14, would probably fall outside of the limits of impact associated with Site 14.

2.16.3 Wetlands and Sensitive Species Surveys in BCV

As summarized by Parr and Hughes (2006), activities that affect wetlands are regulated under federal law (Sect. 404 of the Clean Water Act, Federal Water Pollution Control Act, 33 USC 1251) and state law (Tennessee Water Quality Control Act, TN Code Annotated 70-324). Federal and state permits are required to conduct dredge-and-fill activities in a jurisdictional wetland (i.e., an area that meets the criteria established by the U.S. Army Corps of Engineers for a wetland). Impacts to wetlands are avoided whenever possible. If impacts are unavoidable, they are minimized through steps such as project design changes or the implementation of best management practices. Compensatory mitigation in the form of wetland restoration, creation, or enhancement is a required permit condition under certain circumstances.

The following subsections review wetlands and sensitive species surveys made within BCV that relate specifically to one or more of the proposed EMDF sites. The surveys include original wetland surveys completed for the entire BCV, and surveys associated with construction of the existing EMWMF and the ETTP/EMWMF haul road, with the new haul road required for the UPF project at Y-12, and with recent surveys at the proposed EMDF Site 5. The details of the Site 5 surveys are presented in Section 5 along with other site-specific conditions.

2.16.3.1 Wetlands Surveys Encompassing EMDF Sites 6b, 7a, and 14

Results of wetland surveys for the entire BCV watershed, including all of the proposed EMDF sites, were presented in a 1993 report by Rosensteel and Trettin (*Identification and Characterization of Wetlands in the Bear Creek Watershed*). The authors note the close relationship between shallow ground water and wetland areas in the Executive Summary to this report: "*Most of the wetlands had ponded water and/or saturated soils within 12 inches of the surface during the 1992 growing season. The presence of a shallow water table in these areas, in spite of their small drainage areas and the below-normal precipitation for the year, suggests that these areas remain saturated or saturated near the soil surface throughout most years and that ground water and/or shallow subsurface flow are the primary sources of moisture*."

The delineated wetlands are shown in Figure E-53 and in other close up views of the proposed EMDF sites presented below in Sections 3 through 6. Wetlands delineated near Site 5 are reviewed separately below as more recent wetland surveys, site disturbances, and mitigation efforts associated with the UPF haul road warrant a more detailed review than that for the other proposed EMDF sites.

Wetlands delineated near Site 6b are localized mostly along the central to upper reaches of NT-5 and NT-6 directly adjacent to the footprint. The wetland locations suggest the possibility of local strike parallel ground water flow from the uplands area below the footprint directly toward discharge zones along the adjacent valley floors.

Wetlands near Site 7a (and 7b) are similar to those found at Site 6b and were delineated only along the valley floors of NT-10 and NT-11 directly adjacent to the footprint along the central and upper reaches of the NTs. The wetland locations again suggest the possibility of strike parallel shallow ground water flow from the uplands toward the adjacent NT valley floors. Wetlands were not delineated along the lower reaches of NT-10 and NT-11 south of the haul road.

Several wetlands occur within and adjacent to the footprint of Site 14. Two were delineated within the footprint along an east-west trending swale cross cutting the footprint, where an underdrain is proposed. Several relatively extensive wetlands were also identified along the floor of NT-15 to the west and southwest of the Site 14 footprint suggesting that shallow ground water discharge from the uplands area of Site 14 is directed toward discharge zones along NT-15. Two other wetlands were delineated along the lower reaches of NT-14 southeast of Site 14 and south of the existing EMWMF/ETTP haul road. Rosensteel and Trettin note that the morphology and hydrology of NT14 differs from all other NTs in BCV. They state that NT-14 had no flowing water (September observation); a deep, steep-banked channel; and no wetlands along the main channel upstream of the power line right of way. Small wetland areas were identified along a shallow-banked subtributary (p. 24, Rosensteel and Trettin 1993).

2.16.3.2 T&E Vascular Plant and Fish Surveys for the EMWMF Including EMDF Sites 5 and 6b

Two separate field surveys were completed in 1998 for the battery limits of the EMWMF that included not only the EMWMF footprint area but adjoining areas that include the footprint areas of Sites 5 and 6b for the proposed EMDF (Figure E-54). Pounds (1998) conducted a "rapid assessment" to identify T&E species of vascular plants, and Ryon (1998) conducted a survey to identify T&E fish species. Results are summarized below; the original reports provide additional details.

Pounds (1998) indicated that no federally listed plant species are known from or are likely to be found on the project site (i.e. – the battery limits shown in Figure E-54). He noted that forest clearing would eliminate some habitat for state-listed ginseng and pink lady's slipper but added that large areas of habitat on the ORR will remain for these species. He also noted that the wetland areas at NA28 and RA5 (See Figure E-53) were previously recommended for special protection in part because of rare plants. He recommended protection of these and other wetlands and careful application of Best Management Practices in areas near wetlands.

The fish survey by Ryon (1998) focused primarily on the Tennessee dace, listed as a species in need of management but not identified as a T&E species. He noted that State guidance on species in need of management indicates that it is unlawful to knowingly destroy the habitat of such species without a permit, and recommended obtaining proper permitting and a mitigation plan to offset the planned loss of or impact on Tennessee dace habitat. His plan objectives included addressing sediment control procedures, replacement channels for stream loss (NT-4), protection of vegetated stream buffer zones, and post construction monitoring. The similarity of Sites 7a and 14 to the area encompassed by these studies, suggests that similar conditions may be encountered at Sites 7a and 14 further downstream in BCV.

2.16.3.3 2005 Environmental Survey Report for the ETTP/EMWMF Haul Road Corridor

An environmental survey was conducted in 2004/2005 to assess sensitive natural resources that would be impacted by the haul road corridor between the ETTP and the EMWMF. The haul road generally follows the strike of BCV along the power line right of way north of and roughly parallel with Bear Creek Road. The haul road lies just south of the footprints of Site 5 and Site 14 but crosses the footprints of Sites 6b and 7a and would require rerouting south of those footprints. The results of the survey thus have some bearing on the proposed EMDF sites. The results of the survey were presented in a report by Peterson et al (2005). The survey evaluated rare plants and vegetation assemblages, rare wildlife and their habitat, rare aquatic species, and wetland/floodplain areas.

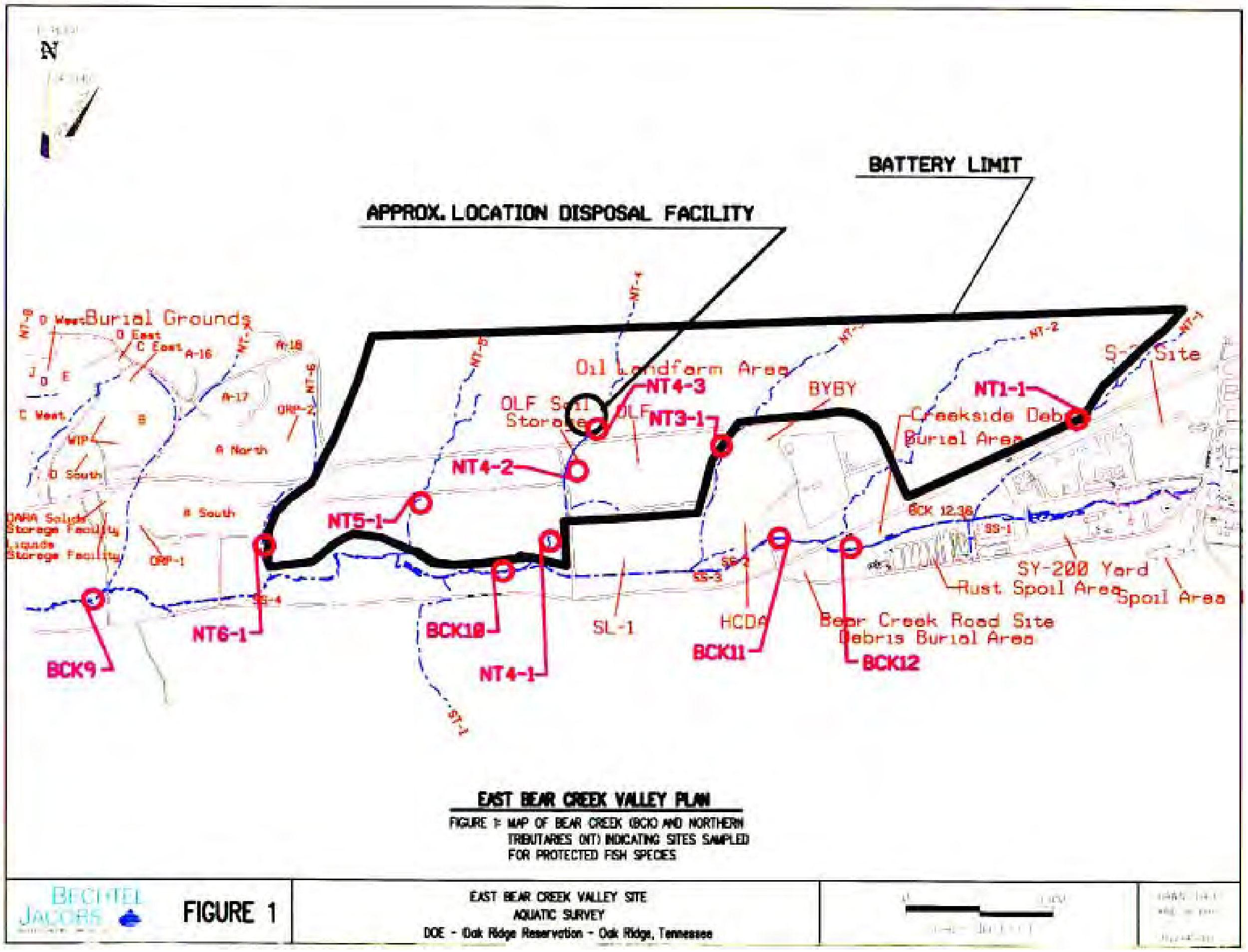

Figure E-54. Area encompassed by two separate 1998 T&E surveys of vascular plants and fish

The conclusions of the survey relevant to BCV and the EMDF sites indicated that "the most significant natural resource disturbance associated with the Haul Road's construction is undoubtedly the potential aquatic and wetland impacts near Bear Creek and its major tributaries [NT-13, NT-14 (Gum Branch), NT-15, and a western tributary]. Bear Creek and its major tributaries contain the rare Tennessee dace, and forested wetlands adjacent to these streams were generally found to be of high natural quality. Fragmentation of interior forest was also a concern as road construction was deemed a potential impact on forest-interior neotropical migrant birds. However, a thorough review of past records as well as the present surveys found no evidence of rare, T&E wildlife species or plants present within the Haul Road corridor." (Peterson et al, 2005).

2.16.3.4 Wetland and Sensitive Species Survey for the UPF Project

A wetland and sensitive species survey was conducted as part of the UPF project at the Y-12 Complex to address a new haul road extending from BCV over to the UPF facility located within the main industrial complex at Y-12. Three wetland areas (designated as Wetlands 6, 7, & 8) were identified along the east and southeast margins of the proposed EMDF Site 5 footprint. Results were presented in a report by Giffen et al (2009), and the former wetland areas were subsequently reconfigured during the UPF haul road construction in 2014 with implementation of wetland mitigation measures under an approved TDEC ARAP permit. Prior to the road construction and reconfiguration, these former wetland areas were visited and photographed by Pro2Serve field staff in 2014 as part of Site 5 field reconnaissance. The wetland areas were identified as probable discharge zones for shallow ground water within the valley floor areas of NT-2 subtributaries adjoining the Site 5 footprint where underdrain trench/blanket networks would be warranted. Additional details of impacts to Site 5 are addressed below in Section 5.0.

Aside from the obvious impacts to wetlands, the report by Giffen et al (2009) noted the need to protect the aquatic environment for the Tennessee Dace. The report noted that extreme measures were taken during the construction of the EMWMF haul road to avoid excess sedimentation to Bear Creek and its tributaries which can disrupt seasonal spawning. Measures to protect these fish included the implementation unique culvert designs for NT crossings (Pcterson et. al. 2005). Site-specific control measures of particular importance to protecting the Tenncssee dace include using appropriately sized culverts and box bridges to prevent the impoundment of normal and base flows; using box bridges where appropriate to minimize impacts to existing streams with sensitive habitat; and designing specific oversized, partially submerged culverts with light infiltration to maintain and support fish movement. In addition, the timing of construction to be outside the critical periods when migration and reproductive activities of the Tennessee dace are at a peak is of great importance.

2.16.3.5 Recent Wetland and Ecological Surveys At and Near Site 5

Detailed surveys were conducted by Rosensteel (2015) to make detailed stream hydrologic determinations and accurately delineate wetlands within the upper NT-3 watersheds at Site 5. In addition, ecological surveys were completed for Site 5 by Schacher (2015a/b). Results of these recent surveys are summarized below in Section 2.17. Similar detailed surveys will be warranted for any of the other EMDF candidate sites if selected for development.

2.16.4 Summary of Aquatic Resources Monitoring Results in Bear Creek

As previously noted, virtually all of Bear Creek within BCV is designated as ANA2 within the Oak Ridge National Environmental Research Park (Parr 2012; Baranski 2011). The stream habitats of upper Bear Creek and its tributaries have been impacted from headwater contamination originating from Y-12 waste disposal sites in EBCV (Southworth, et al. 1992). Despite those impacts, habitats in the upper reaches of Bear Creek such as those near BCK 12.34 support small populations of benthic taxa of Pycnopsyche luculenta, Chimarra sp., Neophylax spp. (perhaps 2 species), Optioservus sp., Rheopelopia sp., and Psilotreta sp., which are relatively intolerant to pollution. Although segments of the upper Bear Creek stream channel are periodically dry from karst stream flow capture in the summer/fall dry season, portions of the stream support a rather healthy community of benthic macroinvertebrates. During dry periods much of the benthic fauna may migrate to the hyporheic zone of the stream.

In general, the diversity and abundance of aquatic fauna were found to increase with distance from the contaminated headwaters (Southworth, et al. 1992). This may also be due, in part, to increases in stream depth and continuity of flow. A total of 126 benthic invertebrate taxa were recorded in Bear Creek, including crustaceans, aquatic worms, snails, mussels, and insects. Southworth et al (1992) collected representatives of 11 orders of insects, including springtails, mayflies, dragonflies and damselflies, stoneflies, crickets and grasshoppers, alderflies and caddisflies, butterflies and moths, beetles, true flies, and true bugs. Southworth, et al. (1992) noted that mayflies, highly sensitive to heavy metal pollution, were almost totally absent in all but the lower reaches of Bear Creek. Upstream areas were numerically dominated by midge larvae, which is typical of polluted streams (Southworth et al. 1992).

Nineteen species of fish were recorded in Bear Creek during surveys in 1984 and 1987, and data provide evidence of ecological recovery in Bear Creek since 1984 (Southworth, et al. 1992; Ryon 1998). Studies have concluded that much of Bear Creek contains a limited number of fish species that appear to have robust populations (high densities and biomass). Fish surveys reported by Southworth et al (1992) over two decades ago near the headwaters demonstrated a stressed condition without a stable, resident fish population. However, headwater streams often do not support very diverse fish fauna. Four fish species were found to predominate in the upper reaches of Bear Creek (above kilometer 11) including blacknose dace (*Rhinichthys atratulus* Hermann, 1804), Tennessee dace (*Phoxinus tennesseensis* W.C. Starnes & R.E. Jenkins 1988), creek chub (*Semotilus atromaculatus* Mitchell, 1818), and stoneroller (*Campostoma anomalum* Rafinesque, 1820). Ryon (1998) noted the presence of creek chub and blacknose dace in NT-3. By comparison, 14 fish species occur downstream from SR 95.

Biological monitoring of stream sites in BCV watershed has been conducted since 2004 to measure the effectiveness of watershed-scale remedial actions (DOE 2012). Biological monitoring includes contaminant accumulation in fish, fish community surveys, and benthic macroinvertebrate community surveys. Data from BCV are compared to reference sites on similar sized creeks outside the ORR. Additionally, annual monitoring has been conducted on NT-3 south of the Haul Road to document the progress of stream restoration after the BY/BY remediation was completed (Peterson, et al. 2009).

Fish are collected twice a year at sampling locations BCK 3.3, BCK 9.9, and BCK 12.4 and analyzed for a suite of metals and polychlorinated biphenyls (PCBs) (DOE 2012). Mean mercury concentrations in rockbass (*Ambloplites rupestris*) from lower Bear Creek increased in 2011, averaging 0.79 µg/g in fall 2010 and 0.68 µg/g in spring 2011. These mercury levels are over three times higher than those found in the same species from the Hinds Creek reference site and are above the EPA-recommended fish-based AWQC of 0.3 µg/g. Redbreast sunfish (*Lepomis auritus*) collected along the stretch of Bear Creek between BCK 4.6 and BCK 9.9 had average mercury concentrations of 0.39 µg/g in fall 2010 and 0.29 in spring 2011. These concentrations are comparable to those seen in Fiscal Year 2010. Redbreast sunfish feed on lower trophic level prey than rockbass, and typically have between 15–40% lower mercury levels.

Concentrations of nickel, cadmium, and uranium in stoneroller minnows were highest in upper Bear Creek and decreased with distance downstream (DOE 2012); Southworth, et al. (1992) reported similar findings. Cadmium and uranium concentrations in fish from the lower end of the creek were higher than reference values in 2011. Nickel concentrations were similar to those from fish from the Hinds Creek reference site. PCB concentrations in stoneroller minnows in fall 2010 and spring 2011 averaged 2–4 µg/g, continuing the long-term trend of elevated levels in fish. As with metals, PCB levels in minnows decrease downstream.

Fish communities in Bear Creek have generally been stable or slightly variable in terms of species richness (DOE 2012). The number of species present at sites BCK 3.3 and BCK 9.9 is similar to or higher than the Mill Branch reference stream. The BCK 9.9 sample site has seen a steady increase in species richness, in part because the downstream weir was bypassed, allowing more upstream migration of fish species.

East Bear Creek (measurement stations BCK 9.9 and 12.4, above and below NT-3) and NT-3 continue to support fewer pollution-intolerant benthic macroinvertebrate taxa than nearby reference streams, particularly during the fall dry season (DOE 2012), and TDEC (2012) indicates that both of its measurement sites at BCK 9.6 and BCK 12.3 are slightly to moderately impaired, respectively, but neither meet the state macroinvertebrate index score for this region. These findings agree with observations made by Southworth, et al. (1992) that the number of pollution intolerant species, and overall species richness, increases with distance downstream. Farther downstream at BCK 3.3, results continue to indicate that the condition of invertebrate community is comparable to reference conditions. This is especially encouraging because BCK 3.3 is downstream of most of the contaminated ground water discharges in the Bear Creek (DOE 2012). Most contaminant levels also decrease downstream.

The Tennessee dace, a major constituent of the fish population above the weir at Bear Creek km 4.55, is a Tennessee-listed in-need-of-management species and its habitat is protected by the state of Tennessee.

Ryon (1998) did not observe Tennessee Dace in NT-3 sampling, but does indicate that NT-2 south of the Haul Road should be capable of supporting small fish populations, including Tennessee dace. Peterson, et al. (2009) indicated that Tennessee Dace had occasionally been observed in NT-3 south of the Haul Road. No federal- or state-listed T&E aquatic species have been observed in Bear Creek or its tributaries (Southworth, et al. 1992).

2.16.5 Lower NT-3 Stream Ecology after Remedial Actions South of Site 5

The lower reaches of NT-3 downstream of Site 5 were impacted by remedial actions at the BY/BY. Site contaminants and remedial actions at the BY/BY did not impact Site 5 as it is located upslope and hydraulically upgradient of the BY/BY in an area believed to be historically undisturbed and uncontaminated from waste disposal activities at Y-12. Remedial actions at the BY/BY included removal of soils, capping, hydraulic isolation, and re-configuring and lining the channel of NT-3 from approximately the south side of the Haul Road culvert to approximately 100 ft upstream from the confluence of NT-3 with Bear Creek. Remedial actions to remove contaminated soils from the BY/BY were completed in 2003; stream restoration was completed at the same time. The stream was restored with low-amplitude meanders and the banks seeded with native grasses and other species.

Surveys of NT-3 stream and riparian habitats downstream from the Haul Road were conducted from 2004 through 2011 to assess the effectiveness of BY/BY remediation (DOE, 2012; Peterson, et al. 2009). In-stream and riparian habitats have shown generally improving conditions over that time, but have not yet met the metric goals set for stream and riparian habitat. Continued successional changes in vegetation to more shrub and tree species is expected within the restoration area over time. Surveys included measures of in-stream habitat within established stream transects and adjacent riparian habitat.

The lower NT-3 stream channel near the BY/BY is roughly 1–2 ft wide, but can flow outside the channel at some bends during high flow events and allow for some riparian wetland development. Channel morphology was relatively stable, but showed some normal adjustments (aggrading/degrading and slight meander migration). Stream sediments consist of poorly sorted gravel substrate, with cobbles, sand, silt, and clays in some reaches. Filamentous algae are present in some areas of the stream. Clear water and many fish were observed in pools during the 2011 survey. Lower NT-3 water quality measures (pH, DO, temperature) were generally found to be similar to a reference stream, but specific conductance was found to be higher (DOE 2012).

Riparian vegetation coverage is improving, and the difference in mean canopy cover from 2008 (3.4%) to 2011 (13.2) is marked, even though the mean percentage of ground cover declined slightly, from 94.2–88.6%, over the same period. The mean number of plant species per transect also declined, from 15.8–13.6. This is apparently due to an invasive plant species (*Lespedeza cuneata*) that out-competes native species.

Peterson, et al. (2009) reported evidence that the macroinvertebrate community in NT-3 is degraded relative to nearby reference sites, and that no major changes occurred over the period from 2004 through 2008. The average number of species per sample and taxonomic richness of the pollution-intolerant mayflies, stoneflies, and caddisflies in NT-3 were consistently two to three times lower than in reference streams. Differences between NT-3 and reference sites in the number of species of mayflies, stoneflies, and caddisflies were greatest in October, when stream flow was least. A well-developed mature riparian zone moderates diurnal and seasonal swings in stream temperature and reduces the flow rate and suspended solids load associated with storm-water runoff. This increases chemical and physical instability in the stream, preventing the recovery of species with less tolerance for impaired water quality. Improved riparian conditions should lead to improved aquatic conditions.

According to Peterson, et al. (2009), only a single fish species, the western black-nose dace (*Rhinichthys obtusus*) has been routinely observed in NT-3. Largescale stonerollers (*Campostoma oligolepis*), creek chubs, or Tennessee dace have been occasionally observed. Conversely, between four and nine fish species are commonly found in nearby reaches of upper Bear Creek. This may be due to the shallow stream depth under normal conditions, poor substrate conditions, and tendency of the stream to go dry in late summer.

2.16.6 Terrestrial Habitats and Sensitive Species in BCV

Regional plant communities within BCV typify those found in Appalachia from southern Pennsylvania to northern Alabama. However, natural and disturbed conditions vary among the proposed EMDF sites. The Site 7a and 14 footprints and surrounding areas are largely undisturbed forest. In contrast, the Site 6b footprint area was denuded and partially excavated for borrow material, and has been completely regraded with a grass cover and sediment drainage basin and a haul road leading into the adjacent EMWMF. Over half of the Site 5 footprint was logged following the May 2013 blowdown that toppled trees across the site. The surface of Site 5 has also been reconfigured in places during road construction for Phase I site drilling. The descriptions below therefore apply primarily to general conditions at Sites 7a and 14, and to some undisturbed areas surrounding Sites 5 and 6b.

2.16.6.1 Terrestrial Flora

Much of the natural upland forest on the ORR, including much of BCV, is a mixed mesophytic forest dominated by oaks (*Quercus* spp.), hickories (*Carya* spp.), and yellow poplar (*Liriodendron tulipfera*), with co- or subdominant beech (*Fagus grandifolia*) and maples (*Acer* spp.). Evergreens such as shortleaf pine (*Pinus echinata*), Virginia pine (*P. virginiana*), and loblolly pine (*P. taeda*) are intermixed in deciduous-dominated forests, and are found in more or less pure stands, especially on recovering disturbed land and in plantations. Other trees that may be present as secondary or understory species include black cherry (*Prunus serotina*) and dogwood (*Cornus florida*) (Kitchings and Mann 1976). Much of the forest is open, with little herbaceous undergrowth. Some areas may have a moderate to dense undergrowth composed of rhododendron or laurel, but these are confined to relatively small niche areas. The herbaceous layer includes ferns, plantains, groundsel, and vines.

Bottomland and wetland sites are characterized by sweet gum (*Liquidambar styraciflua*), sycamore (*Platanus occidentalis*), and black willow (*Salix nigra*), with red maple (*Acer rubrum*), black walnut (*Jugans nigra*), and boxelder (*Acer negundo*). The herbaceous layer may contain sedges (*Carex* spp.), rushes (*Juncus* spp.), cattails (*Typha* spp.), and bulrushes (*Scirpus* spp.).

2.16.6.2 Terrestrial Fauna

Predators including coyote (*Canis latrans*), red and the gray fox (*Vulpes fulva* and *Urocyon cinereoargenteus*, respectively), bobcat (*Lynx rufus*), and weasel (*Mustela frenata*) are widespread throughout the ORR. Black bears (*Ursus americana*) have occasionally been reported on the ORR, but these appear to be animals in transit, not permanent residents. White-tail deer (*Odocoileus virginianus*), the only ungulate currently known to frequent the area, inhabit upland and bottomland forests throughout the ORR. Elk are also occasionally sighted on the ORR.

Striped skunk (*Mephitis mephitis*), opossum (*Didelphis virginiana*), raccoon (*Procyon lotor*), eastern cottontail rabbit (*Sylvilagus floridanus*), groundhogs (*Marmota monax*) are small omnivores and herbivores common to both forest and field. Numerous members of the order Rodentia are present, including chipmunks (*Tamias striatus*), eastern grey squirrel (*Sciurus carolinensis*), and flying squirrel (*Glaucomys volans*), as well as several species of mice. Shrews and voles are also common throughout the ORR.

Streams and lake banks offer suitable habitat for muskrats (*Ondatra zibethica*) and beaver (*Castor canadensis*). Marsh rice rats (*Oryzomys palustris*) may live in wet areas along open waters that have a dense herbaceous growth of grasses and sedges.

2.16.6.3 Avifauna

The upland forest provides habitat for a large number of resident and migratory bird species. Resident woodpecker species common to mature deciduous forests include yellow-shafted flickers (*Colaptes auratus*), redbellied woodpeckers (*Melanerpes carolinus*), hairy woodpecker (*Picoides villosus*), downy woodpeckers (*P. pubescens*), and pileated woodpeckers (*Hylatomus pileatus*). The common crow (*Corvus brachyrhynchos*) and blue jay (*Cyanocitta cristata*) are also present in the deciduous forest.

Songbirds found in ORR forests are represented by Kentucky warbler (*Geothlypis formosus*), pine warbler (*Setophaga pinus*), yellow-breasted chat (*Icteria virens*), and ovenbird (*Seirus aurocapilla*), Carolina chickadee (*Poecile carolinensis*), scarlet tanager (*Piranga olivacea*), mourning dove (*Zenaida macroura*) and tufted titmouse (*Baeolophus bicolor*) are considerably less selective. Game birds include turkey and ruffed grouse (*Bonasa umbellus*).

Red-tailed hawk (*Buteo jamaicensis*) and sharp-shinned hawk (*Accipiter striatus*) are raptors common year-round on the ORR. Turkey vultures (*Cathartes aura*) and black vultures (*Coragyps atratus*) are also common on the ORR. The Northern harrier (*Circus cyaneus*) and broad-winged hawk (*Buteo platypterus*) are migratory visitors.

2.17 RECENT WETLAND AND ECOLOGICAL SURVEYS AT SITE 5

Recent surveys (circa 2013-2015) completed at Site 5 (EBCV) include: 1) wetland delineation and stream determination surveys of upper NT-3 tributaries; 2) aquatic life surveys of NT-2/NT-3 tributaries; 3) terrestrial surveys; 4) and an acoustic bat survey following the May 2013 blowdown.

2.17.1 Wetland Delineation and Stream Determinations at Site 5

Rosensteel (2015) performed detailed wetland identification and delineation surveys and made hydrologic determinations for streams and wet weather conveyances for the three branches of NT-3 within and adjacent to the western Site 5 footprint. The report by Rosensteel (2015) includes complete findings and additional details on methods, procedures, and regulatory criteria for wetland identification and delineation, stream determinations, and jurisdictional and hydrologic determinations for the surveyed areas. Only key findings are presented below.

The recent surveys for upper NT-3 did not include the headwater tributaries of NT-2 at and near Site 5. However, earlier wetland surveys reported by Rosensteel and Trettin (1993) included the NT-2 tributaries at and near Site 5, and those survey results have been incorporated into drawings for Site 5. Figure E-55 illustrates the locations and acreage of the six small upper NT-3 wetlands delineated by Rosensteel (2015). These wetland areas are consistent with previous wetland surveys throughout BCV by Rosensteel and Trettin (1993), but the recent surveys were completed in 2013 and 2014 using a portable global positioning system (Trimble GeoXT) to more accurately delineate the wetland boundaries and stream segments. Four wetlands were previously delineated in the upper NT-2 watershed along the southeast and east margins of Site 5 by Rosensteel and Trettin (1993). The collective survey reports from 1993 and 2015 identify all the wetlands at and near the Site 5 footprint, although the NT-2 wetlands reported in 1993 may not have been delineated to the same level of accuracy as those along NT-3 at and near Site 5.

The five wetlands (wetlands A, B, C, D, and F) in the upper NT-3 watershed at Site 5 are included in RA5, the Quillwort Temporary Pond wetland area, named for the Carolina quillwort (*Isoetes caroliniana*) that was observed in the area. Baranski (2011) noted that the Carolina quillwort might be a rare species, but it is not a Federal or state-listed species of concern. RA-5 may also be an important amphibian breeding ground (Parr, pers. comm., 2012). The lower portions of Wetlands C and D appear to be formed in part as a result of water backed up by a metal plate with a V shaped notch welded across the north upstream end of the NT-3 culvert passing under the Haul Road. This restrictor plate was installed in September 2002 to restrict downstream flow and facilitate the restoration of NT-3 south of the Haul Road after the BY/BY cap was constructed. The plate remains in place as of March 2016.

Rosensteel (2015) also performed hydrologic determination surveys for the three headwater branches of NT-3 at Site 5. The survey found that 450 linear feet of NT-3a and NT-3b exhibited the characteristics of wet weather conveyances. The remaining segments of NT-3a and NT-3b, and all of NT-3c, a total of 2,780 linear feet, are classified as streams. Results are shown in Figure E-55.

NT-3a (west) above the headwater spring is designated as a wet weather conveyance. From the spring to the wetland at the Haul Road NT-3a is a perennial or intermittent stream. It receives discharge from the EMWMF diversion ditch during rain events. Its bed is gravelly upstream from a small gravel access road to EMWMF monitoring well GW-916, but cuts through sediments from there to the downstream wetlands.

NT-3b (middle) was designated as a wet-weather conveyance upstream of the EMDNT3-SP3 spring prior to the downburst and timber recovery, with segments of defined channel and swale segments without a defined channel. The lower third to half of this wet-weather conveyance was impacted by logging operations. Subsequent Phase I road construction rechanneled flow, with some storm runoff directed to NT-3b near the spring and some storm and baseflow runoff bypassing the former wet weather conveyance in a new channel roughly 100 ft east of EMDNT3-SP3. This intermittent flow bypasses the EMDNT3-SWG1 flume entering the main channel of NT-3 just west of the flume. From EMDNT3-SP3 to the wetland just downstream, NT-3b exhibits a small channel with perennial to intermittent flow. Discharge is dispersed as it enters the lower wetland.

NT-3c (east main channel) is designated as an intermittent to perennial stream throughout its length. NT-3c arises at a headwater spring in a narrow ravine on the south flank of Pine Ridge and flows in a defined channel to the wetlands near the Haul Road. A few segments of the channel are incised 4–5 ft but the channel is typically no deeper than 1-2 ft.

The six wetlands delineated by Rosensteel (2015) in Figure E-55 represent areas where the water table is believed to intermittently or perennially intersect the ground surface. These areas are therefore target locations for the underdrain network to ensure the water table is lowered and maintained at a lower elevation below the Site 5 footprint. The largest of the wetland areas (Wetland D – 0.9 acre and Wetland C – 0.2 acre) partially encompasses the area of ponding on the north side of the Haul Road created in part by the damming effect of the restrictor plate noted above. Future removal of the restrictor plate would allow these areas to be better drained and might therefore reduce the extent of these artificially ponded wetlands.

2.17.2 Aquatic Life Stream Survey at Site 5

An aquatic life stream survey was conducted in May 2013 in NT-2 and NT-3 as part of the initial characterization of Site 5 (Schacher 2015a). The survey was not entirely comprehensive in nature or extent and supplemental surveys may be warranted if Site 5 is selected for EMDF construction. This survey used direct observation, and kicknet and rock and debris sampling to collect biologic samples. Samples were then examined under a microscope and identified using dichotomous keys and appropriate references.

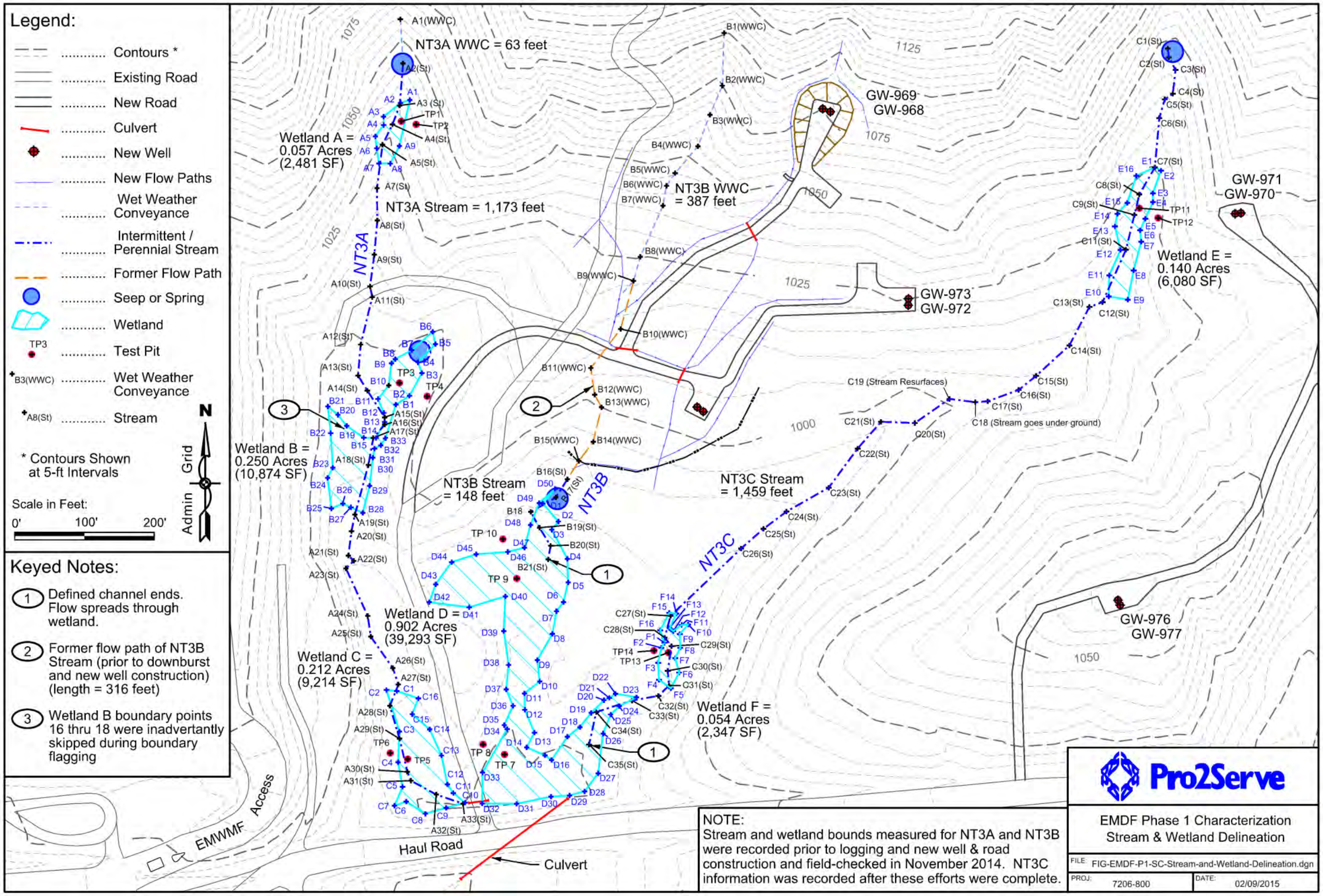

Figure E-55. Delineated wetland areas and stream determinations recently made by Rosensteel (2015) for the NT-3 headwaters at Site 5

The survey found the following Orders of aquatic taxa in NT-2 and NT-3:

- Aquatic taxa collected/identified from NT-2:
  - Ephemeroptera (mayflies; 1 family represented, Leptophlebiidae)
  - Plecoptera (stoneflies; 2 families represented)
  - Tricoptera (caddisflies; 2 families represented, Hydropsychidae, Philopotamidae) [Note: based on collection of unique caddisfly cases, 2-3 more families of this order inhabit this stream]
  - Coleoptera (riffle beetles, 1 family represented)
  - Odonata/Anisoptera (dragonflies, 2 families represented)
  - Diptera (true flies, 2 families represented)
  - Megaloptera (hellgrammites, 1 family represented)
  - Annelida (aquatic segmented worms)
  - Hydracarina (water mites)
  - Crustacea/Decapoda (crayfishes)
  - Vertebrata/Amphibia/Caudata (salamanders)

- Aquatic taxa collected/identified from NT-3:
  - Ephemeroptera (mayflies; two families represented: Ephemerellidae, Leptophlebiidae)
  - Plecoptera (stoneflies; one family represented: Nemouridae)
  - Tricoptera (caddisflies; three families represented: Hydropsychidae, Philopotamidae, Limnephilidae) (Note: based on collection of unique caddisfly cases, 2–3 more families of this order inhabit this stream.)
  - Coleoptera (riffle beetles, one family represented)
  - Odonata/Zygoptera (damselflies, one family represented)
  - Diptera (true flies, four families represented)
  - Megaloptera (hellgrammites, alderflies, two families represented)
  - Annelida (aquatic segmented worms)
  - Hydracarina (water mites)
  - Crustacea/lsopoda (sow bugs)
  - Crustacea/Decapoda (crayfishes)
  - Vertebrata/Amphibia/Caudata (salamanders)

The aquatic invertebrates identified in the survey are indicative of very good to excellent water and habitat quality for these two streams. Although crayfish and salamander larvae were found, no fish were collected, nor was any suitable habitat identified. The Tennessee dace was not found in either stream.

2.17.3 Results of Recent Terrestrial Surveys at Site 5

Surveys for terrestrial rare, T&E plants and animals and sensitive habitats were conducted by a qualified botanist on January 22, 2013, and May 7–9, 2013 (Collins 2015), prior to the May 2013 downburst (Schacher 2015b). Additional surveys were planned but not completed due to the extensive wind damage.

2.17.3.1 Terrestrial Flora/Vegetation Surveys

Three vegetative cover types were identified: bottomland hardwood forest, mixed hardwood forest, and upland hardwood forest. These cover associations are topographically controlled, and boundaries are gradational. Invasive plants were abundant along the roadside at the south side of the tract but were essentially absent elsewhere on the site.

Bottomland hardwood forest occurs along the creeks at the base of the ridge. This forest is dominated by red maple, yellow poplar, sweet gum, American hornbeam (*Carpus caroliniana*), black willow, and green ash (*Fraxinus pennsylvanica*). Understory shrubs include alder (*Alnus serrulata*) and hearts-a-busting (*Euonymus americanus*). The herb and vine layer is chiefly Christmas fern (*Polystichum acrostichoides*), crossvine (*Bignonia capreolata*), curly dock (*Rumex crispus*), cinnamon fern (*Osmunda cinnamomea*), pink weed (*Polygonum pensylvanicum*), and poison ivy (*Toxicodendron radicans*). Some areas appear to be wet for extended periods and other are only moderately moist.

Bottomland hardwood areas rapidly grade into the mixed hardwoods forest which occurs in drier soils on the lower slopes of Pine Ridge. The mixed hardwood forest is dominated by white oak (*Quercus alba*), black gum (*Nyssa sylvatica* var. *sylvatica*), sassafras (*Sassafras abidum*), hickory (*Carya glabra, C. tomentosa, C. pallida*), yellow poplar, red maple, black cherry (*Prunus serotina*), and persimmon (*Diospyros virginiana*).

The upland hardwood forest extends from the mixed hardwood forest to the top of the ridge. The lower slope is chiefly, oaks (*Quercus alba, Q. falcata, Q. prinus, Q. velutina*), persimmon, black gum (*Nyssa sylvatica*), sassafras (*Sassafras albidum*), hickories, sourwood (*Oxydendrum arboreum*), and chestnut oak (*Q. prinus*). As one goes from the lower slope to the upper slope, persimmon and white oak become less prominent and chestnut oak and various hickories, sassafras, and sourwood become dominant. The shrub layer is extremely sparse and open. The shrub layer is mostly hearts-a-busting in the in the lowest areas and grades to huckleberry (*Vaccinium* spp.) and farkleberry (*V. arboretum*) nearer the ridgeline. The herb layer is extremely sparse, consisting chiefly of Christmas fern, crossvine, sawbrier (*Smilax glauca*), and spotted wintergreen (*Chimaphila maculata*).

No habitats were observed on the proposed EMDF site that were deemed “excellent” or “highly suitable” for Federal-listed or State-listed plants. However, habitat was observed that was considered “marginal” or “somewhat suitable” for some of these rare plants. A checklist of 22 status plant species known to occur in either Anderson or Roane counties was used to guide field surveys. Of these, 11 were eliminated on the basis that no suitable habitats occurred on the EMDF site. The 11 remaining species, six are listed as Threatened in Tennessee, and have the potential to occur on the EMDF site. These are:

- Northern bush-honeysuckle (*Diervilla lonicera*)
- Mountain (or Southern) bush-honeysuckle (*D. sessifolia* var. *rivularis*)
- Hairy willow-herb (*Epilobium ciliatum*)
- Fen orchis (*Liparis loeselii*)
- Tuberculed rein orchid (*Platanthera flava* var. *herbiola*)
- White fringeless orchid (*P. integrilabia*)

The Northern bush-honeysuckle is common throughout much of North America, and is only listed in Tennessee. Mountain bush-honeysuckle is not listed outside of Tennessee.

Four of the remaining five species of interest are Tennessee-listed as being of special concern, and the fifth has been de-listed:

- Schreber’s aster (*Eurybia schreberi*)
- Mountain honeysuckle (*Lonicera dioica*)
- River bulrush (*Bolboschoenus fluviatalis*)
- Small-headed rush (*Juncus brachycephalus*)

As noted in Section 2.6.1, a severe wind event largely destroyed the forest throughout the central and southern portions of the EMDF site, and heavily damaged the remaining forest along the upper slopes of Pine Ridge. Much of the previous habitats and forest areas described above are gone or reduced in extent.

2.17.3.2 Terrestrial Fauna Surveys

Few surveys of terrestrial animals have been conducted at or near Site 5. Mitchell, et al. (1996) surveyed one wetland area (Site A-10) near the confluence of NT-5 with Bear Creek and a mixed hardwood-pine site along NT-1 (Site A-11, Y-12 meteorological tower), and did not document any T&E terrestrial vertebrate species. They observed four then-protected bird species at sites on Chestnut Ridge along South Tributary-2 and Walker Branch. The yellow bellied sapsucker (*Sphyrapicus varius*), listed in Tennessee as in need of management, was sighted at three stations. This species is migratory, breeding in Canada and the northern tier states. The cerulean warbler (*Setophaga cerulea*) was sighted at two sites. This bird is a migratory species deemed as in need of management in Tennessee, but is not federally-listed. A third species is the sharp-shinned hawk, seen at one site. This widespread raptor is not currently a state- or federal-listed species, but is listed as an in need of management species by the state. Finally, a Cooper's hawk (*Accipiter cooperii*) was sighted at one site. This species is not federal- or state-listed, and is not currently listed as being in need of management. Several migratory species, such as the Northern harrier; state-listed as in need of management, but not federally listed have been observed on the ORR, but should not pose a concern at Site 5 because the disturbed area is small relative to the available undeveloped areas.

An acoustic bat survey was conducted by ORNL Natural Resources Division personnel to determine species of bats present in the windthrow area near Site 5 prior to approving timber recovery (K. McCracken, pers. comm. 2014). Acoustic monitors were placed at the locations shown by green dots in Figure E-56. Six bat species were detected as shown in Table E-15. Of those only one, the Northern long-eared bat, is listed as threatened. The gray and Indiana bats that are listed as endangered were not detected.

2.17.4 Other Natural Resources

There are no known economically significant mineral resources in BCV at or near the proposed EMDF sites. The Maynardville Limestone provides a local source of aggregate for construction in the Oak Ridge/Knoxville area but supplies from local quarries are abundant and readily available.

2.18 CULTURAL RESOURCES

As summarized by Parr and Hughes (2006), cultural resources on the ORR include (1) surface and buried archaeological materials (artifacts) and sites dating to the prehistoric, historic, and ethnohistoric periods; (2) standing structures that are more than 50 years old or, if newer, are important because they represent a major historical theme or era; (3) cultural and natural places, selected natural resources, and objects with importance for Native Americans; and (4) American folklife traditions and arts.

The Cultural Resources Management Plan (CRMP - DOE 2001) for the DOE ORO provides the mechanism by which the DOE can comply with cultural resources statutes, address cultural resources in the early planning process of its undertakings, and implement necessary protective measures for its cultural resources prior to initiating undertakings. According to the CRMP, the principal cultural resources statutes that apply to DOE ORO undertakings include the Antiquities Act of 1906, the Historic Sites Act of 1935, the National Historic Preservation Act of 1966 as amended, the Archeological and Historic Preservation Act of 1974, the American Indian Religious Freedom Act of 1978, the Archaeological Resources Protection Act of 1979, and the Native American Graves Protection and Repatriation Act of 1990.

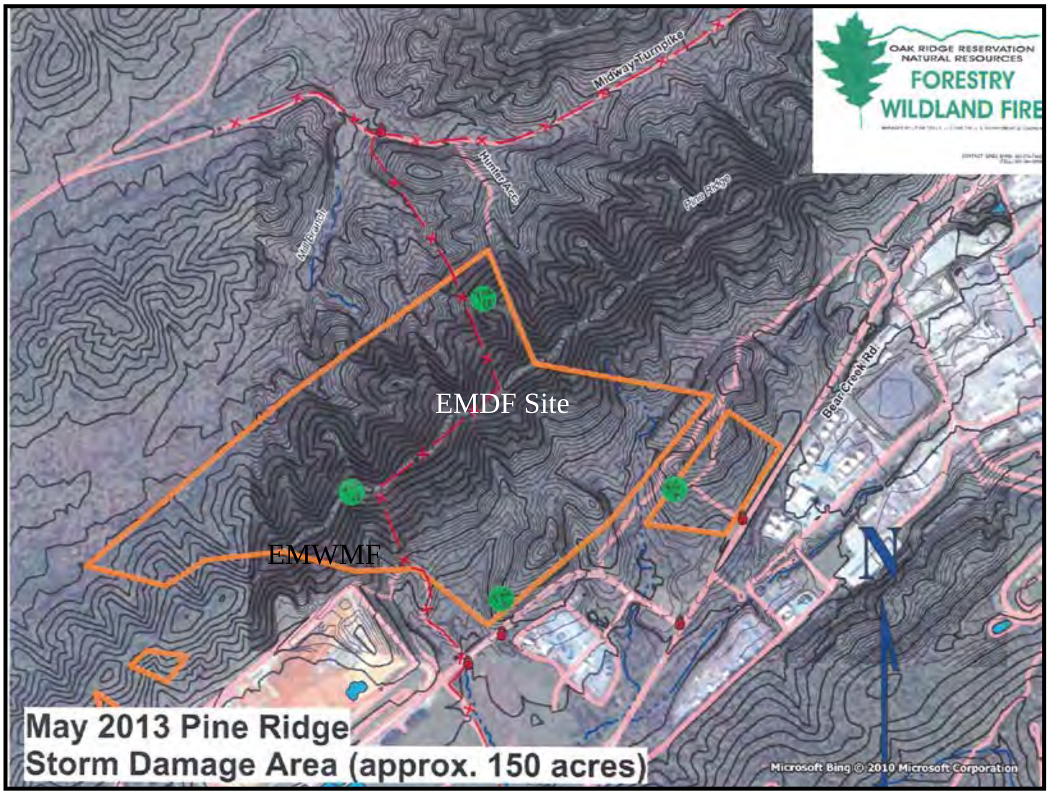

Figure E-56. Locations of acoustic stations used in the 2013 bat survey near EMDF Site 5

[Note: Orange outlines indicate approximate severe windthrow area]

Table E-15. Results of acoustic bat survey encompassing the Site 5 area

Common Name	Species	Acoustic Detection	Tennessee Status	Federal Status
Big brown bat	*Eptesicus fuscus*	X	Not listed	Not listed
Eastern red bat	*Lasiurus borealis*	X	Not listed	Not listed
Silver-haired bat	*Lasionycteris noctivagans*		Not listed	Not listed
Hoary bat	*Lasiurus cinereus*		Not listed	Not listed
Gray bat	*Myotis grisescens*		Endangered	Endangered
Eastern small-footed bat	*Myotis leibli*	X	Need of Management	–
Little brown bat	*Myotis lucifugus*	X	Not listed	Not listed
Northern long-eared bat	*Myotis septentrionalis*	X	Not listed	Threatened
Indiana bat	*Myotis sodalis*		Endangered	Endangered
Evening bat	*Nycticeius humeralis*		Not listed	Not listed
Tri-colored bat	*Perimyotis subflavus*	X	Not listed	Not listed

The following subsections review historical inventories and assessments of prehistoric and historic archaeological sites on the ORR that included BCV. Relationships of the sites identified in BCV are reviewed in relation to the proposed EMDF sites, including data gaps where additional surveys may be warranted.

2.18.1 Previous Reconnaissance-Level Surveys

The earliest assessments of archaeological and historical sites on the ORR were documented by Fielder (1974), and Fielder et al (1977), which included parts of BCV. Because of the enormous size of the ORR, the survey areas were limited in extent. The 1974 Fielder survey included a general survey of a broad area reproduced in Figure E-57, roughly 1000 ft by 4000 ft adjacent to Bear Creek in the area south of EMDF Sites 5 and 6b. No historic or prehistoric sites were reported in this area, but the scale of the drawing covering the entire ORR, and the absence of report details for this particular area suggest that the survey was limited in its nature and extent.

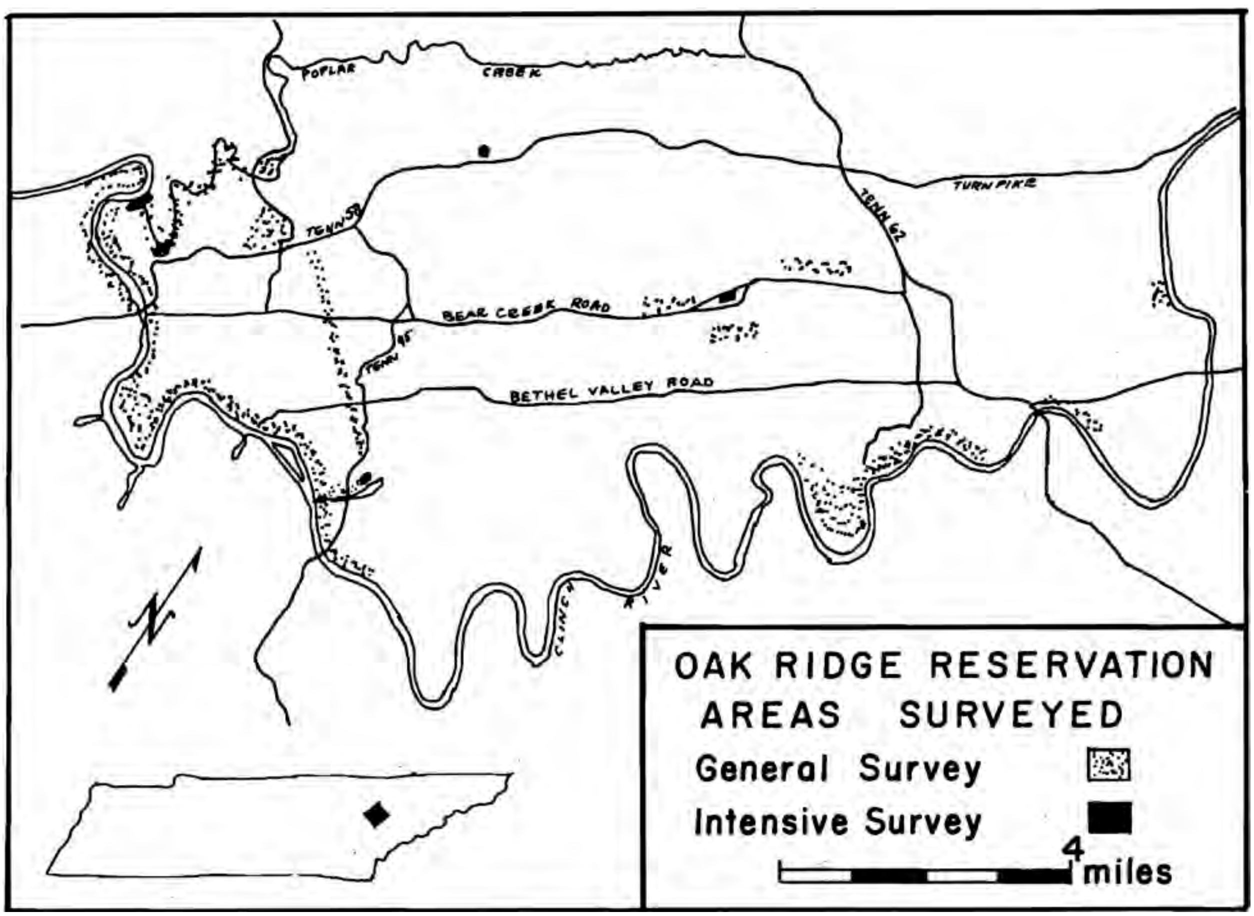

Figure E-57. General survey area for a prehistoric archaeological survey conducted in EBCV by Fielder (1974).

[**Note:** Most of BCV near the proposed EMDF sites was not surveyed; Figure 1 from Fielder 1974]

The 1977 survey by Fielder et al focused on historic structures and identified seven structures in BCV along and north of Bear Creek Road between Pine Ridge and Bear Creek. The structures are shown on Figure E-58 relative to the proposed EMDF sites [Note: locations were made according to latitude and longitude coordinates provided by DuVall and Souza (1996)]. The seven structures were all classified as "Condition 2 – Foundation Only". The report recommendations did not address any of these sites specifically other than to indicate that two of the selected sites (846A and 849A) contained structural materials that could be used in other historic restoration and reconstruction projects. The current condition of these structures is unknown.

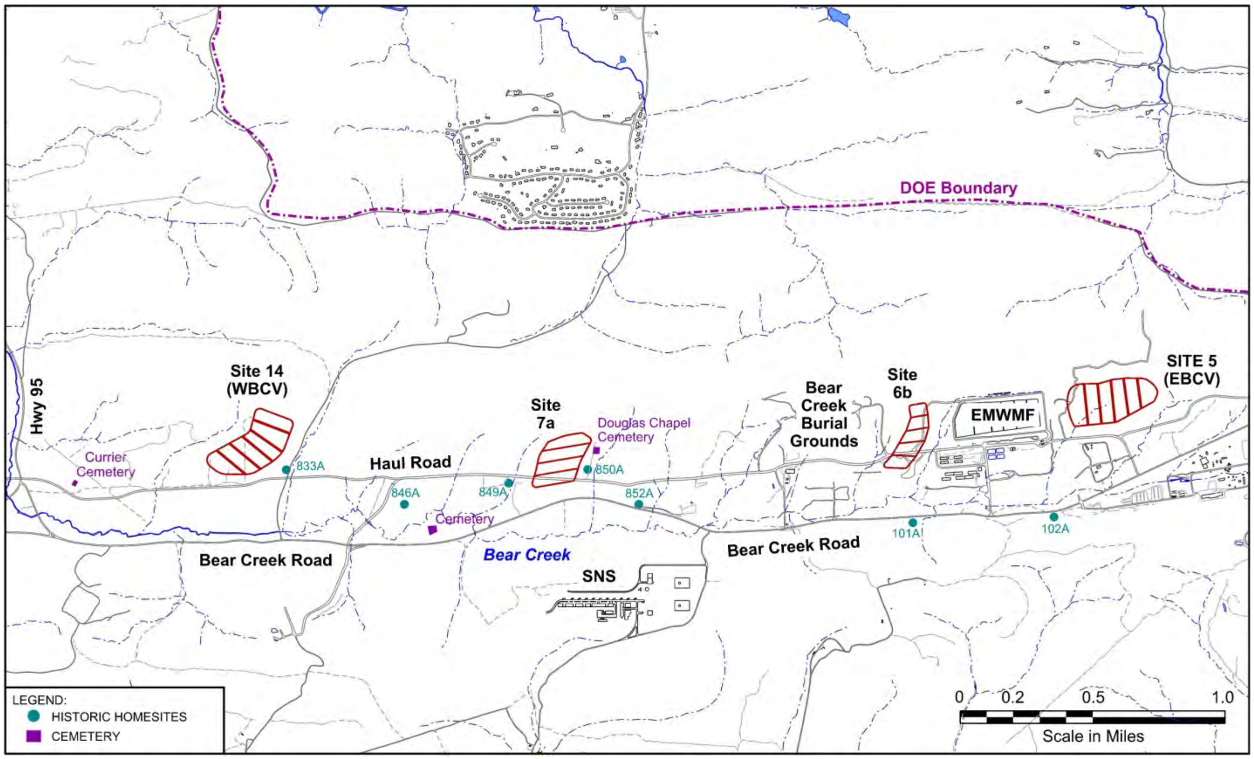

Figure E-58. Locations of historic home sites and cemeteries in relation to the proposed EMDF sites in BCV

[**Note:** cemetery locations from USGS 7.5 minute quadrangle; home site coordinates from Fielder 1977]

An archaeological evaluation of previously recorded and inventoried prehistoric and historic archaeological sites on the ORR was conducted in 1994 as reported by DuVall and Souza in 1996. The evaluation included the relocation and assessment of known or previously inventoried prehistoric and historic sites to determine eligibility of sites for inclusion in the National Register of Historic Places. It did not include any systematic field reconnaissance or shovel tests to identify new sites, and for BCV sites merely relied on the previous reports by Fielder (1974) and Fielder et al (1977). Of the seven pre World War II sites noted above, the report indicated three sites (846A, 850A, and 852A) could not be relocated and had apparently been eliminated by site activities since the 1970s. Foundation materials were still present at locations 833A and 849A in west and central BCV, and 101A/102A on the south side of Bear Creek Road in EBCV. The report simply reaffirmed the previous Fielder report findings of no prehistoric archaeological sites in BCV, but again no new field work was conducted to identify prehistoric sites beyond the very limited area surveyed by Fielder shown in Figure E-57.

The conditions at the former home site 833A would warrant further assessment if Site 14 is selected as the site of the EMDF. The DuVall and Souza (1996) report indicated that the 850A site near proposed EMDF Site 7a, could not be relocated. The location of this site could also be reassessed if Site 7a were selected for the EMDF. The remaining former home sites appear to be in locations unlikely to be impacted by EMDF site construction.

2.18.2 Previous Archaeological Surveys in EBCV at and near Sites 5 and 6b

A project specific archaeological survey (DuVall 1998) was conducted in support of the EMWMF in EBCV. The survey areas included Sites 5 and 6b in addition to the EMWMF. The reconnaissance by DuVall (1998) was conducted on May 11, 1998, to assess adverse impacts to cultural resources located within the boundaries of Federally-licensed, permitted, funded or assisted projects, in compliance with the National Historic Preservation Act of 1966 (Public Law 89-665; 16 USC 470; 80 Stat. 915), National Environmental Policy Act of 1969 (Public Law 91-190; 91 Stat. 852; 42 USC 4321-4347) and Executive Order 11593 (May 13, 1971).

DuVall (1998) conducted a Phase I reconnaissance survey for areas that were being considered for the EMWMF. The survey was designed to fill in coverage gaps from an earlier survey by Bentz 1992 (as referenced in DuVall 1998). As shown in Figure E-59, the combined archaeological survey areas cover nearly all of the entire proposed EMDF Site 5 and Site 6b footprints. The previous archaeological survey by Bentz (1992) was conducted to address potential construction impacts from the ORR storage facility sites A, B, and C that were proposed in the early 1990s but never constructed (See areas A, B, and C on Figure E-59). DuVall noted that "*Bentz (1992) excavated a total of 257 shovel tests. Two flakes were recovered from two shovel tests in the Site C area. The survey was considered negative for archaeological sites due to the highly deflated nature of the area.*" The DuVall report stated that the 34 screened shovel tests from the 1998 survey were also negative with no evidence of archaeological materials.

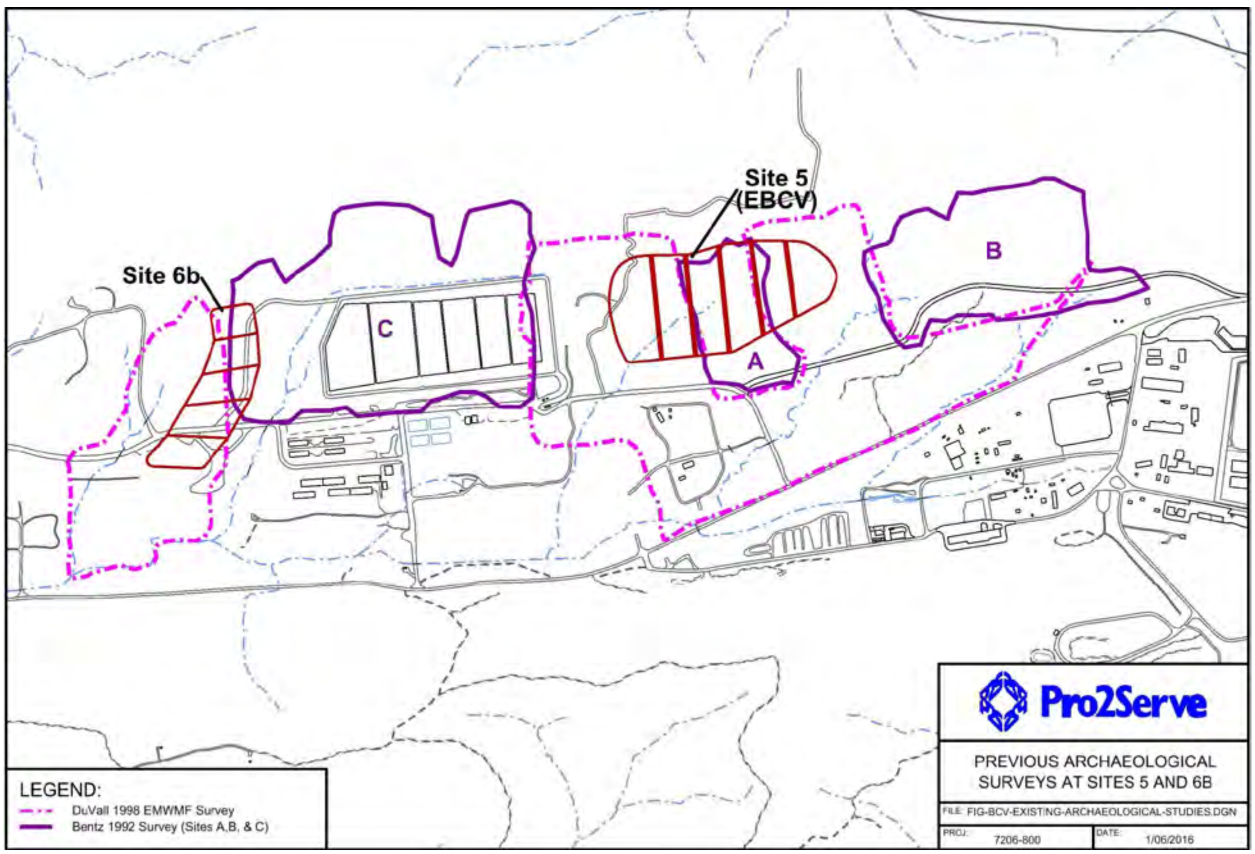

Figure E-59. Archaeological survey areas previously conducted at and near proposed EMDF Sites 5 and 6b

The report concluded that "*Based upon the reconnaissance, a search of the site files at the Tennessee Division of Archaeology and a search of the National Register of Historic Places, the proposed construction on the site will have "no effect" on any property included in or eligible for inclusion in the National Register of Historic Places pursuant to 36CFR60.4. The pedestrian reconnaissance with shovel tests failed to identify any archaeological materials. The area is of extremely low probability due to the steep side slopes, constricted drainways and deflated ridgetops.*"

The DuVall report also noted that contractors should be made aware of the present Tennessee burial law which protects both marked and unmarked, historic and prehistoric interments. In the event that human skeletal material is unearthed during construction activities, construction in the vicinity should cease and the Tennessee Division of Archaeology notified immediately.

2.18.3 Other Cultural Resources and Future Needs

Parr and Hughes (2006) identified three cemeteries and historic homesites within BCV as shown in Figure E-60. Figure E-58 illustrates the locations of these cemeteries (and previously noted historic homesites) with respect to the proposed EMDF sites.

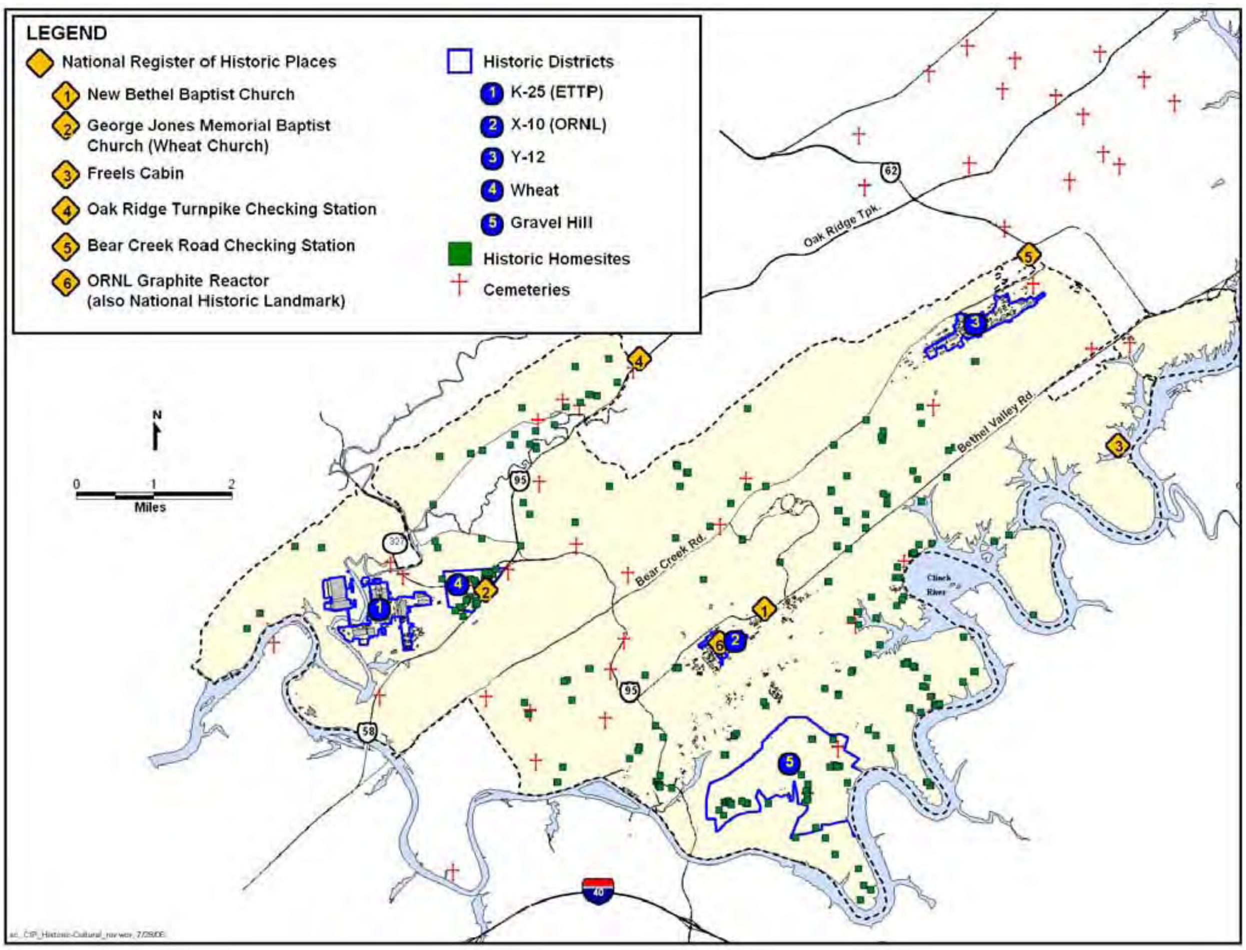

Figure E-60. Historic homesites and cemeteries in BCV identified by Parr and Hughes (1996)
[From Parr & Hughes 2006, Figure 10]

Of the three cemeteries, only the Douglas Chapel Cemetery is located in close proximity to the footprint of proposed Site 7a. The remaining cemeteries appear to be distant enough from the proposed sites to avoid any potential impacts associated with the landfill or possible support facilities/structures that would be required in proximity to the footprints. If Site 7a is selected as an EMDF footprint, the preliminary design might have to be modified to accommodate the Douglas Chapel Cemetery. Alternatively, the adjacent Site 7b (identified but culled in Appendix D) might be considered as a replacement for the Site 7a footprint. Site 7a was selected in part over Site 7b based on the apparent location of two USGS identified seeps within the Site 7b footprint, and the apparent absence of any USGS identified springs or seeps within the Site 7a footprint. No field reconnaissance has been conducted at Site 7a (or 7b) to verify the location or current conditions of the Douglas Chapel Cemetery, springs and seeps, or historic home sites.

The previous archaeological surveys of prehistoric and historic sites at and near Sites 5 and 6b suggest that additional surveys may not be warranted if either of these sites are selected for the EMDF. However, the absence of project-specific archaeological surveys for Sites 14 and 7a suggest that surveys will be required at these sites if either is chosen for the EMDF. As previously noted, detailed surveys are required early in the planning process and prior to any construction in order to satisfy applicable regulations and statutes, and DOE requirements.

3. SITE 5 – EAST BEAR CREEK VALLEY

Sections 3 through 6 address the detailed characteristics for the proposed EMDF sites sequentially from Site 5 in EBCV to Site 14 in WBCV. Because the proposed EMDF sites are all located roughly along geologic strike with one another and in areas of generally similar topography, the results from site investigations at and adjacent to the proposed sites can be used to some degree to infer general conditions that are possible at each of the EMDF sites. Among the proposed sites, the WBCV area at and near the Site 14 footprint has received the most site characterization. Although Site 5 has had little site-specific characterization other than the limited Phase I investigation completed in 2014/2015, much characterization has been done at sites directly east and west of Site 5. Characterization at Sites 6b and 7a has been quite limited such that little data were available for use in preparing the conceptual design for these sites.

As demonstrated in subsequent sections and in Attachments A and B, Site 5 has received more scrutiny in the last 2-3 years because of several favorable characteristics and its location within the industrialized Zone 3 segment of EBCV. It was decided that Site 5 might warrant preliminary investigations to provide data to determine its viability among candidate disposal sites under consideration by DOE. DOE therefore proceeded with preliminary plans and investigations at Site 5 that are reported as part of the current RI/FS in Attachments A and B to Appendix E. Similar recent preliminary investigations have not been completed at Sites 6b, 7a, and Site 14, resulting in obvious disparities in characterization data currently available among the proposed EMDF sites presented below. Additional site characterization will be completed by DOE if the on-site alternative is approved and based on the final selection of an EMDF site(s). The site conceptual models for BCV and Site 5 are presented above in Section 2.8, along with other general aspects of BCV presented in Section 2.0. Those sections may be referenced to supplement materials presented below and to provide important background information relevant to Site 5.

3.1 LOCATION AND GENERAL SITE CONDITIONS

Site 5 is located in EBCV adjacent to and east of the existing EMWMF within Land Use Zone 3, the restricted Brownfield area designated as DOE controlled industrial use (Figure E-61). In addition to the currently operating EMWMF, Zone 3 includes historical waste disposal/management areas such as the S-3 ponds, BCBG, BYBY, etc. The Site 5 footprint is located upslope and hydraulically upgradient of the historical waste sites and thus avoids any current overlap with existing ground water contaminant plumes in BCV (See Figure E-2). Site 5 is situated between the lower elevation south-facing slopes of Pine Ridge

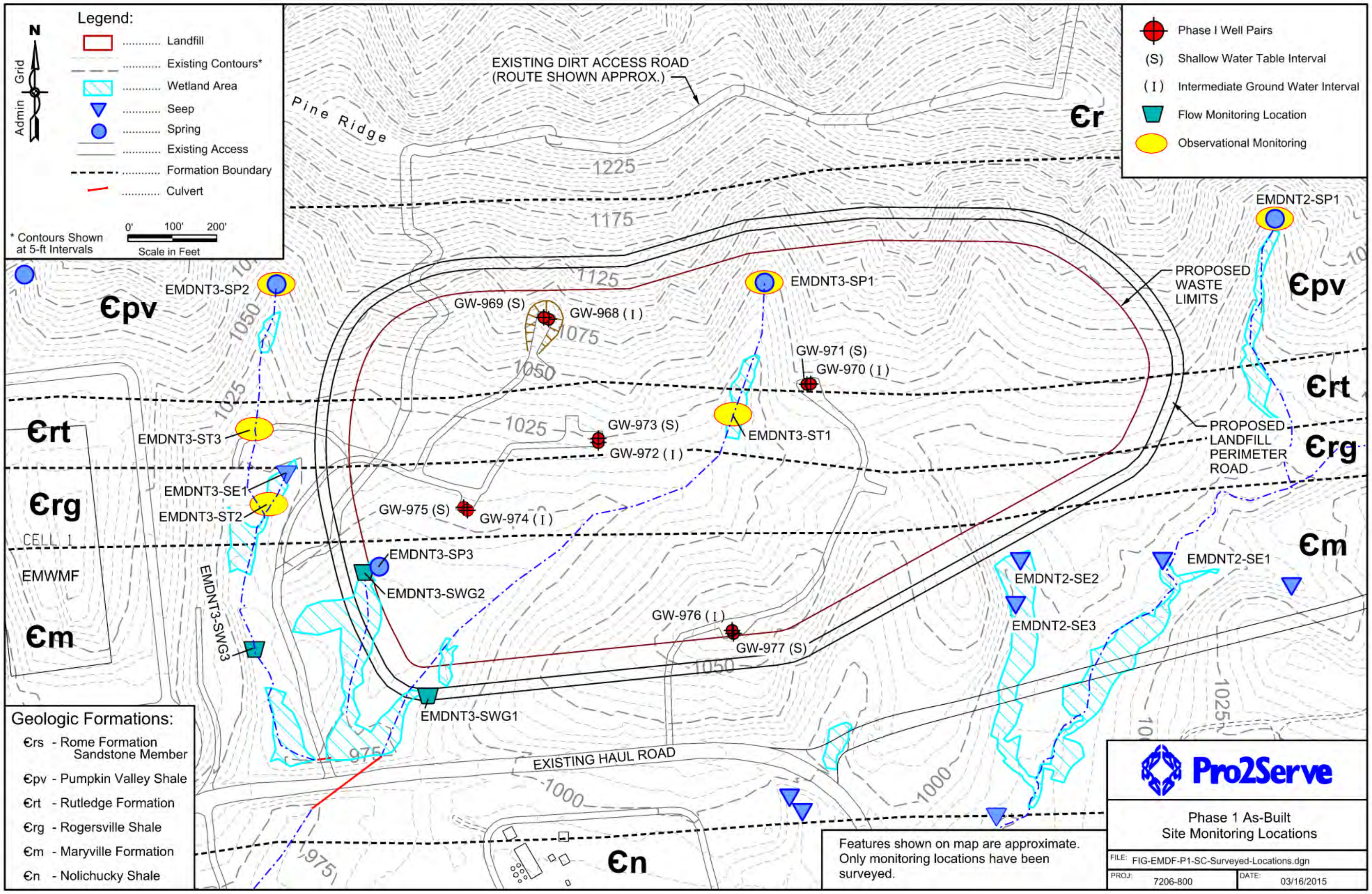

Figure E-61. Site 5 footprint illustrating key features of Site 5 and Phase I investigation locations

and the subsidiary “spur” ridge underlain by the Dismal Gap/Maryville formation. Conceptual design drawings indicate the overall Site 5 footprint would occupy approximately 70 acres; the waste footprint would occupy approximately 30 acres within the broader footprint.

The site is situated on undeveloped land within the headwaters of NT-2 and NT-3 tributaries, with the Haul Road marking the approximate south boundary, and a northern boundary along the middle to lower flanks of Pine Ridge. The site is approximately 1,100 ft north of Bear Creek at the nearest point. The current position of the Y-12 security boundary “blue line” is roughly coincident with the west edge of the footprint (see engineering design figures in Chapter 6 of this RI/FS).

Among the candidate sites, Site 5 is situated closer to Pine Ridge and farther from Bear Creek (See Figures E-7 and E-9). Site 5 is adjacent to the operational area of Y-12, and will remain under DOE control and within DOE ORR boundaries for the foreseeable future. No change in the current BCV ROD land use designations would be required if the EMDF is constructed at this site.

Figure E-9 (Section 2.7) and E-61 illustrate the site topography, stream channels, and surface water drainage paths at Site 5 and adjacent areas. The current geomorphic surface is relatively stable and there is no evidence of recent mass movement in the area. The bedrock at Site 5 and within BCV as a whole dips toward the southeast at an average dip angle of around 45 degrees, at an angle generally much steeper than the gentler south facing slopes of the ground surface. Surface slopes on the south flank of Pine Ridge are concave. Upper slopes feature sharp interfluves separated by deep, steep-sided ravines and first order stream valleys that coalesce and open on to lower slopes with broader valleys.

Vertical topographic relief near Site 5 spans 275 ft from the highest elevations along Pine Ridge at ~1250 ft to the lowest elevations at ~975 ft near the southwest corner of the site. Pine Ridge has a relatively steep north-facing scarp slope, and a more concave less steep south facing slope. Along its north side, the footprint is located against the lower south flank of Pine Ridge underlain by the Pumpkin Valley Shale. The central portions of Site 5 are located within the strike valley between Pine Ridge and the spur ridge to the south. The central portion of Site 5 is underlain by the less resistant beds of the Pumpkin Valley Shale, Friendship/Rutledge formation, and Rogersville Shale. The conceptual design layout is situated so that the spur ridge would form a natural bedrock buttress along the south side of the footprint, underlain by the lower Dismal Gap/Maryville formation. The close proximity of Site 5 to the crest of Pine Ridge limits the watershed area available for surface runoff and ground water recharge to a very narrow swath upslope of the footprint. This greatly limits the potential for flooding or mass movement in areas upslope of the site.

No signs of landslides or mass wasting have been observed at Site 5. Three steeply incised ravines occur at Site 5, each with headwater springs: one near the north center of the footprint, the other two in the headwater sections of the valleys along the east and west sides of the footprint (Figure E-61). There are no indications of sinkholes, sinking streams, or resurgent springs indicative of typical karst features at or close to Site 5. As noted elsewhere, karst features are well documented over 1000 ft south of Site 5 along the outcrop belt of the Maynardville Limestone over which Bear Creek flows

3.2 HISTORICAL ASSESSMENT OF SITE 5

Review of available historical topographical maps and site reconnaissance suggest little indications of anthropogenic alterations and no indications of waste disposal activities at Site 5. There are no current operations at the site. Review of the USGS 7.5-minute quadrangle maps for the Bethel Valley Quadrangle for 1935, 1941, 1953, 1968, 1989, and 1998 (progression is shown in Figure E-62) indicate that much of the site has been wooded throughout the period. The 1935 map shows a rectilinear clearing that extended up the flank of Pine Ridge near NT-3, then turning northwest parallel to the ridge crest until it joined with a large cleared area east of NT-2. Two presumably residential or farm structures are south of the site near Bear Creek with one to the northeast. Other than driveways from Bear Creek Road to the structures, no roads or trails are shown for the area. By 1941, much of the former rectilinear cleared area had become forested, with a slight expansion of cleared areas around NT-2. The core wooded area at the site apparently remained wooded from the pre-war period from 1935-1941.

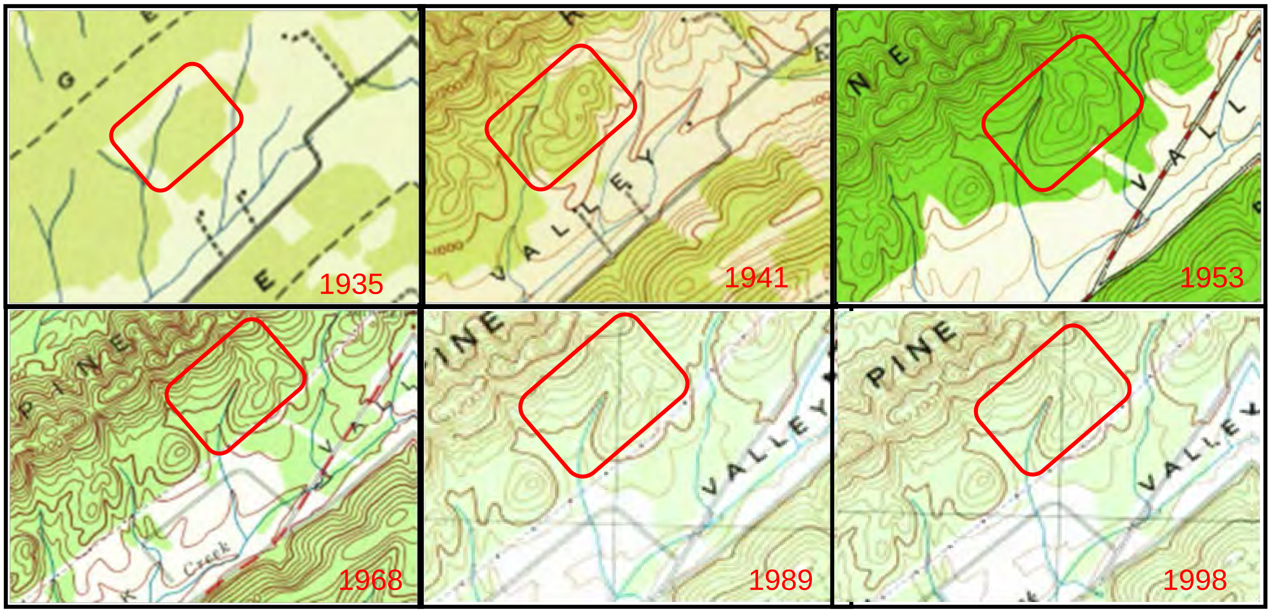

Figure E-62. Historical sequence of USGS 7.5 minute topographical maps of the Site 5 area

[Red rectangle shows approximate location of the proposed EMDF Site 5.]

By 1953, after government acquisition the entire footprint area was entirely reforested, as was much of the former open area along and east of NT-2. The flatter areas nearer to Bear Creek remained open, and the structures were no longer evident. The forested and reforested areas have remained essentially constant since 1968, except for the power line near the south edge of the site. Based on this review, it appears that most of the candidate site remained forested from 1941 to 1998. The map reviews suggest that over the pre and post war periods no industrial activities have occurred at the site beyond the installation and maintenance of the power line.

3.3 RECENT CHANGES IN SITE CONDITIONS AT SITE 5

Since 2013, the natural conditions at Site 5 have been altered by wind damage, timber recovery, road construction for Phase I drilling, and UPF road construction and wetland mitigation.

3.3.1 May 2013 Wind Damage, Logging, and Phase I Road Construction

Site 5 was mostly forested until a severe wind storm on May 19, 2013, toppled trees across much of the site. Subsequent logging activities and Phase I road construction have cleared much of the site of tree cover and rearranged previous natural drainage pathways for portions of the NT-3 sub tributaries at the site. Wind speeds of greater than 85 miles per hour, as estimated by the National Weather Service (Mori, pers. comm., June 5, 2013), were directed down both flanks of Pine Ridge causing extensive wind throw. Figure E-63 shows the approximate outlines of the damaged areas (Byrd, pers. comm. 2013). Approximately 75% of the Site 5 area in the NT-3 and NT-2 watersheds was severely impacted by this event, and the remaining forest along the upper slopes of Pine Ridge was heavily damaged. Numerous trees fell or were snapped off, but destruction was particularly heavy and widespread along the primary east branch of NT-3 in the footprint and in portions of the lower valley of NT-2. The forest in much of the lower part of the NT-3 basin within the footprint was essentially obliterated, although pockets of forest within the upper slopes and eastern areas of the footprint remained relatively undisturbed. According to the National Oceanic and Atmospheric Administration Enhanced F-Scale Damage Indicators (NOAA 2013), uprooted or snapped hardwood trees indicate wind speeds between 91 and 134 miles per hour. The Y-12 West Tower meteorology station recorded a wind speed of 75 miles per hour during the storm. The Y-12 West Tower is roughly 0.5 mile from the EMDF site, outside the damaged area.

Figure E-63. Area of severe wind impacts due to the May 19, 2013 downburst

[Map courtesy Greg Byrd, ORNL Natural Resources Division]

During the Spring and Summer of 2014, DOE coordinated timber recovery operations over the damaged area which removed the majority of saleable timber in the damaged area. Subsequently, additional clearing and access road construction was completed to support drilling for the Phase I site characterization efforts at Site 5. Figure E-64 is an aerial photograph of the site taken in September 2014 showing the impacts to Site 5 from salvage logging and road construction.

3.3.2 Impacts from UPF Haul Road Construction

Additional changes along the southeast margins of the Site 5 footprint occurred in late Summer/Fall 2014 from construction of a new haul road for the UPF to be constructed in the main Y-12 complex area well east of Site 5. Road and wetland mitigation construction has resulted in the reconfiguration of the natural valleys, seep/spring areas, and stream channels along the southeast margin of Site 5 that receive ground

Figure E-64. September 2014 aerial view to the southwest of proposed EMDF Site 5 (EBCV) after blowdown salvage logging and site road construction

[Phase I surface and ground water monitoring locations and approximate waste limit outline shown in red]

water seepage draining southward from Pine Ridge within the saturated zone of the subsurface in the areas below cells 4, 5, and 6 of the Site 5 footprint. The areas impacted by the UPF construction coincide with portions of the underdrain system and underdrain outfall locations proposed in the EMDF conceptual design for Site 5. These low elevation areas represent zones of natural ground water convergence and discharge along the southeast margin of Site 5.

Two former natural wetlands along NT-2 tributaries were destroyed and partially reconstructed as new wetlands as compensatory mitigation for wetland areas impacted by UPF haul road construction. Figure E-65 shows the general reconfiguration of these drainage areas and the pre-construction locations of seeps/springs identified by the USGS in 1994. Details of the original natural surface water features (seeps, springs, stream channels) in these areas are described below in relation to surface water hydrology at Site 5 based on more recent field reconnaissance and preliminary mapping. Figures E-66 and E-67 show pre and post construction photographs of the larger of the two wetland areas reworked during the UPF road construction (identified in the center of Figure E-65 in the vicinity of EMDNT2-SE2 and-SE3). The conceptual design for this area includes two trench drains and a relatively large blanket drain as part of the underdrain network below Cells 5 and 6. A smaller underdrain trench and blanket drain network is proposed for the smaller tributary just southwest of this larger one (See Section 6 of the RI/FS Report for details).

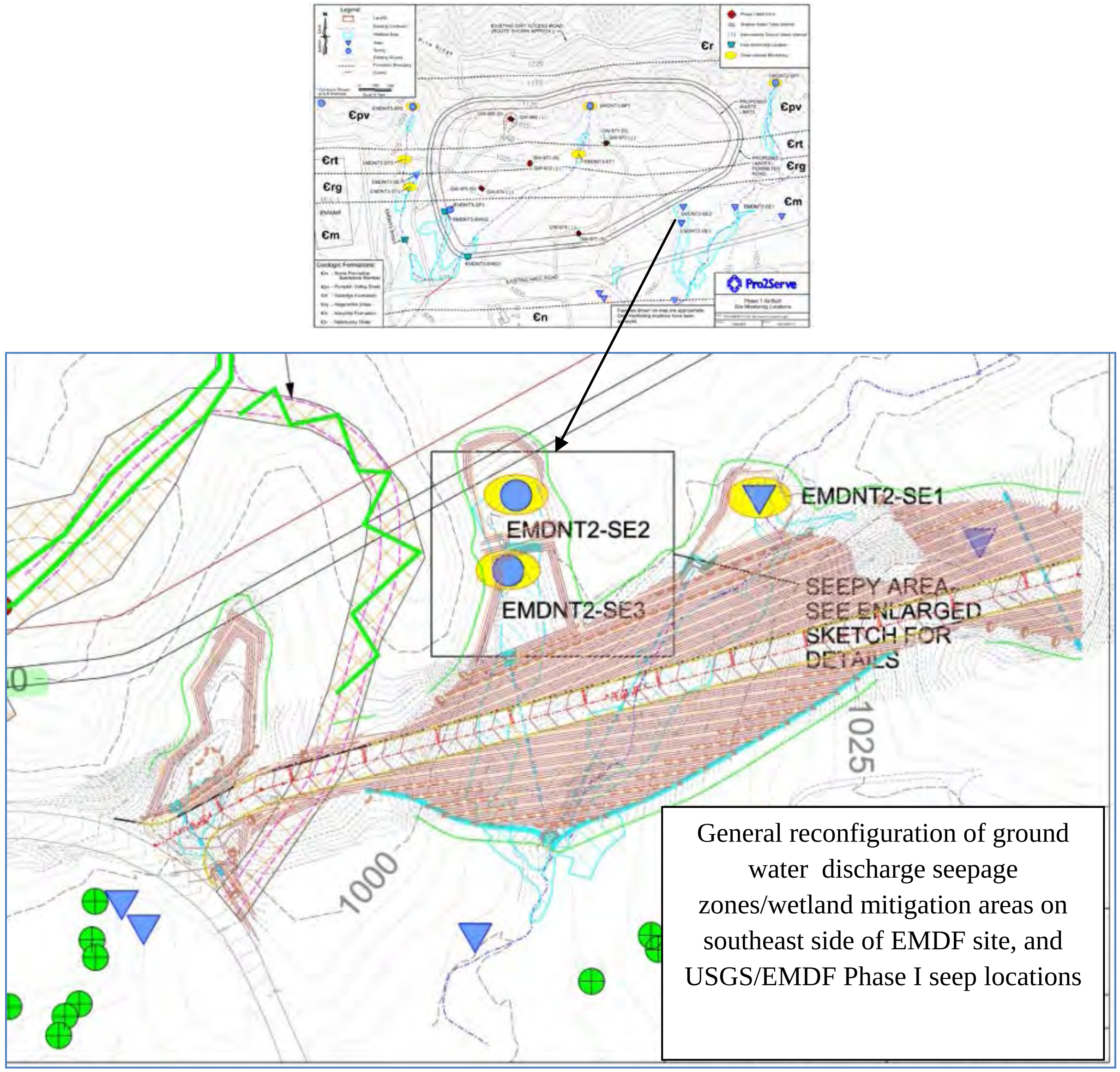

Figure E-65. Ground water discharge zones along the southeast side of Site 5 reworked by 2014 UPF Haul Road Construction

[NOTE: This drawing shows approximate areas and configuration of UPF road contours and reconfigured seep areas. The drawing does not represent as built conditions.]

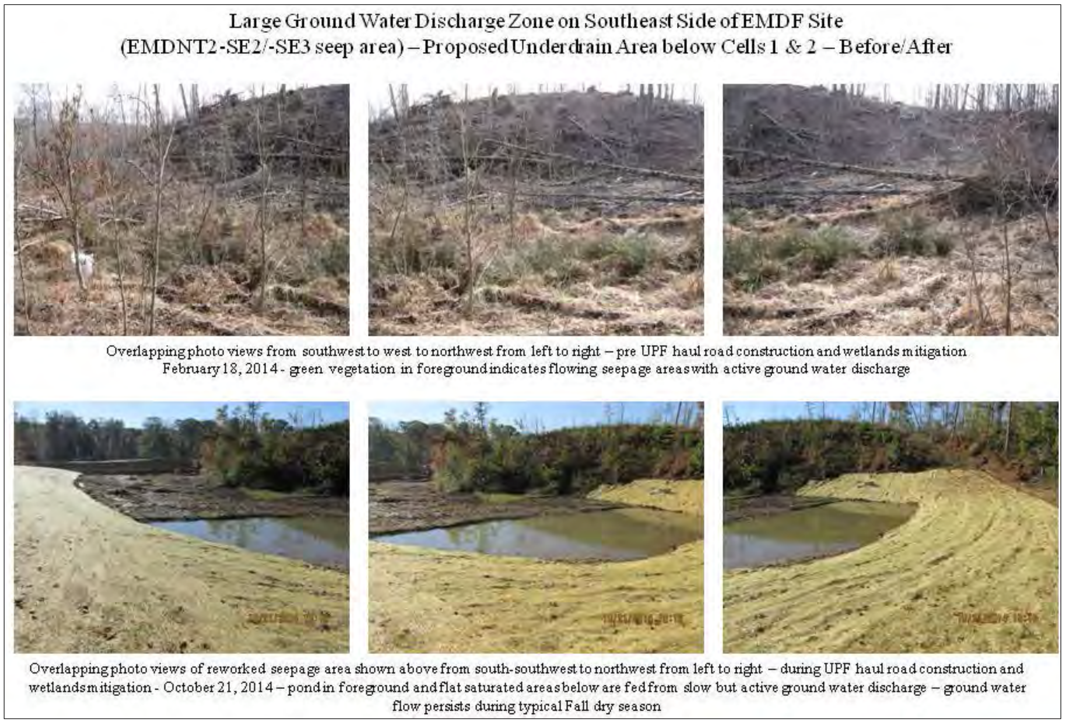

Figure E-66. Natural wetlands and constructed wetlands area on southeast side of Site 5 before and after UPF haul road construction.

Figure E-67. Early UPF wetlands construction of seep/ground water discharge area at southeast side of Site 5

3.4 PREVIOUS INVESTIGATIONS AT AND NEAR SITE 5

Previous investigations at and adjacent to Site 5 provide a substantial amount of characterization data relevant to the planning and design of the EMDF if located at Site 5. The general types of data include surface water hydrology, subsurface hydrogeology, and engineering design data. Much of the adjacent site data is along geologic strike with Site 5 where site conditions are very similar. One of the first steps in the Data Quality Objectives (DQOs) process applied to projects administered under CERCLA includes a careful review of available information. The following subsections summarize the available data sources and cite references for complete details useful for project planning and design. Figure E-68 shows the surface locations from previous investigations including borings, monitoring wells, piezometers, test pits, and surface water monitoring stations. The figure includes the recent 2014/2015 Phase I investigation locations at Site 5 along with previous investigation locations in surrounding areas. This figure provides an index to key locations referenced below. Project participants are encouraged to review and incorporate results from these previous investigations into project planning and design if Site 5 is chosen for the EMDF. More detailed summaries of previous investigations at and near Site 5 are provided in Attachment A.

Previous surface water investigations at and near the EMDF include:

- A USGS inventory and wet/dry season measurements of springs, seeps, and stream flows including NT-2/NT-3 tributaries crossing and adjacent to Site 5 (Robinson and Johnson, 1995, and Robinson and Mitchell 1996);
- EMWMF pre-design NT tributary stream flow measurements, including one NT-3 location near the center of the Site 5 footprint (BJC 1999); and
- An EMDF Phase I limited site investigation for Site 5 that included instrumentation and one year of continuous monitoring of stream flow rates and water quality parameters at nine surface water locations (see Attachments A and B).

Previous subsurface investigations (geotechnical and hydrogeological) at and near Site 5 include:

- Geotechnical engineering investigations of Sites B and C, east and west (respectively) of the EMDF footprint (Ogden 1993a and b);
- Pre-construction test pits with geotechnical sampling and analysis of regolith soils/weathered bedrock at the EMWMF (CH2M Hill 2000; WMFS 2000);
- Monitoring well drilling and installation at the EMWMF (BJC 1999) and water level monitoring by EMWMF operations staff (unpublished UCOR data 2014);
- Monitoring well construction and monitoring data at other sites in east BCV peripheral to the EMDF site (B&W Y-12 2013); and
- An EMDF Phase I limited site investigation for Site 5 that included the drilling, logging, and testing of five well pairs (shallow/intermediate depth) with instrumentation and one year of continuous monitoring of water level fluctuations and basic water quality parameters (see Attachments A and B).

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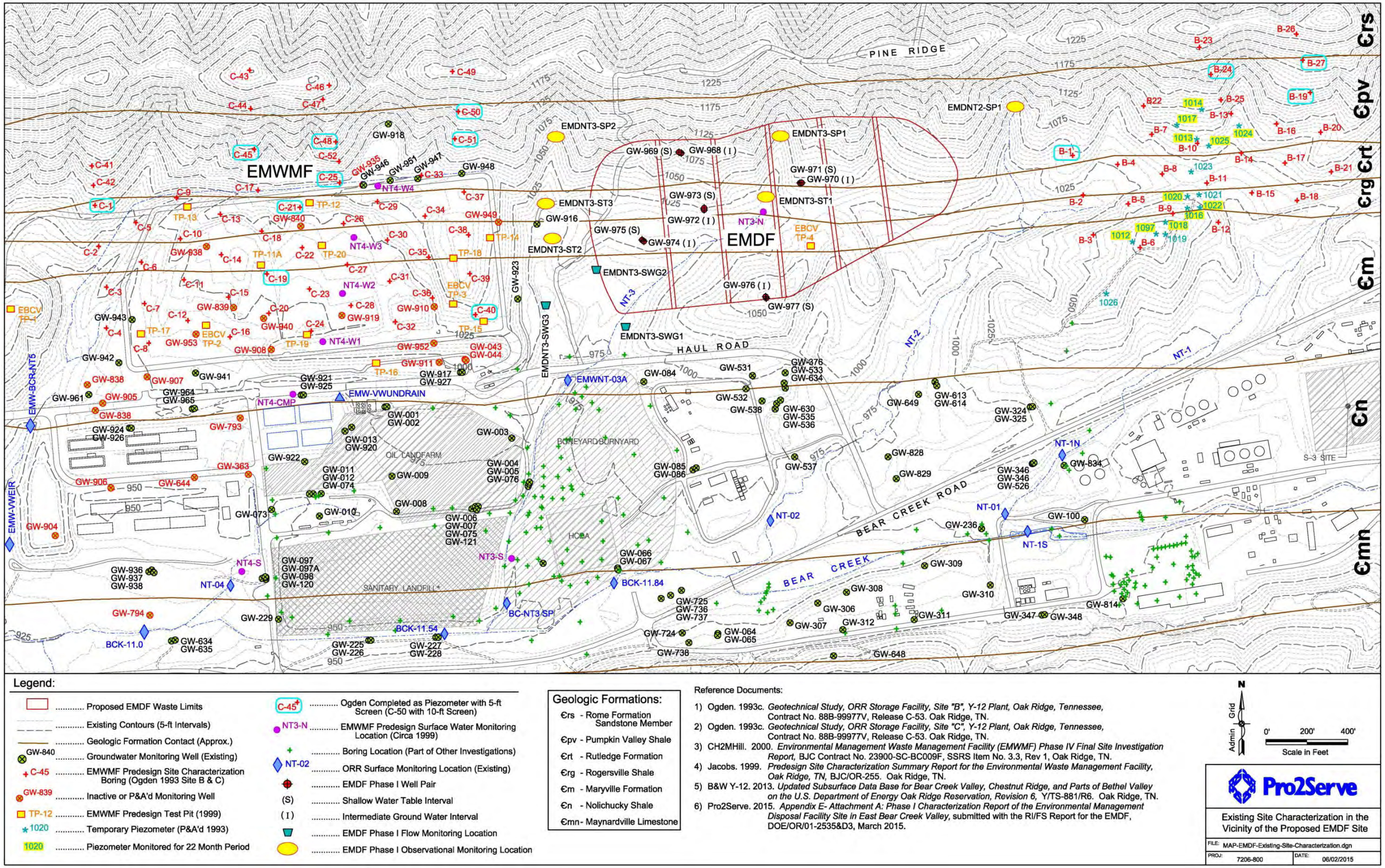

Figure E-68. Locations from previous investigations in Bear Creek Valley at and near the proposed EMDF Site 5

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3.4.1 Surface Water Investigations

The USGS completed an inventory and single event measurements of wet and dry season base flow at spring, seep, and stream locations across the entire length of BCV in the mid 1990's that included the NT-2 and NT-3 tributaries crossing Site 5 (Robinson and Johnson, 1995, and Robinson and Mitchell 1996). Results are presented below under the descriptions of surface water hydrology at Site 5. More accurate and nearly continuous stream flow monitoring was completed in support of the EMWMF along upper portions of the NT-3, NT-4, and NT-5 tributaries during the late 1990's (BJC 1999). More recently, a limited Phase I investigation was conducted at Site 5 that included measurements of stream flow and basic water quality parameters at three flume locations in the upper NT-3 watershed, and weekly point measurement monitoring at three headwater springs and three stream channel locations at locations intermediate between the spring and flume locations. The Phase I monitoring was conducted for a one year period from around December 1, 2014, through November 2015. Several site reconnaissance events were also conducted by Pro2Serve prior to the Site 5 Phase I investigation to observe, document, and photograph springs, seeps, and stream flow at and near the Site 5 footprint. The Phase I results are presented in their entirety in Attachments A and B.

3.4.2 Subsurface Investigations

Subsurface investigations were completed by Ogden in 1992/1993 at sites on either side of and along geologic strike with Site 5 (Ogden 1993a and b). The Ogden geotechnical investigations were intended to support the design of above ground waste storage facilities that were subsequently never constructed by the DOE. They included 27 borings at Site B, adjacent to Site 5 on the northeast, and 52 soil borings at Site C, now occupied by the EMWMF directly southwest of Site 5 (see locations on Figure E-68). The geotechnical and hydrogeological data from these investigations is extensive and particularly relevant to Site 5 because of the close similarity of surface and subsurface site conditions among the sites. Pre-construction test pits and monitoring well drilling and installation were conducted at the EMWMF (circa late 1990s/early 2000s) directly adjacent to and along strike with Site 5 (BJC 1999, CH2M Hill 2000, WMFS 2000). In addition, subsurface investigation results are available from monitoring well drilling just south of the Haul Road below Site 5, and for portions of the BCBG further to the southwest and along strike to the EMDF (BNI 1984). Results of multiple investigations at waste sites and ground water contaminant plumes in BCV were synthesized in the multi-volume BCV RI report (DOE 1997). More recent published ground water contaminant plume maps clearly show that the EMWMF and Site 5 are located in uncontaminated areas hydraulically upgradient from the nearest hazardous waste source areas and contaminant plumes in BCV (UCOR 2013a; Elvado 2013).

The most recent Phase I subsurface investigation at Site 5 included the drilling and installation of five shallow/intermediate depth well clusters within the proposed footprint. The Phase I investigation included regolith sampling with limited geotechnical sampling and analysis and slug testing at the shallow well locations. Borehole geophysical logging, packer tests, and rock coring (at two locations) were conducted at the deeper bedrock well locations. Instrumentation and hourly monitoring of ground water levels and basic water quality parameters was conducted for a one year period from December 2014 through November 2015.

As described in Section 3.0, extensive surface and subsurface investigations completed in WBCV at and near the proposed EMDF Site 14 provide additional information that is relevant to Site 5 as surface and subsurface conditions at the two sites are similar. The collective results from neighboring sites in BCV provide a valuable and unique source of detailed information that is important for properly planning future investigations at Site 5, for interpreting investigation data, and for the detailed design of the proposed disposal facility.

3.4.3 Limited Phase I Site Characterization

A limited Phase I field investigation and one year monitoring program was conducted at Site 5 in 2014-2015. The Phase I scope of work included (See locations on Figures E-61 and E-68):

- Installation of five shallow/intermediate level monitoring well pairs (ten wells) with hourly monitoring of water levels and basic water quality parameters from December 2014 through November 2015.
- Cutthroat flume installations at three locations along upper NT-3 sub tributaries with monitoring of stream flow rates and basic water quality parameters at 20 minute intervals from December 2014 through November 2015
- Single weekly monitoring events at three headwater spring and three intermediate stream channel locations to document estimated flow rates and basic water quality parameters
- Borehole descriptive logging of regolith and bedrock materials, rock coring at two well locations, and testing including packer tests in selected open hole bedrock intervals in the intermediate level wells, and slug tests in the shallow wells
- Geotechnical sampling and laboratory analysis from relatively shallow subsurface soil samples
- Standard borehole geophysical logging in the five deep borings including selected intervals with heat pulse flowmeter testing

Complete results of the Phase I investigation with interpretations and conclusions and including detailed descriptions of field methods and equipment, etc., are provided in Attachments A and B. Attachment A includes an interim report previously submitted with the D3 version of the RI/FS Report submitted in March 2015. Attachment B provides a final addendum presenting the complete results for the full year of surface and ground water monitoring completed in November 2015.

3.5 SITE 5 SURFACE WATER HYDROLOGY

The following subsections review the general characteristics of surface water hydrology at Site 5, and results of previous investigations of surface water conditions at and near Site 5. Previous investigations and reports pertinent to Site 5 include: 1) USGS base flow studies of NT-2/NT-3, 2) pre-design investigations for the EMWMF, 3) the BCV RI Report (DOE 1997), 4) wetland delineation and stream determination surveys, 5) field reconnaissance at Site 5 to assess surface water conditions of the underdrain network, and 6) a full year of stream and headwater spring monitoring completed as part of the Phase I investigation at Site 5.

3.5.1 General Characteristics of Surface Water Hydrology at Site 5

Site 5 sits within the headwater tributaries of NT-2 and NT-3. A surface water divide crosses the Site 5 footprint; runoff from the general area of cells 5 and 6 flows south and southeast toward NT-2 while runoff from cells 1-4 flows into the NT-3 watershed. The main NT-2 stream channel lies southeast of Site 5. Three smaller NT-2 sub-tributary valleys extend northward from the main channel draining the eastern third of the footprint. The most deeply incised sub-tributary of NT-2 bounds the east side of the footprint and terminates in a headwater spring (EMDNT2-SP1; see Figure E-61) at the base of a narrow ravine cut into Pine Ridge. This stream channel provides a base level for the water table along the east side of Site 5. Site reconnaissance at Site 5 has shown that surface runoff from the eastern third of the footprint does not occur along distinct continuous stream channels with any persistent water flow as seen on the west half of the site. Surface runoff within the more elevated smaller eastern subwatersheds of the site appears to drain more diffusely into the subsurface and migrate via shallow ground water to discharge at seeps and stream channels at lower elevations beyond the southern margins of Site 5.

The main stream channel of NT-3 (NT-3c - east) crosses the footprint from southwest to northeast across cells 1-4 terminating in a headwater spring at EMDNT3-SP1 in an incised narrow ravine of Pine Ridge similar to that at the NT-2 headwater spring, EMDNT2-SP1. Two smaller sub-tributaries (NT-3b – middle, and NT-3a - west) occur along the western border of the Site 5 footprint. The NT-3a - west sub-tributary is also deeply incised into a narrow ravine of Pine Ridge with a headwater spring at EMDNT3-SP2. Wet season high water table elevations along the valley floors at Site 5 are constrained by the stream channel elevations of these NT-2/NT-3 headwater tributaries. The water table appears to provide base flow to the tributary stream channel through discharge into the channel and via springs and seeps along the margins of the channels. Both of the primary NT-2 and NT-3 stream channels flow through culverts under the Haul Road to lower reaches of NT-2 and NT-3 to ultimately join Bear Creek over 1000 ft south of Site 5. A V-notched restrictor plate was welded across the north end of the haul road culvert at NT-3 to allow for remedial actions along lower NT-3 near the BY/BY site. The restrictor plate was never removed following those remedial actions and has a damming effect on the north side of the haul road near the southwest corner of Site 5. Particularly during the wetter winter/spring season, runoff is ponded above the haul road

Stream flows on the most deeply incised stream channels of NT-2 and NT-3 originate as headwater springs where ground water discharges to the surface in relatively small discrete shallow pools (See Figure E-61 EMDNT2-SP1, EMDNT3-SP1, and EMDNT3-SP2). Ground water discharge also occurs in some downstream areas feeding tributary stream channels in the form of more diffuse seeps and springs that occur within delineated wetland areas. The seep areas commonly occur along flatter localized floodplains where surface slopes decrease and along the lower reaches of smaller ravines draining the steeper slopes along Pine Ridge. Ground water yield from seeps and springs is typically greatest during the wet Winter and early Spring non-growing season when evapotranspiration is low and precipitation and ground water levels and recharge are often highest. Field reconnaissance and results from the Phase I Site 5 surface water monitoring locations indicate that flow is continuous during the typical wet nongrowing season in the channels, seep areas, and springs shown in Figure E-61 at and near Site 5. Variations in intermittent or continuous flow were assessed for a full year at the Phase I monitoring locations shown in Figure E-61. Results are presented in Attachment B to Appendix E. The limited results from previous investigations by the USGS and the Phase I results indicate that seasonal summer/fall dry season base flow between storm events along the upper NT tributary channels can diminish to near zero. Field observations at and upstream from the southwest margin of Site 5 indicate that during these dry periods flow diminishes to a trickle at levels barely visible or measureable between interconnected puddles that appear static. Base flow in the stream channels during these periods essentially ceases. The NT-2/NT-3 tributaries gradually gain volume downstream at and below Site 5. Historical flows have been measured at a flume location a few hundred feet upstream of the junction of NT-3 and Bear Creek, but the flow rates there have been tempered by the restrictor plate near Site 5 and do not reflect natural runoff from the entire NT-3 watershed.

It is important to note the relatively small size and intermittent flow conditions of the NT-2/NT-3 stream channels crossing and adjacent to Site 5. The NT-3 channels near the downstream sections of the proposed footprint are typically no more than 2-4 ft in width and less than a foot in depth with base flow water in the channels only a few inches in depth. While the stream channels may fill during significant rainfall/runoff events, the channels may show little or no discernable base flow during the hottest and driest late summer/early fall seasons between storm runoff events.

The Site 5 Phase I stream flow monitoring was intended to partially quantify peak and base flows for a full one year period from December 2014 through November 2015, on the primary NT-3 tributary and two smaller NT-3 tributaries draining the western half of the site. Hydrographs of Phase I stream flow and precipitation data corroborate previous findings from BCV and elsewhere on the ORR demonstrating the close relationships between rainfall and runoff. The recession phases of the Phase I stream flow hydrographs also illustrate the relatively faster drainage via the topsoil stormflow zone versus the slower drainage from the water table interval that both support baseflow to the NT stream channels. Complete results of the Phase I surface water monitoring are presented in Attachments A and B. Results of pre-construction flow monitoring within the former NT-4 watershed at the EMWMF, and post construction flow monitoring of the NT-4 underdrain outfall, also offer data useful for comparison with the NT-3 watershed at Site 5. A number of continuous monitoring stations along the channel of Bear Creek and the flume monitoring station near the mouth of NT-3 just above its confluence with Bear Creek provide long term stream flow records for correlation and potential calibration with stream flow monitoring at and near Site 5.

3.5.2 Previous and Current Surface Water Investigations

Investigations of seeps, springs, and streams at and near Site 5 include: (1) a USGS study of BCV in 1994; (2) stream flow monitoring by Bechtel Jacobs Company LLC (BJC) during the pre-design phase of the EMWMF in 1997-1998; (3) wetland delineation and stream determination surveys, (4) site reconnaissance findings by Pro2Serve; and (5) the full year of Site 5 Phase I surface water monitoring from December 2014 through November 2015.

3.5.2.1 USGS 1994 Seep, Spring, Stream Flow Inventory

The USGS conducted a surface water characterization study in 1994 across the entire BCV watershed including the NT-2/NT-3 watersheds. Springs, seeps, and streamflow measurements were made for NT-2 and NT-3 and sub-tributaries crossing the Site 5 footprint. Two USGS papers were prepared documenting the results (Robinson and Mitchell, 1996, and Robinson and Johnson, 1995). The base flow conditions on NT-2 and NT-3 were measured on March 14 and 15, 1994, respectively, during the wet, nongrowing season and during the growing season on September 9 and 12, 1994, typically a drier period of the year. Daily rainfall data and mean daily discharge hydrograph data for 1994 from Bear Creek near SR 95, indicate that all the measurements made by the USGS were collected during periods of no rainfall when runoff was in a recessional stage so that the measurements represent baseflow periods not made within or shortly after significant precipitation/runoff events.

At each USGS location flow estimates were made by various relatively simple field methods, and basic water quality parameters (pH, specific conductance, temperature, and dissolved oxygen) were recorded. Each location was assigned a unique number with coordinates approximately located using a hand held GPS unit. Flows measured by the USGS on March 14 and 15, 1994, from seeps, springs, and stream channels along NT-2 and NT-3 tributaries to Bear Creek at and near the proposed EMDF site are shown on Figure E-69. Note that all locations measured along the NT-2/NT-3 tributaries indicated zero flow on September 9 and 12, 1994, but the zero values represent their minimum estimated reportable flow rates of <0.005 cfs (<2.2 gpm). Flows for the March 1994 measurements ranged as shown on Figure E-69, from lows of <0.005 cfs from small springs at the uppermost headwaters of the tributaries (at 2310 & 2260), to 0.05 cfs (22 gpm) along the main NT-3 stream path (at 2290) near the approximate center of the EMDF footprint. An overall increase in streamflow from the upper to lower reaches of NT-2 and NT-3 indicate that these tributaries were primarily gaining flow during high baseflow conditions during the March 1994 wetter nongrowing season. In contrast, no flow was recorded at any of the locations along the entire lengths of NT-2 and NT-3 during the September 9 and 12, 1994, measurements suggesting that these tributaries could be intermittently dry or nearly dry during the typical low baseflow conditions late in the growing season. Pro2Serve site reconnaissance and photos from the late summer/early fall of 2014 indicated that the NT-3 tributary channels in the Site 5 footprint contained water in small pools with only very slight water movement between the pools. The limited USGS data do not indicate the nature of ground water seepage and underflow below the valley floors adjacent to the stream channels or intermittent runoff that might occur during high precipitation events during the growing season.

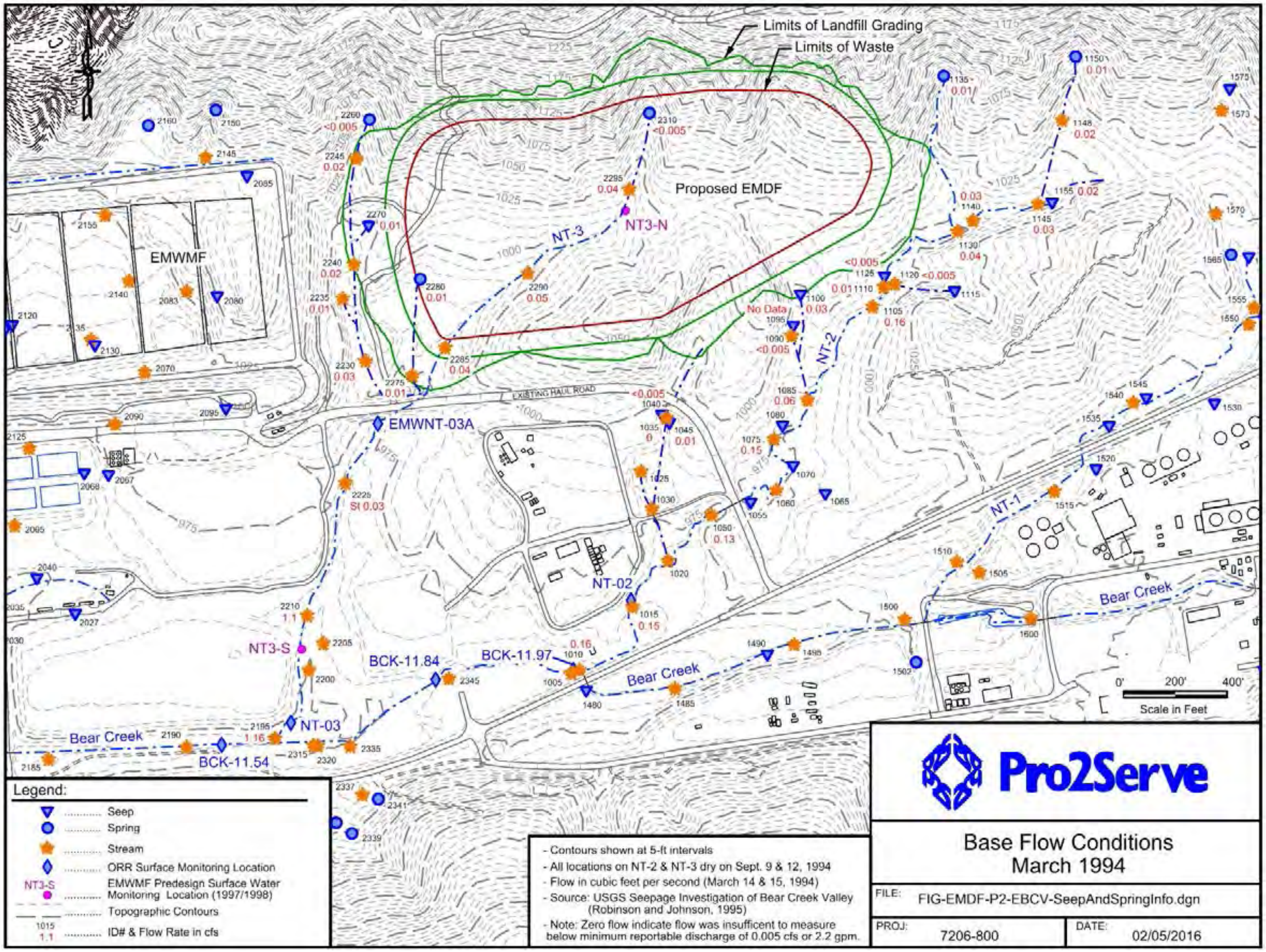

Figure E-69. USGS flow rates measured under base flow conditions in March 1994 at locations within and surrounding the Site 5 footprint [Note: USGS base flow rates measured in September 1994 at the same stations were all reported as "zero" (i.e. <0.005 cfs or 2.2 gpm)]

As shown on Figure E-69, roughly twenty measurement locations were identified within or near the proposed Site 5 footprint with additional locations downstream. Three of the headwater spring locations were included in the Phase I Site 5 monitoring program for weekly observational monitoring (see Figure E-61 and equivalent USGS locations 1135, 2310, and 2260 shown in Figure E-69).

The USGS identified gaining/losing reaches along Bear Creek and the various tributaries and sub-tributaries across the overall BCV watershed. However, their data was limited to only two baseflow events, their measurement locations were limited in number relative to the scale of the EMDF site, and their methodologies for determining flow in the upper reaches of the NT tributaries were relatively inaccurate. The gaining/losing reaches identified by the USGS along the NT tributaries at and near the EMDF should therefore be viewed with caution. The nature of gaining/losing segments in these upper watershed channels is likely much more complex than implied by the USGS results. The results of the ongoing Site 5 Phase I monitoring were intended to partially address the nature of intermittent andperennial flow at Site 5 and relationships between temporal and spatial variations in stream baseflow and ground water discharge.

3.5.2.2 EMWMF Pre-design Stream Flow Measurements

Stream flow monitoring was conducted in 1997/1998 at two locations along NT-3 (NT3-N and NT3-S), and at six locations along NT-4, and two locations along NT-5 to evaluate precipitation, runoff, and peak flow conditions in support of the EMWMF design (see BJC 1999 - Appendix G – Phase III Surface Water Report). A continuous monitoring rain gage was installed at one of the stations (NT4-CMP) for correlation of precipitation data with streamflow hydrographs. The ten locations are shown on Figure E-70. Water quality parameter measurements were not included in their measurement program. Stream flow hydrographs are provided in Appendix G of BJC 1999.

The data for the two locations along NT-3 and other locations along NT-4 are reviewed for their relevance to current and future characterization of runoff and engineering design at Site 5. The upper NT-4 watershed was similar in nature and scale to the upper NT-3 watersheds. The EMWMF runoff and precipitation data are also useful for comparison with peak and base flow rates obtained during the Phase I Site 5 investigation (2014/2015) and corresponding Y-12 west tower precipitation data). The NT3-N weir/monitoring station was located near the center of the proposed Site 5 footprint. The NT3-S location was far downstream about 400 ft north of the confluence of NT-3 with Bear Creek. Because of equipment malfunctions, the continuous streamflow monitoring data at NT3-N only covered the 3.5 month period from December 13, 1997, through April 1, 1998. Similarly, the NT3-S station only covered the period from November 8, 1997, through April 1, 1998. At NT3-N, two peak flow events on about March 9 and March 18, 1998, of 0.67 cfs (300 gpm) and 1.5 cfs (681 gpm) are correlative with maximum precipitation events of 0.07 and 0.12 inches of precipitation, respectively. Maximum flow rates downstream at NT3-S for the same events were 5.1 cfs (2300 gpm) and 6.9 cfs (3105 gpm). Much higher precipitation events on the order of 0.5 to 1 inch or more of maximum rainfall did not occur during the measurement period so the peak flow data noted above do not reflect much higher potential streamflow that might occur under more extreme precipitation/runoff events. The hydrographs illustrate one period of relatively low baseflow from about February 26 through March 5, 1998, where streamflow is <0.02 cfs (<10 gpm), and <0.11 cfs (<50 gpm) at NT3-N and NT3-S, respectively. Those data are within the same order of magnitude as the USGS single point baseflow data measured in March 1994.

Prior to construction of the EMWMF, the former NT4-CMP stream gage location near the south center of the EMWMF, measured drainage from the upper part of the former NT-4 watershed approximately 20 acres in size (this 20-acre area was determined fairly accurately using pre-EMWMF topo maps imported into AutoCadd). This area is comparable to portions of the existing NT-3 drainage areas north of the haul road within the Site 5 footprint.

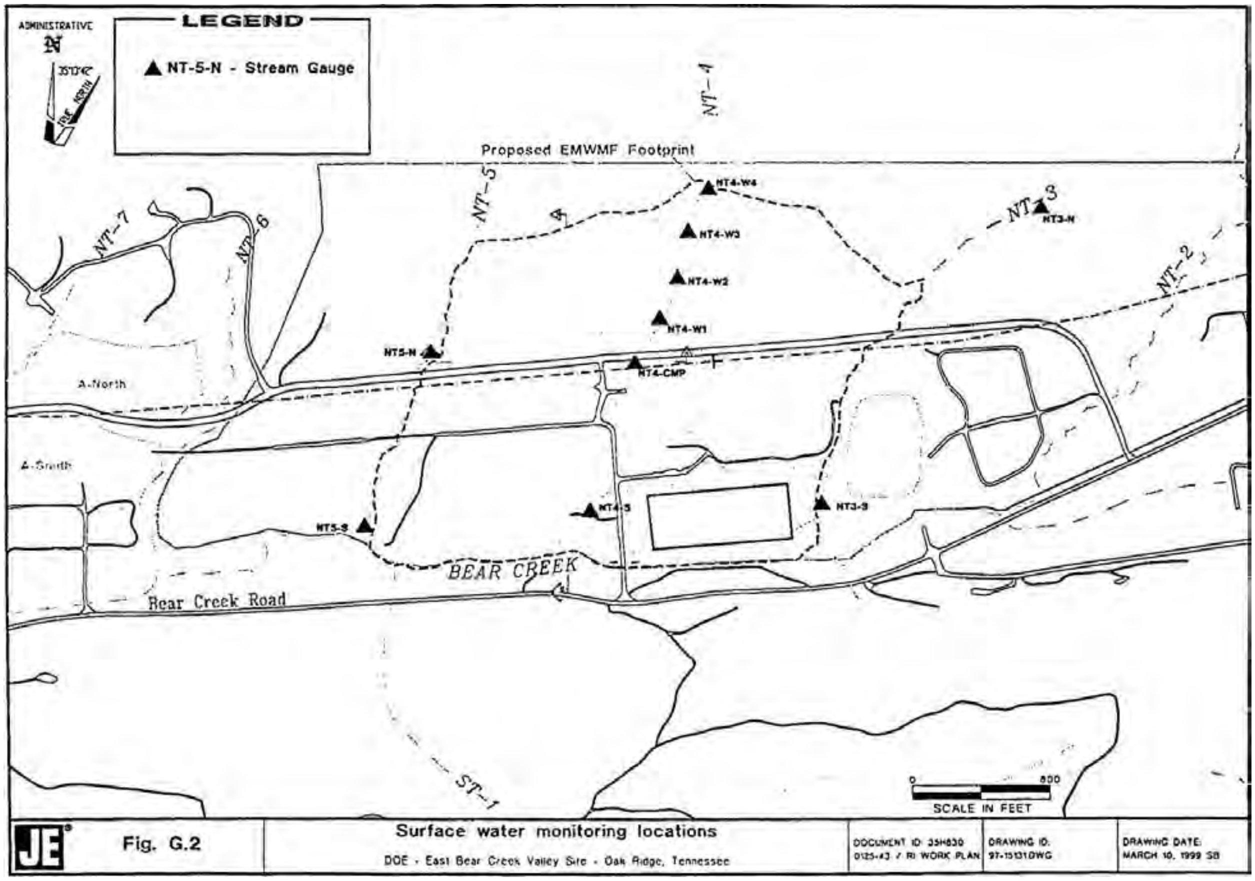

Figure E-70. Surface water monitoring stations for EMWMF pre-design characterization (1997/1998)

Hydrograph and precipitation data from NT4-CMP, which cover almost a full year of runoff from May 1997 through April 1998, provide an indication of summer and winter peak flows. Peak surface runoff events were recorded at NT4-CMP in the June/July/August 1997 growing season with a maximum of approximately 1500 gpm with a 0.19 inch rainfall event, and during the wetter non-growing season from January through April 1998 timeframe with a maximum peak flow event of 6,155 gpm caused by a 0.40 inch precipitation event (see Appendix G of BJC 1999, Figs G-5 and G-12). These results provide baseline runoff data that may be useful for estimating peak and base flow discharge from the NT-2/NT-3 tributary watersheds at Site 5 for comparable watershed areas and site conditions.

3.5.2.3 Bear Creek Valley Remedial Investigation Report

The Remedial Investigation Report completed for BCV (DOE 1997) includes several aspects of surface water hydrology relevant to Site 5. These are associated with: 1) a water balance model for BCV; 2) annual and seasonal changes in hydrology; 3) short-term transient hydrologic responses to storm events; 4) soil saturation, interflow, and surface runoff conditions; 5) transient responses in tributary flow rates draining from Pine Ridge; 6)hydrograph analyses of surface flow and relationships of surface runoff with subsurface stormflow and ground water flow and discharge; 7) a conceptual model for transient responses in surface and ground water; and 8) karst related recharge/discharge relationships that occur south of Site 5 within the Maynardville Limestone and Bear Creek along the floor of BCV north of Chestnut Ridge.

The extensive information and technical interpretations provided in the BCV RI Report provide an important source of background information applicable to the hydrology of Site 5 and the surrounding area and to similar conditions at the other EMDF sites in BCV. The BCV RI Report should be referenced for extensive details to supplement those provided herein.

3.5.2.4 Site 5 NT-3 Wetland Surveys and Hydrologic Determinations

Results of stream and wetland surveys by Rosensteel (2015) and Rosensteel and Trettin (1993) were presented above in Section 2.17.1. These surveys are noted here for their importance to Site 5 hydrology as they delineate several wetland areas that are often coincident with the locations of seeps and springs and broad valley floors representing areas of ground water discharge where the water table intersects the surface. These areas are also important target areas for properly designing the underdrain system to ensure that natural subsurface pathways for ground water discharge are effectively captured and drained.

3.5.2.5 Field Reconnaissance of Surface Water Hydrology at Site 5

The USGS spring and seep GPS coordinate locations (on the order of 3-5 m accuracy) were plotted on existing site maps and used during 2014 Pro2Serve field reconnaissance to verify and clarify the field conditions of the 1994 USGS locations at and near Site 5. Because the seeps and springs at Site 5 represent zones of ground water discharge, their identification and characterization are important to the proper design of the proposed underdrain system for the EMDF. Many of the USGS locations were assigned new designations consistent with Y-12 nomenclature for surface water monitoring in BCV. Figure E-71 shows the locations and new nomenclature defined in the Phase I Site 5 investigation for seeps/springs at and near the footprint. At a few locations the USGS designations for springs or seeps were redefined by Pro2Serve based on the 2014 field observations.

The Winter and early Spring 2014 field reconnaissance by Pro2Serve included traverses along each of the NT-2/NT-3 tributaries at the EMDF Site on February 18 and 28, March 25, and April 17, 2014. Observations and photographs indicated that stream flow during this time period was continuous at and below the three headwater springs at USGS locations 2260, 2310, and 1135 (Phase I monitoring locations EMDNT3-SP2, EMDNT3-SP1, and EMDNT2-SP1, respectively) and at and below the USGS seep location 1100 (EMDNT2-SE2) along the southeast side of the EMDF footprint. No indications of surface water runoff or stream channels were identified above these locations. Each of the three headwater spring locations occurs near the center of the mapped outcrop belt of the Pumpkin Valley Shale, and appear to be unrelated to formational or lithological boundaries (see geologic formation contacts shown on Figure E-71). Each of the three spring locations also occur very close to the 1050 ft elevation contour near the base of ravines cutting deeply into the steep south facing slopes of Pine Ridge. The springs appear to occur where the water table within regolith soils and saprolite intersects the surface near topographic changes between the steepest slopes of Pine Ridge and lower less steep intermediate slopes. Discharge at the springs is probably also driven by the steeper hydraulic gradients in shallow ground water draining southward from the crest of Pine Ridge. The approximate lengths and routes of continuous winter season stream flow along the NT-2 and NT-3 tributaries documented in field reconnaissance adjacent to and crossing the Site 5 footprint are reflected in the blue line stream paths and wetland areas shown on Figure E-71.

An additional site reconnaissance by Pro2Serve was made on November 20, 2014, along the north-south trending ravines on the steep south face of Pine Ridge located across the eastern third of the footprint between the USGS spring locations 2310 and 1135 (Phase I monitoring locations EMDNT2-SP1 and EMDNT3-SP1). No stream flow was observed along those ravines, nor was there any indication of any active stream channels. Infiltration of surface water from these ravines and other smaller ones in the Site 5 footprint appears to directly recharge shallow ground water that discharges at seeps/springs and wetlands located further downslope such as those in the broad seepage and wetland area illustrated in Figure E-72.

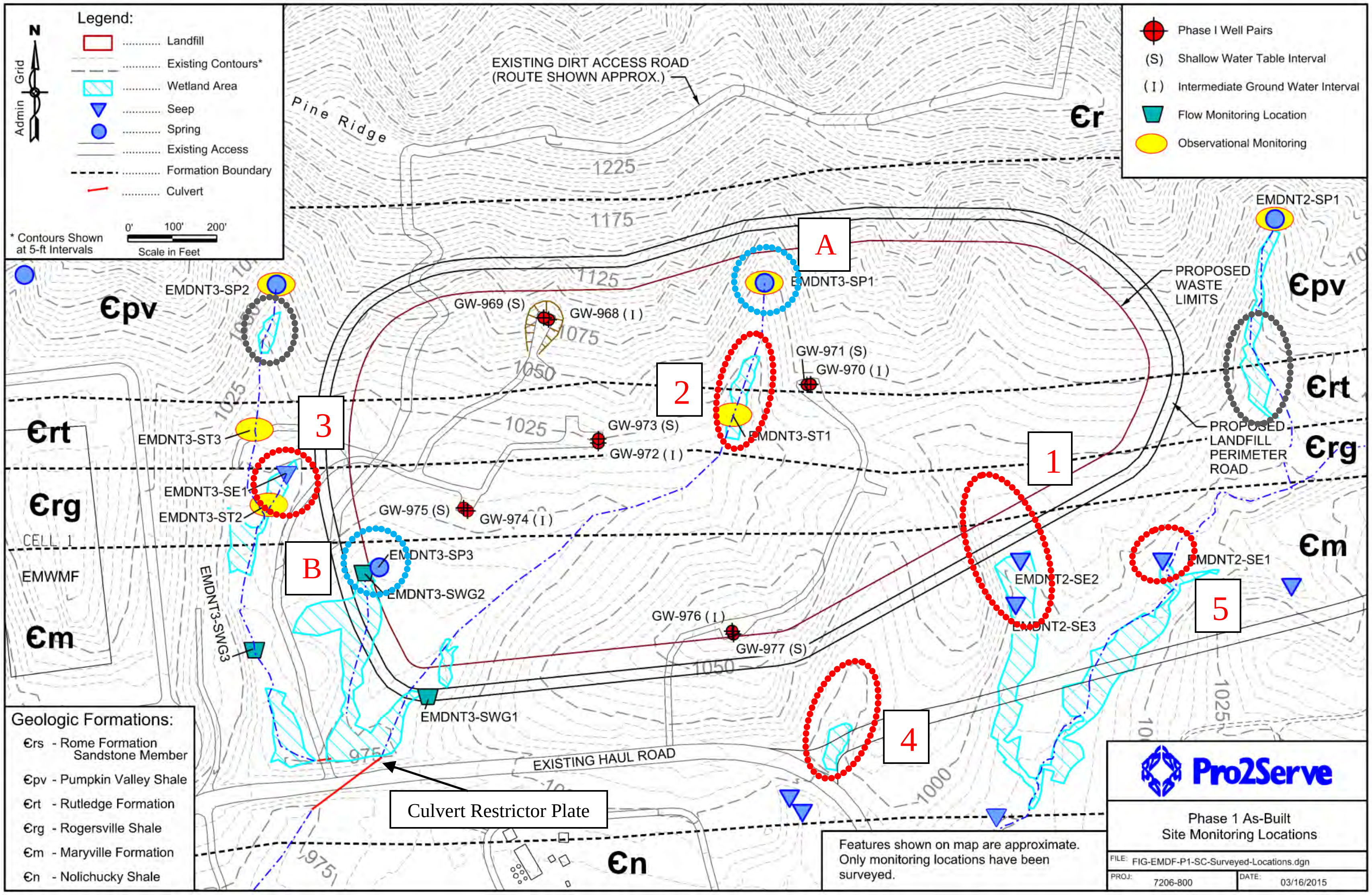

Figure E-71. Locations of seeps (1-5), and springs (A/B) relevant to ground water discharge and the proposed underdrain system at Site 5

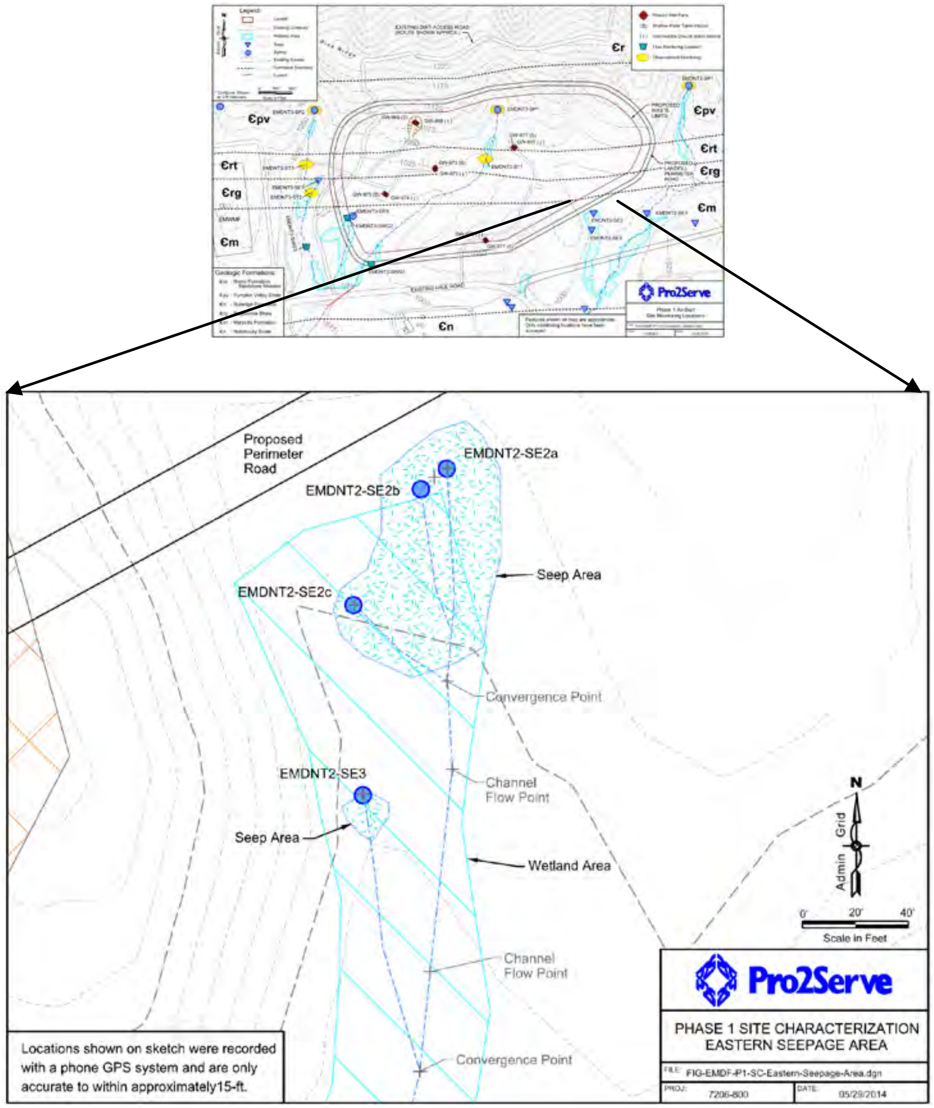

Figure E-72. Former surface water features in ground water discharge zone on the southeast side of Site 5 before UPF haul road construction

NOTE: See previous figures for reference to former USGS locations 1100 and 1095 (EMDNT2-SE2/-SE3 locations, respectively).

The site reconnaissance of the NT-2/NT-3 tributaries also indicated that the tributaries include one or more relatively short lengths where the stream channel runs just below the ground surface along soil pipes in the surficial alluvial/colluvial materials only to reappear downstream in surface flow without any noticeable change in volume. Several seep locations and seepage areas were identified by Pro2Serve that were not identified in the USGS study, but these fall within areas delineated and surveyed as a part of the wetlands surveys conducted at and near Site 5. These areas are shown on Figure E-71 and E-72 as wetland areas and most appear to represent zones of ground water discharge at least during the wetter non-growing season when the water table is at its highest level. No subsurface investigations have been conducted along the NT drainage paths to characterize hydrogeological conditions and interactions between surface water and ground water within and adjacent to those paths.

Subsections below summarize observations based on the early 2014 Pro2Serve field assessments relative to the previous investigations, the Phase I limited investigation, and preliminary planning for additional characterization at Site 5. Figure E-71 illustrates the locations of seeps and springs referenced to the following descriptions. The locations are reviewed in order from the highest to lowest in terms of the apparent general volume of ground water discharge at each location, and therefore with the greatest potential for discharge to the various parts of the proposed underdrain system network at Site 5.

Location 1 - Large Seepage Area near EMDNT2-SE2a,b,c, –SE3 (USGS Locations 1090/1095/1100)

Location 1 is the largest seepage area associated with the Site 5 underdrain system. In the Summer/Fall of 2014 this area was completely reworked and regraded from its natural undisturbed state into a pond/basin during the UPF road construction. The area is coincident with part of the proposed underdrain that would underlie Cells 5 and 6. The natural drainage in the area was found to be more complex than suggested by the two USGS spring/seep locations previously identified there [1090 (ST), 1095 (SE), and 1100 (SE)].

During the site traverses in the February/March 2014 wet winter season, multiple seepage faces in this area were observed to discharge and coalesce into distinct small stream channels typically 8–12 in. across and 3–6 in. or more deep that connected into a main channel draining the entire area toward the south into the main NT-2 stream channel. Figure E-72 is a pre-construction closeup schematic drawing of this broad, flat, relatively large ground water discharge zone and former wetlands area. At least three locations (GPS located as EMDNT2-SE2a, -SE2b, SE2c in Figure E-72) were identified with a visible spring-like flow that drained downslope into coalescing channels into a main trunk stream, with an additional seepage area assumed to be equivalent to the USGS location 1095 (GPS located as EMDNT2-SE3 in Figure E-72). This entire area was boggy and included cattails and other hydrophytic vegetation. The overall area clearly represents a significant discharge zone for the stormwater flow zone and for shallow/intermediate ground water from upgradient areas.

The area shown in Figure E-72 coincides with the lower part of the underdrain system for proposed Cells 4, 5, and 6 (the Site 5 cells are numbered 1 through 6 from west to east). The area shown in Figure E-72 and two other areas nearby were partially excavated and reconfigured as part of the wetlands mitigation process during recent road construction for the UPF haul road (See previous descriptions and Figures E-65 through E-67). The reconfigured areas shown in Figure E-65 are based on pre-UPF haul road construction design drawings and are not as-built drawings. However, they are very similar to the as-built conditions. The former locations of seeps and seepage areas near USGS locations 1100 (EMDNT2-SE2a, b, c), 1095 (EMDNT2-SE3) and 1125 (EMDNT2-SE1) were excavated during the UPF construction and wetlands mitigation process, but these areas still represent locations of significant ground water discharge emanating from the Site 5 footprint to the north. Photographs documenting this seepage area before and during construction and wetlands mitigation for the UPF haul road are provided in previous figures. Observations and photos made in August and October 2014 during the UPF reworking of the area demonstrated the presence of shallow ground water discharge and slow surface flow during the initial upslope cuts made to create the artificial upslope pond and afterwards following completion of the upslope pond. Field observations indicate that the excavated basins in this area were immediately filled with water that continued to slowly drain downstream under baseflow conditions fed by shallow ground water discharge. The broad ravine into Pine Ridge located due north of this area appears to funnel and convey shallow ground water southward from the steeper slopes of Pine Ridge into this topographically low area where the water table intersects with the ground surface. As shown in conceptual design figures (See Section 6 of RI/FS Report), this area is identified for two converging trench drains with a relatively large overlying blanket drain – both as part of the overall underdrain system for this area. The overall seepage area before the UPF construction was roughly delineated as 75–100 ft wide and 200–300 ft long. Suburface conditions in this area are unknown (e.g. – extent of alluvial and colluvial materials, depths to saprolite, competent bedrock, and the rates and horizontal/vertical hydraulic gradients of ground water discharge, etc.). The underdrain networks are intended to capture and drain this type of slow ground water seepage to avoid the potential for blockage and upwelling of ground water into the geobuffer, if underdrains are not utilized and if pre-existing valleys and ravines at the EMDF sites are filled in with compacted low permeability fine-grained soils.

Location 2 – Seep area near EMDNT3-ST1 (Wetland E near USGS 2295)

Location 2 includes the Wetland E area located near USGS stream flow location 2295 and just upstream of the EMDNT3-ST1 Phase I weekly stream flow monitoring location. The area is a relatively flat floodplain area along the upper reaches of the main NT-3 tributary channel bisecting the Site 5 footprint. Site reconnaissance during the wet winter season of 2014 showed several seepage faces with flow indicating shallow ground water discharge zones where steep upland slopes coincide with the relatively flat floodplain surface. This area is coincident with part of the proposed underdrain system along the primary tributary of NT-3 crossing the EMDF footprint. The nature and extent of regolith (particularly alluvial/colluvial materials) and shallow bedrock materials and ground water flow/discharge conditions is unknown here and at other similar areas along each of the NT-3 tributary valley floor areas.

Location 3 - Seepage Area at EMDNT3-SE1 (Northern part of Wetland B; USGS location 2270)

This area is a fairly extensive seepage area located at the northeast end of Rosensteel’s Wetland B that may be seasonally as large as 40–60 ft across with seepage flow that coalesces into a distinct channel that flows downstream to merge with the main westernmost NT-3 channel draining the valley that heads at USGS location 2260 (EMDNT3-SP2). This area appears to be a localized zone of ground water discharge during the wet Winter/Spring season and is located along the lower section of a swale draining south and southwest from Pine Ridge. Site reconnaissance suggests that discharge from this seep area may dwindle down to almost nothing during the warm and typically drier parts of the growing season, even though ground water movement may slowly continue in the shallow subsurface of this area. The EMDF Phase I weekly stream monitoring location EMDNT3-ST2 is located roughly 30–50 ft downstream of this seepage area. This seepage area is coincident with a segment of the conceptual underdrain design on the west side of Site 5. Subsurface hydrogeological conditions here are unknown. Site 5 Phase I weekly estimates of stream channel flow at EMDNT3-ST2 provide data for the 2015 dry season drainage from this area (See Attachment B).

Location 4 – Seepage Area near intersection of New and Old Haul Roads

The valley just north of USGS seep locations 1040/1045 (Location 4 in Figure E-71) was also reconfigured during the UPF haul road construction. The area is identified on conceptual design drawings for a relatively small underdrain system and outfall south of Cells 4 and 5. This area represents an apparent zone of shallow ground water discharge draining from the small valley upslope. The USGS identified two seeps (1040/1045) at lower elevations on the downstream side of the Haul Road just south of this area draining from the same small valley. Site reconnaissance before the UPF haul road construction indicated a very small stream channel with minor flow on the north side of the haul road that drained into a culvert leading southwest below the haul road. Subsurface hydrogeological conditions here are unknown.

Location 5 - Seepage area at EMDNT2-SE1 (USGS location 1125)

This area was identified during the Pro2Serve 2014 site reconnaissance as a relatively large seepage area (roughly 20 × 40 ft; estimated, not measured) along the floodplain on the north side of the main NT-2 stream channel. The area was boggy with cattails and other hydrophytic vegetation. Its location along the northwest side of NT-2 suggests that this area may represent a localized area of ground water discharge originating from upland areas to the northwest within the Site 5 footprint. This area was not included in the proposed underdrain conceptual design. Unlike many other seep areas, this area does not occur at the base of a valley or ravine, suggesting that seepage here may be more influenced by flow along preferential subsurface pathways that do not conform to surface topography. The area was reconfigured during the UPF haul road construction so that the location of the former seepage area may no longer be clearly identifiable. Subsurface hydrogeological conditions here are unknown.

Seep areas cross gradient to the EMDF Site

These two locations are shown on Figure E-71 inside the black dashed oval areas east and west of the Site 5 footprint. While not identified as underdrain network areas, these areas have some potential to receive a portion of ground water discharge (and therefore potential future ground water contaminant releases) that could move laterally away from Site 5 in directions parallel with the geologic strike of beds underlying the footprint.

Location A - Headwater spring at EMDNT3-SP1 (USGS location 2310) and other headwater springs

Seeps noted by the USGS at locations 2310 (EMDNT3-SP1) and 1135 (EMDNT2-SP1), were found by Pro2Serve to be distinct continuously flowing small headwater spring locations during the nongrowing Winter/Spring seasons. The same was true for the spring at EMDNT3-SP2 (USGS location 2260). Each marks a distinct point along the valley floor where stream channel flow begins. No obvious stream channels were observed above these locations but a distinct channel was clear below each spring location [since the May 2013 blowdown event, the spring at EMDNT3-SP2 is surrounded with downed trees and brush obscuring the former surface conditions]. These locations were identified for weekly visual assessment and water quality monitoring during the Phase I site investigation. Monitoring results are provided in Attachment B. The trench drain component of the proposed underdrain system would be extended at least up to the spring at the EMDNT3-SP1 location near the top center of the Site 5 footprint to enhance dewatering and lowering of the water table. Subsurface hydrogeological conditions at and near this spring are unknown.

Location B - Spring at EMDNT3-SP3 (USGS location 2280)

This spring also appears to be a distinct spring rather than a seep but is located well downslope from the steeper sections of Pine Ridge. The areas above and below this spring, near the EMDNT3-SWG2 flume location, is identified as part of the conceptual design for the underdrain system. Subsurface hydrogeological conditions at and near this spring are unknown. A small intermittent wet weather conveyance channel occurs above this location and can be traced far upslope into a narrow valley into Pine Ridge. A traverse along this conveyance on April 17, 2014, identified the locations of two small (<2–3 ft^2) wet locations with green algae growth that appeared to indicate locations where very small intermittent seepage flow may have occurred at times during the winter season. A flume (EMDNT3-SWG2) was installed roughly 20 ft downstream of this spring during the Site 5 Phase I investigation to monitor flow rates. Natural runoff upslope of this spring was dramatically altered by logging and road construction during the Phase I investigation [see Attachment A – the Site 5 Phase I report for details and maps associated with the reconfiguration of runoff and effects on the surface water hydrology].

3.5.2.6 Site 5 Phase I Investigations of Surface Water

Attachments A and B present the results of the limited Site 5 Phase I investigation that included a full year of monitoring at several surface water stations at Site 5 (see locations on Figure E-61). The monitoring locations included:

- three cutthroat flume locations for measuring and logging stream flow rates and water quality parameters at 20 minute intervals (EMDNT3-SWG1, -SWG2, -SWG3), and
- weekly point measurements at three headwater spring locations (EMDNT2-SP1, EMDNT3-SP1, EMDNT3-SP2) and three stream channel locations (EMDNT3-ST1, -ST2, and -ST3) for estimates of flow rates and measurements of water quality parameters

The results of the Phase I surface water monitoring are presented in Attachments A and B. Attachment A describes field methods and results for the initial monitoring period from December 2014 through February 2015. Attachment B provides monitoring results for the entire monitoring period ending in November 2015.

3.5.3 Surface Water Contaminant Monitoring Along Lower NT-3 below Site 5

Surface water samples have been collected annually at two locations along the lower stretches of NT-3 downstream of Site 5 as part of the on-going Water Resources Restoration Program to measure the uranium isotopic composition, nitrate, ^{99}Tc, and VOCs (DOE 2012). These contaminants are associated with releases from the BY/BY site, Hazardous Chemical Disposal Area, Sanitary Landfill, and Oil Landfarm that leach to lower reaches of NT-3, and a nitrate ground water plume from the S-3 Ponds that has migrated in the Nolichucky Shale and which partially discharges to surface water along downgradient flow paths. As reported in DOE (2012), a sample collected at monitoring station NT3-1E immediately downstream of the culvert under the Haul Road did not contain measureable uranium, nitrate, ^{99}Tc, or VOCs. Samples collected at the NT-3 integration point along the southernmost segment of NT-3 all contained measurable uranium and one sample contained a trace of nitrate. No ^{99}Tc or VOCs were detected in these samples. Uranium (^{234}U and ^{238}U) concentrations at the NT-3 integration point declined steadily from 1999 through 2007 but then began to increase again. Continuous flow-paced sampling was resumed at the lower NT-3 monitoring station because the uranium levels exceeded the 4.3 kg/year flux standard set in the ROD. Differences between the pre-remediation and post-remediation isotopic composition of uranium suggests that contributions are from a different source than the BY/BY (DOE 2012).

Prior to the completion of remedial actions in 2003, the lower reaches of NT-3 south of Site 5 were affected by contaminants, mainly uranium and mercury, leaching from the BY/BY site. The lower segment of NT-3 below Site 5 is sampled for four quarters near the end of each Five-Year Review period and analyzed for TDEC AWQC, and uranium flux is measured quarterly each year. Water at the NT-3 sampling station upstream of the confluence with Bear Creek generally meets AWQC, but exceeded the AWQC for heptachlor for one of the four quarterly samples collected during 2010. The annualized uranium flux continues to exceed the NT-3 goal of 4.3 kg/year. These contaminants are most likely from the BY/BY site, Hazardous Chemical Disposal Area, or Unit 6 Landfill on the east side of NT-3. The Site 5 footprint is located well enough upstream of historical contaminants along NT-3 such that detection monitoring should not be influenced by any downstream contaminants from the sources decribed above.

3.6 SITE 5 HYDROGEOLOGY

The previous subsurface investigations completed on either side of Site 5 provide a considerable amount of geotechnical and hydrogeologic data relevant to likely conditions at Site 5. The limited Phase I investigation completed in 2014/2015 involved the installation, testing, and monitoring of five cluster wells and provides the only site-specific subsurface data for the Site 5 footprint. The results of previous investigations surrounding Site 5 are summarized above along with references to original documents providing investigation findings. The hydrogeological site conceptual model for Site 5 is presented in Section 2.8.

The results of the Site 5 Phase I investigation are presented in Attachments A and B and include detailed descriptions of Site 5 hydrogeology and graphics illustrating subsurface conditions based on the limited site-specific data collected to date. These Attachments also include sections addressing surface water hydrology presented in greater detail than that presented in preceding sections. Attachment A provides a comprehensive summary of the Phase I investigation scope and field methods. Attachment A also presents investigation findings and interpretations of regolith and bedrock hydrogeology at Site 5 based on sampling and analysis of soil/saprolite and rock cores, borehole geophysical logging and heat pulse flow meter tests, slug and packer tests, geotechnical lab analysis, and hourly ground water monitoring for a full year. Attachment A presented interim monitoring results from December 2014 through February 2015. Attachment B presents monitoring results and interpretations based on the full year of surface and ground water monitoring. Detailed site cross sections provided in Plates to Attachments A and B illustrate subsurface hydrogeological conditions, and water table (potentiometric surface) contour maps in the Attachments illustrate generalized shallow ground water flow paths at and near Site 5 representative of seasonal high water table conditions. Hydrographs of precipitation data and water levels in the shallow/intermediate depth Phase I well clusters illustrate spatial and temporal variations in ground water levels in response to the frequency and duration of precipitation events and broader seasonal changes in precipitation and evapotranspiration.

The Phase I investigation was intended to demonstrate the suitability of Site 5 as a viable location for the proposed EMDF in response to specific concerns regarding Site 5 (see TDEC/DOE correspondence related to the limited Phase I investigation work plan; DOE 2013). If Site 5 were selected, then additional investigations would be completed at Site 5 to support more complete characterization and engineering design.

4. SITE 6B – EAST BEAR CREEK VALLEY

Very little site-specific data are available at and near Site 6b. The following subsections review the site location, general site features, limited results of previous investigations, and the surface water and hydrogeological conditions at and near Site 6b. The hydrogeological site conceptual model for BCV and Site 6b were presented in Section 2.8 and may be referenced in relation to the site descriptions below.

4.1 SITE 6B LOCATION AND GENERAL SITE CONDITIONS

Figure E-73 shows site topography and key features of the proposed Site 6b footprint and surrounding areas. Site 6b has been significantly altered by soil borrow removal and by construction activities associated with the adjacent EMWMF. The original undisturbed elevations across the site are illustrated in subsequent site figures; the recent much lower and level site topography and alterations to the site are illustrated in Figures E-73 and E-74. Conceptual design cross sections through Site 6b (provided in the RI/FS Report) indicate as much as 50 ft of regolith has been removed across the former crest of the footprint area for borrow material, placing the current ground surface at Site 6b much closer to the underlying water table. Figure E-74 is a 2015 satellite image showing current conditions at Site 6b and relationships with the adjacent EMWMF and BCBG.

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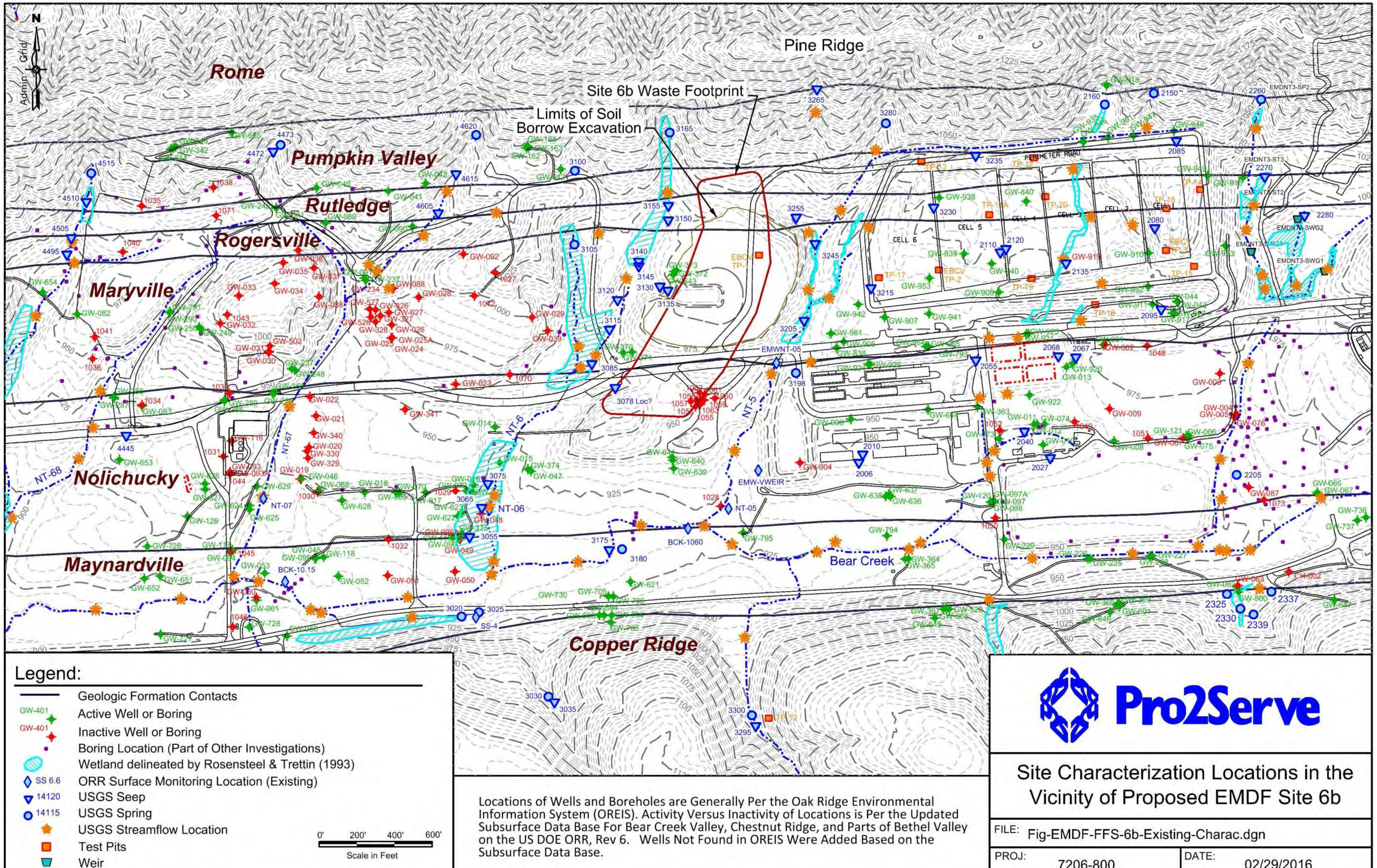

Figure E-73. Key site features and previous investigation locations at proposed EMDF Site 6b

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Figure E-74. 2015 Google satellite image roughly centered on Site 6b

North of the Haul Road, the figure illustrates grass covered areas encompassing the previous soil borrow area crossed by an EMWMF access road and runoff basin within the 6b footprint.

As shown in Figures E-1 and E-9, Site 6b is unique in that it is much longer and narrower in a general north-south direction relative to the other proposed EMDF sites. Sandwiched between the existing EMWMF on the east and the BCBG site on the west, the footprint is constrained to a relatively narrow upland area between NT-5 and NT-6. To best accommodate the estimated waste volume requirements, the footprint is elongated further north and south relative to the other sites. This places the southern part of the footprint much closer to karst features within the outcrop belt of the Maynardville limestone south of the site and extends the northern margin of the footprint up against the lower south flanks of Pine Ridge.

From north to south, the footprint spans the outcrop belts of the Friendship/Rutledge, Rogersville, Dismal Gap/Maryville, and the lower third of the Nolichucky Shale. Figure E-73 illustrates the NT-5 and NT-6 stream channels bordering the east and west sides of Site 6b, and the Bear Creek channel south of the footprint draining the upper watersheds of BCV toward the southwest. Wetland areas identified by Rosensteel and Trettin (1993) are shown in and adjacent to the Site 6b footprint along the middle and upper reaches of NT-5 and NT-6. Other features include the USGS spring, seep, and stream channel inventory and flow measurement locations and the outcrop belts of the geologic formations underlying Site 6b and adjacent areas. The contact between the Nolichucky Shale and Maynardville Limestone is located at a distance of 597ft south of the southern waste limit boundary at Site 6b.

The Site 6b footprint is centered across the former crest of a knoll underlain by the Dismal Gap/Maryville formation, leveled by the borrow excavations. Elevations across the waste footprint range from around 1015 ft on the north along the lower flanks of Pine Ridge to around 950 ft near the southeast and southwest corners of the footprint, over a range of 65 vertical feet. The main leveled part of the site sits at an elevation of about 975 ft. The northern margins of the footprint sit across a natural saddle between Pine Ridge and the former Dismal Gap knoll. Current slopes drop relatively gently toward the adjacent NT-5/NT-6 valleys east and west of the footprint and toward the valley floor along Bear Creek to the south. A pronounced northward bend along Bear Creek places it much closer to the southern boundary of the footprint than any of the other proposed EMDF sites (~550 ft from the southern boundary – See distances among the sites shown in Figure E-7). As shown in the satellite image, most of the Site 6b footprint is open with grass cover. Forested areas occur along the footprint margins adjacent to the NT-5/NT-6 valleys and adjacent to Bear Creek. The runoff sediment control basin near the left center of the footprint appears to coincide with a former east-west trending ravine that drained to the southwest into NT-6 as it still does. As shown in Figure E-9 (BCV watershed map), the southern waste limit boundary at Site 6B is the closest to Bear Creek and the Nolichucky/Maynardville contact among the four proposed EMDF sites. The closer proximity offers less opportunity for natural subsurface attenuation of contaminants within the predominantly clastic rock formations of the Conasauga Group occurring north of the Maynardville Limestone where karst features exist.

Figures E-1 and E-9 show that Site 6b is located in the eastern part of BCV in land use Zone 3 designated as DOE controlled industrial use. Site 6b (along with Site 5) is located among other historical waste sites in EBCV where source areas and ground water contaminant plumes occur. Future subsurface contaminant releases from Site 6b could commingle along downgradient surface water and ground water flow paths with existing contaminant plumes emanating from the adjacent EMWMF and BCBG, as well as ground water contaminant plumes along Bear Creek that originate from the S-3 ponds and other sources further upstream and upgradient in EBCV (See Figure E-2).

4.2 PREVIOUS INVESTIGATIONS AT AND NEAR SITE 6B

Previous reports of investigations at Site 6b are limited and mostly related to wetland and surface water assessments previously described that include wetland delineations completed by Rosensteel and Trettin (1993) and the 1994 USGS spring, seep, and stream flow inventory for BCV. Well location maps in the Y-12 subsurface database for BCV (B&W Y-12 2013) show several wells at or near Site 6b between NT-5 and NT-6 and north of Bear Creek. Figure E-73 shows the locations of wetlands, USGS inventory locations, and active and inactive wells at and near the Site 6b footprint. Additional details associated with the available well data are presented below in Secton 4.4. The Y-12 subsurface database provides some basic data for the wells but boring logs with subsurface descriptions and other data, and well construction logs are not provided.

While the site-specific data at Site 6b are limited, several more well locations and surface water monitoring stations occur at and surrounding Site 6b relative to the general absence of data at Site 7a. The characterization data available for Site 6b is primarily associated with the investigation of historical waste sites such as the BCBG located just west of Site 6b, and of ground water contaminant plumes adjacent to and south of Site 6b. Additional site characterization data along geologic strike with and east of Site 6b are available from previous investigations at the EMWMF and Site 5. Although not site-specific to the 6b footprint, the results from these sites are similar to conditions likely to exist at Site 6b. Results from previous investigations at and near Site 6b are summarized in the following sections, and provide the foundation for future investigations if Site 6b is selected for waste disposal.

4.3 SITE 6B SURFACE WATER HYDROLOGY

Surface water runoff at Site 6b flows mostly east and west directly into the adjacent north-south trending tributaries of NT-5 and NT-6, but the soil borrow activities have eliminated ravines cutting across the former knoll north of the Haul Road, and road construction and site use across much of the Site 6b footprint have greatly altered the original natural runoff conditions. Available maps suggest that there are no stream channels along the southern margin of Site 6b that drain directly into Bear Creek. Two relatively small areas have been identified for underdrains in the conceptual design for Site 6b. One occurs at the northeast corner of the footprint along a sub-tributary of NT-5. The other area is located along the west central edge of the footprint (see conceptual design drawings for Site 6b for details). That area is at western downstream end of a ravine that formerly cross cut the former knoll north of the Haul Road. The wetlands delineated along the middle and upper reaches of NT-5 and NT-6 suggest shallow ground water below the Site 6b footprint upland area migrates predominantly along downgradient pathways parallel to geologic strike to discharge along floodplain areas and stream channels along the valley floors on either side of the footprint.

The primary source of quantitative data for surface water hydrology at Site 6b comes from the 1994 USGS inventory report by Robinson and Johnson (1995). Data are also available from BCV surface water monitoring stations along the lowest reaches of NT-5 and NT-6 near their junctions with Bear Creek (stations NT-05 & NT-06), and at station BCK 10.60 along Bear Creek about halfway between the NT-5/NT-6 junctions (See locations on Figure E-73). Surface water monitoring stations associated with the EMWMF are located along the middle and lower reaches of NT-5 (EMWNT-05 and EMW-VWEIR on Figure E-73). Water quality and stream flow monitoring data for these locations are available in the DOE ORR OREIS database system accessible online.

Figures E-75 and E-76 present the USGS base flow point measurements in cfs for seep, spring, and stream channel locations at and surrounding Site 6b for March and September 1994, respectively. These figures also illustrate the original topographic contours (in green) over the former knoll near the center of the site which has subsequently been leveled for soil borrow. The March measurements represent base flow conditions during the typical spring wet season and the September measurements represent base flow conditions during the typical late summer/fall dry season. Flow measurements are presented for the NTs and the section of Bear Creek south of Site 6b. As noted above, the zero values indicate flows below the minimum reportable discharge of 0.005 cfs (2.2 gpm). The zero values do not indicate the stream channels were necessarily dry but that stream flow rates were extremely low and immeasurable using the USGS field methods and equipment. Also as noted above, some of the GPS plotted locations were moved to better coincide with stream channels, site topography, and the locations shown on the USGS schematic drawings.

The two seep locations at USGS stations 3130 and 3135 within or close to the borrow area may have been eliminated, but March and September measurements were recorded as zero. Elsewhere the USGS locations appear to be unimpacted by site clearing/grading work. The “zero” base flow in both the wet and dry season measurements at 3130 and 3135 suggest that seepage flow was recognizable even if not measureable. No recent field reconnaissance has been conducted at Site 6b to verify or document conditions at any of the USGS locations.

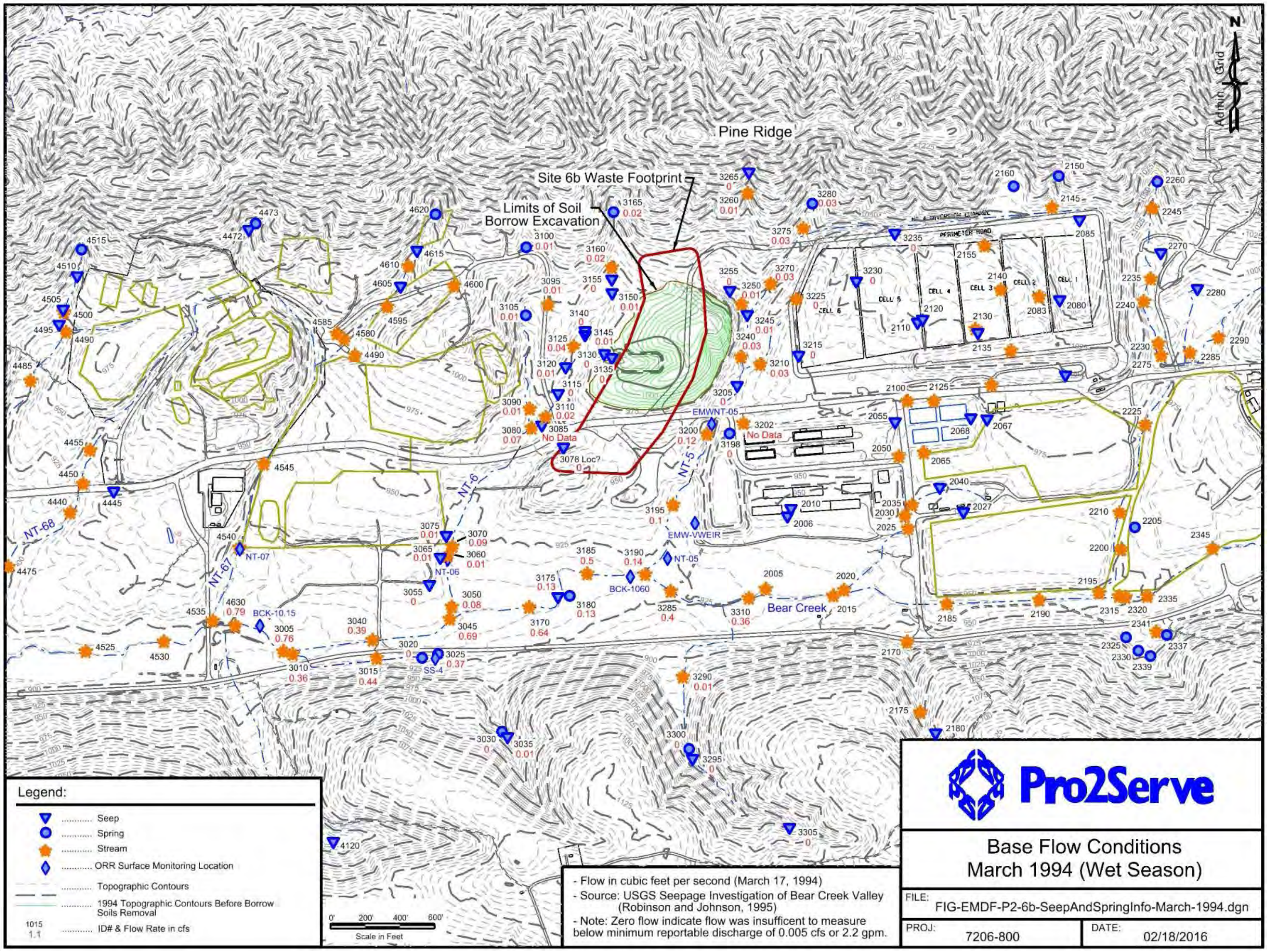

Figure E-75. USGS flow rates measured under base flow conditions in March 1994 at locations surrounding Site 6b

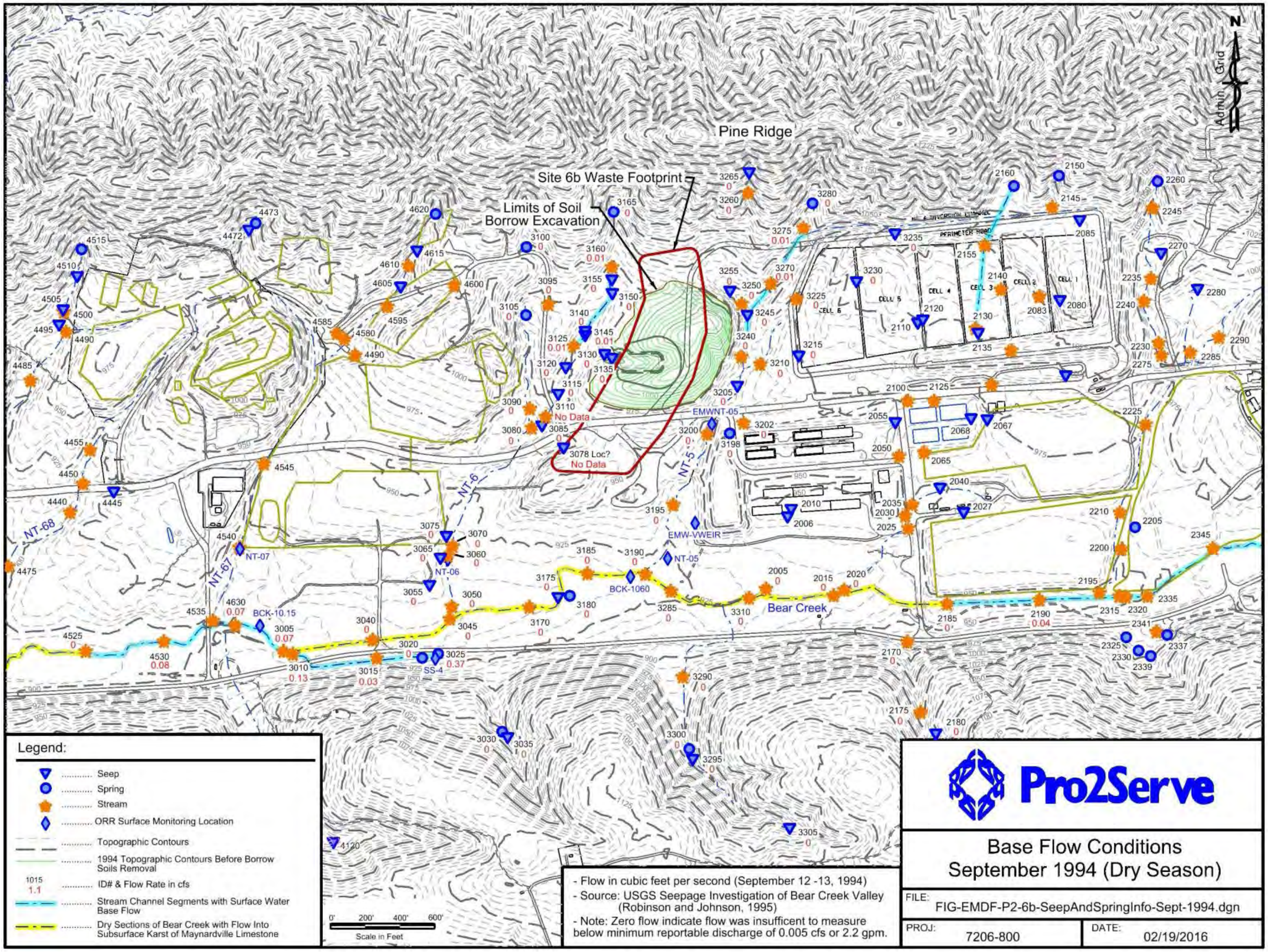

Figure E-76. USGS flow rates measured under base flow conditions in September 1994 at locations surrounding Site 6b

The March data indicate base flow along NT-5 ranging from 0.03 cfs at the headwater spring north of 6b increasing downstream to flows of 0.10-0.12 cfs on the middle to lower reaches of NT-5. The March data also show continuous base flow along NT-6 from 0.02 cfs at the headwater spring down to 0.08-0.09 cfs along the lower reaches of NT-6 near Bear Creek. March flow along Bear Creek south of Site 6b is shown to be continuous, ranging from 0.36 to 0.79 cfs. In great contrast, the September base flow data on Figure E-76 illustrates a dry segment of Bear Creek up and downstream of Site 6b where all of the baseflow surface water during the dry season is diverted into subsurface conduits within the karst flow system of the Maynardville Limestone. This dry segment, highlighted in yellow on Figure E-76, is several hundred feet long and occurs between USGS station 2185 and 3005. The BCV RI Report (DOE 1997) provides detailed descriptions of this and other segments along Bear Creek based on more detailed flow rate monitoring along Bear Creek. The September base flow data along NT-5 and NT-6 also indicate mostly zero flows except for segments along the upper reaches of NT-5 and NT-6 where low flows of 0.01 cfs were recorded as highlighted in blue in Figure E-76.

Except for the segment of dry season baseflow capture along Bear Creek, the USGS data near Site 6b is reasonably consistent with similar data for the other EMDF sites. Results suggest that dry season NT stream base flow is negligible but may occur during short intermittent pulses after significant rainfall/runoff events. As noted for Site 7a and 14, the full year of Site 5 Phase I stream monitoring data strongly suggests that wet season stream flow along NT-5 and NT-6 is likely to be continuous. While the NT dry season flow is intermittent, the USGS data suggest that flow along Bear Creek south of Site 6b is continuous only during the wet nongrowing season even though it is almost certainly perennial within the karst conduits below the stream channel of Bear Creek. The results also suggest that over the course of a year some or all of the surface water draining from the NT-5 and NT-6 watersheds is diverted to subsurface conduits where those stream channels cross into the outcrop belt of the Maynardville Limestone along the lower reaches of NT-5 and NT-6 (See geologic contact location on Figure E-73, only 597 feet below the south edge of the Site 6b footprint).

4.4 SITE 6B HYDROGEOLOGY

The detailed subsurface hydrogeological conditions at Site 6b are poorly known but data available from a few well clusters in and adjacent to the footprint provide some basic site characterization data. Analysis of the Y-12 subsurface database indicates a total of eleven wells clustered at five locations within the upland area between NT-5 and NT-6, and north of Bear Creek (See Figure E-73). The Y-12 database report (B&W Y-12, 2013) does not include copies of original descriptive boring or well construction logs, but does include some well construction data, depths to the top of weathered and fresh bedrock, water level data (max/min/mean values), approximate dates of water quality sampling, and other general information about the wells.

Among the eleven wells, GW-909 was the only well apparently formerly located within the waste footprint. The Y-12 database maps show the location near the center of the footprint but the well was shallow (total depth of 26.10 ft bgs), plugged and abandoned in 1991, and the borehole would have been completed eliminated during site leveling. The database indicates no water level data or sampling history for GW-909. Each of the other four well locations at Site 6b includes either two or three well clusters completed at shallow to intermediate levels in the saturated zone. Total depths of these wells range from 24.3 ft in GW-641 to 158 ft in GW-373. These wells generally include water level data and were sampled for water quality. If Site 6b is selected, the available subsurface data from the five locations could provide some fundamental control points for depths to ground water and bedrock, but additional data would be needed for understanding detailed hydrogeological conditions and to support engineering design and risk assessment/WAC modeling.

Detailed ground water contaminant plume maps and cross sections presented in Volume 2 of the Groundwater Strategy report for the ORR (UCOR 2013a) illustrate the extent of nitrate, alpha, beta, and

VOC [represented by trichloroethene (TCE)] ground water contamination in the shallow (<100 ft depth) and intermediate/deep intervals (>100 ft depth) in EBCV around Site 6b. The plume maps illustrate no nitrate and no beta contamination near Site 6b. However, the plume maps illustrate alpha activity in shallow ground water near the GW-047/GW-374 cluster and TCE contamination in shallow ground water at the GW-047/GW-374 cluster and near the GW-370/GW-371 cluster along the southwest and west margins of Site 6b. The occurrences along the margins of Site 6b appear to represent relatively low concentrations along the upgradient eastern margins of plumes originating from the BCBG. EMDF ground water detection and compliance monitoring that would be required along the western and southwestern downgradient margins of Site 6b have the potential to be complicated by some contaminants originating from the BCBG and potential future commingling of ground water contamination from Site 6b. Complications might also occur in establishing statistically valid background levels for baseline ground water chemistry at Site 6b prior to initial disposal operations (based on at least four quarters of ground water sampling and analysis). Detailed results of ground water sampling and laboratory analysis from the wells at and near Site 6b have not been evaluated but should be available in the OREIS database.

The “Pickett B” and adjacent wells south of Bear Creek and Site 6b (see the several wells near GW-705 in Figure E-73) provide subsurface data for karst flow conditions and water quality in the Maynardville Limestone. But wells are absent directly north of these wells in the vicinity of Bear Creek and the lower more shallow stratigraphic intervals of the Maynardville, where ground water contaminants potentially spreading south from Site 6b might first enter the Maynardville flow regime.

Water table contour maps are not available for Site 6b, but maps for Sites 14 and 5, and for the EMWMF indicate the likelihood that the water table is elevated below the upland areas of the 6b waste footprint and slopes primarily toward the east, west, and south to converge with stream channels and near surface regolith/floodplain materials along the lengths of NT-5 and NT-6, and along Bear Creek to the south. The significant removal of borrow (regolith soils and saprolite) at 6b suggests that the water table may be closer to the flattened and lowered ground surface at 6b relative to similar upland areas that have not been excavated. Generalized ground water flow paths and hydraulic gradients at Site 6b are likely to be similar to those at the other EMDF sites as modified by local topography. Horizontal gradients may be lower than at the other sites based on excavation and leveling at Site 6b. Bedding plane fractures and joints that are strike-parallel will generally tend to drain ground water more rapidly toward the adjacent NTs than toward the south across the strike of the beds. As previously noted, the water table is constrained during the wet season to elevations at or just below the stream channels along the lengths of the NT tributaries and Bear Creek adjacent to the site.

5. SITE 7A – CENTRAL BEAR CREEK VALLEY

Similar to Site 6b, almost no site-specific data are available at and near Site 7a. The following subsections review the site location, general site features, limited results of previous investigations, and the surface water and hydrogeological conditions at and near Site 7a. The hydrogeological site conceptual model for BCV and Site 7a are presented above in Section 2.8 and may be referenced in relation to the site descriptions below.

5.1 SITE 7A LOCATION AND GENERAL SITE CONDITIONS

Figure E-77 shows site topography and key features of the proposed Site 7a footprint and surrounding areas. The figure illustrates the NT-10 and NT-11 stream channels bordering the east and west sides of Site 7a and Bear Creek south of the footprint and draining the BCV watershed toward the southwest. Wetland areas identified by Rosensteel and Trettin (1993) are shown in and adjacent to the Site 7a footprint along the middle and upper reaches of NT-10 and NT-11.

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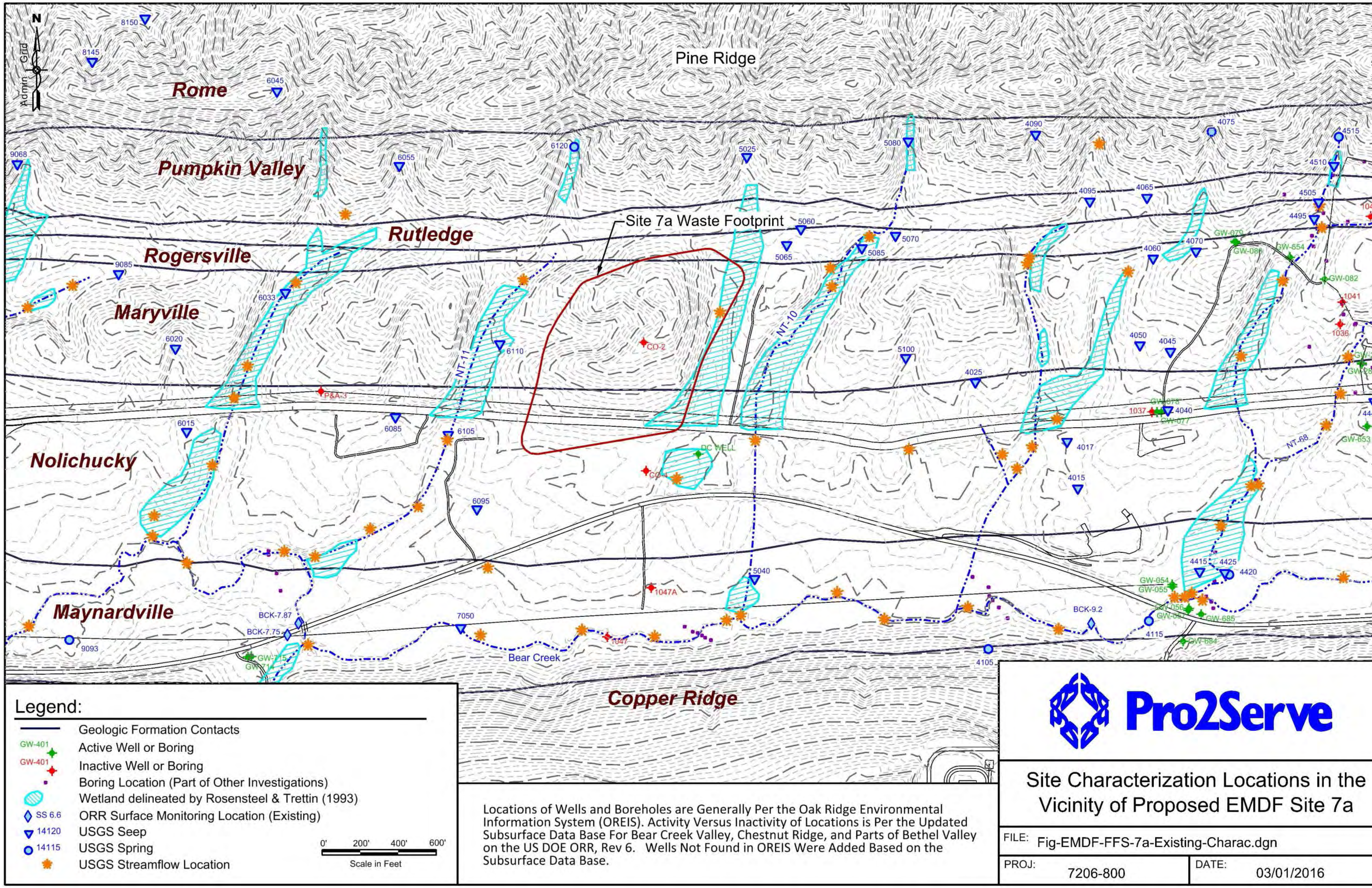

Figure E-77. Key site features and previous investigation locations at proposed EMDF Site 7a

Other features include the USGS spring, seep, and stream channel inventory and flow measurement locations and the outcrop belts of the geologic formations underlying Site 7a and adjacent areas. The contact between the Nolichucky Shale and Maynardville Limestone is shown at a distance 593 ft south of the southernmost waste limit boundary of Site 7a.

The Site 7a footprint is centered just south of the crest of the knoll or spur ridge that is underlain by the Dismal Gap/Maryville formation. The footprint spans the entire outcrop width of the Dismal Gap/Maryville and extends southward across roughly a third of the outcrop belt of the lower Nolichucky Shale. Elevations across the footprint range from around 1050 ft on the crest of the Dismal Gap knoll to 895 ft at the southwest corner, or 155 vertical feet. The northern edge of the footprint sits just south of a saddle between Pine Ridge and the Dismal Gap knoll. Slopes drop sharply along the east side of the footprint into the adjacent valley of the west tributary of NT-10 (designated as NT-10W).

As shown in the 2015 satellite image of Figure E-78, Site 7a and the surrounding area are entirely forested except for areas along the south side of the footprint between the Haul Road and Bear Creek Road, where the area has been cleared. The cleared area includes a recent soil borrow area south and southwest of the southern footprint margin, and two newly constructed wetland basins completed in 2015 for wetland mitigation.

Figure E-78. Circa 2015 Google satellite image roughly centered on Site 7a

As shown in Figure E-9 (BCV watershed map), the southern waste limit boundary at Site 7a is closer to Bear Creek and the Nolichucky/Maynardville contact than the equivalent boundary at Site 5. Unlike the other three proposed footprints, the 7a footprint does not extend as far north as the other sites, placing the entirety of the waste mass relatively closer to Bear Creek relative to the other EMDF sites. Relative to the other EMDF sites, Site 7a is also located near the middle length of BCV roughly midway between the headwaters region and SR 95. Site 7a is located in land use Zone 2 designated for recreational use in the BCV ROD, whereas Site 6b is located further upstream in BCV within Zone 3, designated as DOE controlled industrial use (see Figure E-1). Site 7a is located in a mostly undisturbed forested area of BCV around 2000 ft southwest of the BCBG, the historical waste site located farthest downstream in Zone 3. The Site 7a footprint is located within the mid to upper reaches of the NT-10/NT-11 tributaries upslope and hydraulically upgradient of and isolated from ground water contaminant plumes and surface water contaminants emanating from the waste sites in Zone 3 of EBCV (See Figure E-2).

5.2 PREVIOUS INVESTIGATIONS AT AND NEAR SITE 7A

Previous reports of investigations at Site 7a are limited and mostly related to wetland and surface water assessments. They include the wetland delineations completed by Rosensteel and Trettin (1993) and the 1994 USGS spring, seep, and stream flow inventory for BCV. Well location maps in the Y-12 subsurface database for BCV (B&W Y-12 2013) show only five wells at or near Site 7a between NT-10/NT-11 and north of Bear Creek (see well locations shown on Figure E-77). Of those only one is designated as active (DC Well), with the other four designated as inactive wells (CO-2, CO-4, 1047, and 1047A). Only one location (CO-2) is within the footprint of Site 7a. The other locations are south of the footprint. A 1995 report by SAIC is noted in the Y-12 database with regard to the wells near Site 7a but the database report does not include a full report reference so the purpose of the wells is unclear. The Y-12 database report provides some basic well construction data for the wells but boring logs with subsurface descriptions and other data, and well construction logs are not provided. The subsurface data for Site 7a is therefore quite limited.

5.3 SITE 7A SURFACE WATER HYDROLOGY

Figure E-77 illustrates delineated wetlands and the nearest USGS inventory locations for springs, seeps, and stream measurement locations at and near Site 7a. Surface water runoff at Site 7a flows mostly east and west directly into the adjacent north-south trending tributaries of NT-10W and NT-11. Runoff to the north flows toward the saddle between Pine Ridge and the ridge crest near the center of the 7a footprint. Runoff along the southern third of the footprint flows to the southeast and southwest into the lower reaches of NT-10 and NT-11; surface water at Site 7a does not follow any valleys or ravines directly into Bear Creek to the south of the site. One major ravine drains to the west-southwest near the center of the footprint. This east-west trending ravine and the north-south trending course of NT-10W are both identified as significant drainage pathways that warrant underdrain networks at Site 7a (see conceptual design for Site 7a for details). The wetlands delineated along the mid reaches of NT-10W and NT-11 suggest shallow ground water below the Site 7a footprint upland area migrates predominantly along downgradient pathways parallel to geologic strike to discharge along floodplain areas and stream channels along the valley floors on either side of the footprint.

The primary source of quantitative data for surface water hydrology at Site 7a comes from the 1994 USGS inventory report by Robinson and Johnson (1995). Two BCV surface water monitoring stations along Bear Creek nearest Site 7a occur upstream at BCK 9.20 just below the confluence of Bear Creek and NT-9, and downstream of Site 7a just south of the culvert where Bear Creek flows north under Bear Creek Road (see Figures E-77 and E-79). Monitoring data for these locations and others along Bear Creek are available in the DOE ORR OREIS database system available online. Figures E-79 and E-80 present the USGS base flow point measurements in cfs for seep, spring, and stream channel locations at and surrounding Site 7a for March and September 1994, respectively. The March measurements represent base flow conditions during the typical spring wet season and the September measurements represent base flow conditions during the typical late summer/fall dry season. The locations cover the primary ravine cross cutting the Site 7a footprint and one just south of the footprint, and the watersheds of NT-10 and NT-11, as well as the section of Bear Creek to the south of Site 7a. As noted above, the zero values reported by the USGS indicate that flow was insufficient to measure below the minimum reportable discharge of 0.005 cfs (2.2 gpm).

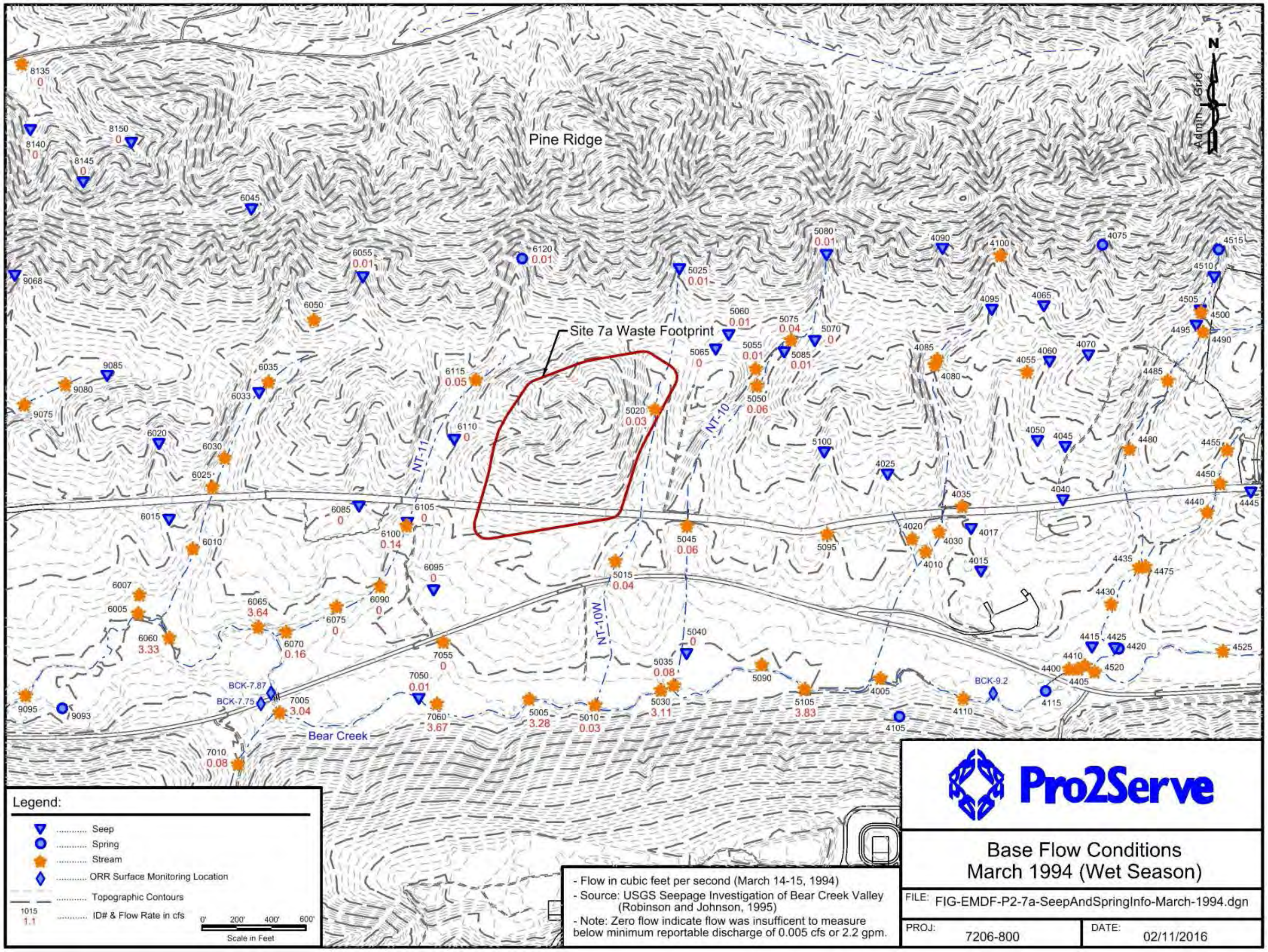

Figure E-79. USGS flow rates measured under base flow conditions in March 1994 at locations surrounding Site 7a

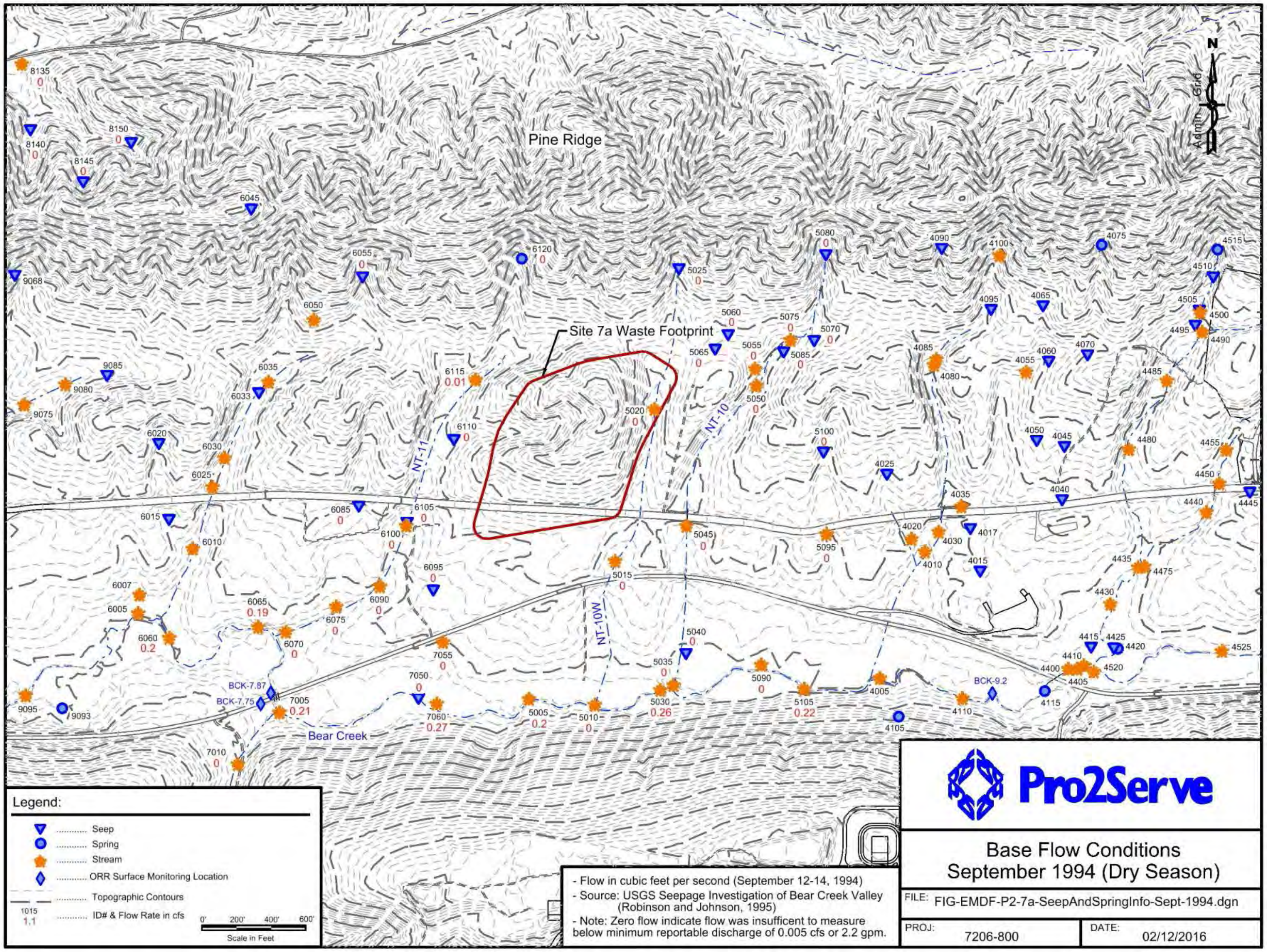

Figure E-80. USGS flow rates measured under base flow conditions in September 1994 at locations surrounding Site 7a

The zero values do not indicate the stream channels were necessarily dry but that stream flow rates were extremely low and immeasurable using the USGS field methods and equipment. Also as noted above, some of the GPS plotted locations were moved to better coincide with stream channels, site topography, and the locations shown on the USGS schematic drawings.

For March and September, the USGS data show zero base flow at the seep (6110) located within the 7a footprint, and zero base flow at the seep just southwest of the footprint (6095). The "zero" base flow in both the wet and dry season measurements at these two locations suggest that seepage flow was recognizable (probably at least during the wet season event) even if not measureable. No recent field reconnaissance has been conducted at Site 7a to verify or document conditions at any of the USGS locations.

The March data indicate base flow along NT-10W ranging from 0.01 cfs at a headwater seep north of 7a increasing downstream to flows of 0.03-0.04 cfs on the lower reaches of NT-10W. Site topography and the USGS schematic drawings indicate that NT-10W flows directly south to Bear Creek without joining the channel along NT-10 just east of NT-10W. The March data also show continuous base flow along NT-11 from 0.01 cfs at a headwater spring down to 0.14 cfs near its confluence with Bear Creek. March flow along Bear Creek south of Site 7a is shown to be continuous, ranging from 3.04 to 3.83 cfs. September base flow along Bear Creek is also continuous but an order of magnitude less than March base flow – ranging from 0.19 to 0.27 cfs. Not all of this flow increases downstream suggesting the possibility of some potential loss to subsurface karst conduits in the area around the NT-11 junction where flows are lower than those upstream. The September base flow data for NT-10 and NT-10W are zero across the entire length of these tributaries, and similar along NT-11 except for a central reach along the west side of the 7a footprint where the USGS maps indicate minor flow of 0.01 cfs (4.5 gpm) at and below station 6115 down to station 6105 where zero flow recurs down to the confluence with Bear Creek.

The USGS data near Site 7a is consistent with similar data for other EMDF sites and suggests that dry season NT stream flow adjacent to the site that occurs between intermittent pulses of rainfall/runoff events may be negligible. The full year of Site 5 Phase I stream monitoring data strongly suggest that wet season stream flow along NT-10/-10W and NT-11 is continuous. While the NT dry season flow is intermittent, the USGS data suggest that flow along Bear Creek south of Site 7a is perennial throughout the year.

5.4 SITE 7A HYDROGEOLOGY

The detailed subsurface hydrogeological conditions at Site 7a are unknown based on the very limited amount of available site characterization data. Searches in the 2013 pdf file version of the Y-12 subsurface database for the five well locations at and near Site 7a indicate: 1) the former wells at CO-2, CO-4, 1047 (CO-1), and 1047A (CO-2) were all plugged and abandoned in 1993 and 1995; 2) no cores, no logs, and no water level data are available; 3) the wells were all completed as open holes at varying depths, apparently installed by the USGS; and 4) references to SAIC reports are not provided so that it is unclear whether any original data such as boring logs or well construction logs are available. The absence of fundamental data (e.g - boring log descriptions of soils and bedrock and ground water level data) from these well locations means that there is essentially no significant data to evaluate site-specific hydrogeological conditions at Site 7a. Basic data such as depths to bedrock (or thickness of overburden regolith) and variations in the thickness of the unsaturated zone across the site (i.e - depths to and configuration of the water table) are unknown. Data from Sites 14 and 5 where the upland areas between adjacent NT valleys have been characterized suggest that regolith thickness could vary from about 10-40 ft or more (surface casing depths at CO-2 and CO4 locations were 10 ft and 37 ft, respectively). The water table contour maps for Sites 14 and 5 suggest that water table "mounds" occur below the subsidiary ridge crests of the upland areas underlain by the Dismal Gap/Maryville formation in BCV where the EMDF footprints partially occur. These mound areas appear to be fed by localized infiltration of precipitation and water table recharge directly across the crest areas. It is also known from the other EMDF sites and the EMWMF that the water table surface converges toward and is constrained locally by the stream channel elevations along the NTs and NT sub-tributaries.

It is reasonable to assume that a local water table mound occurs below the ridge crest near the center of the 7a footprint where infiltration and recharge occurs, and that generalized ground water flow paths and hydraulic gradients convey ground water radially away from the crest area toward the adjacent NTs and to the south toward Bear Creek. Bedding plane fractures and joints that are strike-parallel will generally tend to drain ground water more rapidly toward the adjacent NTs than toward the south across the strike of the beds. The lack of any site-specific data represents a significant technical data gap for Site 7a, and results in much greater uncertainty regarding the proposed base elevations for the landfill cells presented in the conceptual design for 7a (see Chapter 6 of the RI/FS Report). If Site 7a is selected for the EMDF, new site specific hydrogeological and geotechnical data will be required to establish key relationships between the base cell elevations and the underlying water table and bedrock configuration, as well as other data required for detailed design, modeling, etc.

6. SITE 14 - WEST BEAR CREEK VALLEY

Extensive site characterization activities and research were conducted in the WBCV area at and west of Site 14 in support of the LLWDDD program in the 1980's and 1990's. The proposed LLWDDD above ground "tumulus" facility was never constructed but surface and subsurface conditions were investigated and culminated in a PA report (ORNL 1997) for a location within the current Site 14 footprint. Results from the many investigation reports and research papers provide data for Site 14 that are unavailable at Sites 7a/6b (and to a lesser extent Site 5) where little characterization data exists. Because the proposed EMDF sites are all located roughly along geologic strike with one another and in areas of generally similar topography, the results from Site 14 provide insights into similar conditions that may be encountered at Sites 7a/6b and at Site 5. The site conceptual model for Site 14 was presented above in Section 2.8.2 and may be referenced to supplement materials presented below.

Because of the considerable amount of information available for Site 14, the site descriptions below are much more extensive than that for Sites 6b and 7a. The many characterization reports and research papers available for Site 14 should be referenced for additional details only summarized below.

6.1 LOCATION AND GENERAL SITE CONDITIONS

Figure E-81 shows site topography and key features of the WBCV area and the proposed footprint for EMDF Site 14. The figure illustrates the NT-14 and NT-15 stream channels bordering the east and west sides of Site 14 and Bear Creek south of the footprint draining the BCV watershed toward the west. Wetland areas identified by Rosensteel and Trettin (1993) are shown in and adjacent to the Site 14 footprint and for the nearest areas downstream of the site. Other features include the USGS spring, seep, and stream channel inventory and flow measurement locations and the outcrop belts of the geologic formations underlying Site 14 and adjacent areas. The important contact between the Nolichucky Shale and Maynardville Limestone is shown at a distance 656 ft south of the southern waste limit boundary of Site 14. A more detailed topographic map was prepared for the WBCV area in 1984 with 2-ft contour intervals that illustrates site features in greater detail than those of Figure E-81 based on current CADD drawings with a 5-ft contour interval (see subsequent figures).

The Site 14 footprint is roughly centered across a knoll or spur ridge south of Pine Ridge that is underlain by the Dismal Gap/Maryville formation. This subsidiary ridge parallels Pine Ridge throughout BCV and similar knolls or spur ridges are found at each of the proposed EMDF footprints.

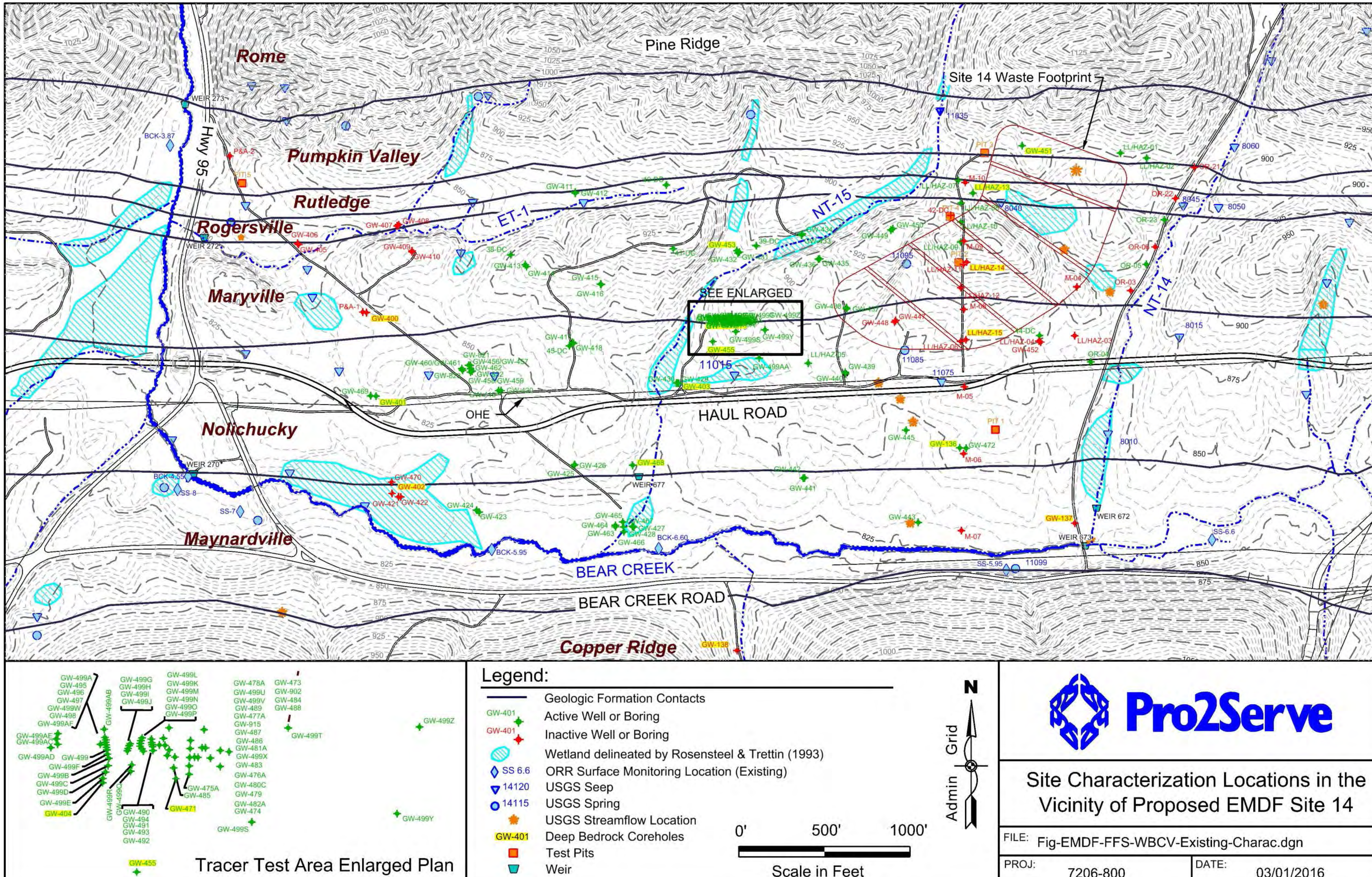

Figure E-81. Key site features and previous investigation locations at proposed EMDF Site 14 in WBCV

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Elevations across the footprint range from around 960 ft along the base of Pine Ridge and the crest of the knoll near the center of the site, to a low of around 865 ft at the southwest corner of the footprint spanning a total vertical range of 95 vertical feet. A saddle cuts across the northern third of the site separating the Dismal Gap knoll from the south flank of Pine Ridge. Slopes drop sharply along the northwest side of the footprint into the adjacent valley of NT-15. Site 14 and the surrounding area are entirely forested.

As shown in Figure E-9 (BCV watershed map), the southern waste limit boundary at Site 14 is closer to Bear Creek and the Nolichucky/Maynardville contact than the equivalent boundary at Site 5, but less than the southern margins of Sites 7a and 6b, which sit closer to Bear Creek and the geologic contact. The greater the separation between the site and these features the greater the potential for natural attenuation of any future ground water contaminant releases from the site footprints.

Site 14 is located farthest downstream in BCV relative to the other proposed EMDF sites, and the only proposed site within land use Zone 1 designated for unrestricted use per the BCV ROD (see Figure E-1). The site is located in a mostly undisturbed area of BCV farthest downstream from historical waste sites and not impacted by ground water contaminant plumes or surface water contaminants emanating from historical waste disposal sites in Zone 3 of EBCV.

6.2 PREVIOUS INVESTIGATIONS AT AND NEAR SITE 14

Previous investigations at and near Site 14 in WBCV include surface and subsurface field investigations, monitoring, testing, and the development of conceptual and computer models of contaminant fate and transport. The previous investigations also include several other investigation and research projects shedding light on the complex surface water hydrology and hydrogeology of BCV and Site 14. Most of the work appears to have been coordinated and contracted by staff of Martin Marietta Energy Systems (MMES), the prime DOE contractor for the ORR facilities at the time. The reports documenting investigations and research come primarily from contractor reports prepared by Golder Associates, Inc. (Golder), and those prepared by MMES under the auspices of ORNL. A USGS report (Robinson and Johnson 1995) documents the locations and base flow characteristics of springs, seeps, and streams in BCV including the WBCV Site 14 area. Results of the USGS and Golder/ORNL investigations specific to Site 14 are addressed below as part of the review of surface water hydrology and hydrogeology for Site 14.

It should be noted that the many reports and research papers comprise hundreds of pages of text, tables, figures, plates, and raw and plotted data. The summaries below are therefore no substitute for a review and evaluation of the original materials. If Site 14 is selected as the EMDF, these materials will warrant detailed reviews by project participants as a foundation for future work and to avoid redundant site characterization.

6.2.1 Golder Reports

Most of the original investigations near Site 14 were reported by Golder in a series of reports from 1988-1989 (Golder 1988a/b/c/d, and 1989a/b/c). Golder was tasked “to perform a geohydrologic site characterization and ground water flow computer model” for the proposed LLWDDD site. Their work included the following major sequential tasks:

1. Work Plan Development
2. Well Logging and Geohydrologic Testing
3. Hydraulic Head Data Collection
4. Groundwater Geochemical Sampling and Analysis
5. Contaminant Transport Model Validation
6. Groundwater Flow and Contaminant Transport Conceptual Model
7. Groundwater Flow and Contaminant Transport Computer Model

Reports documenting results of these tasks were obtained by Pro2Serve from Golder in 2012 for Tasks 3, 4, 6, and 7 but could not be obtained for Tasks 1 and 2. The Task 2 report (Golder 1988a) was apparently submitted in six volumes. A pdf file version of Volume II of VI of the Task 2 report was obtained and includes three Appendices A, B, and C, with some important data relevant to Site 14. The Volume II Appendix A includes eight procedures for field methods including rock core and borehole logging, packer and pump tests, and others. Appendix B1 includes rock core logs for ten of the deep bedrock coreholes continuously cored to great depths at various locations across the WBCV area to define most of the entire bedrock sequence of the Conasauga group formations. The logs include those for GW-136, GW-137, GW-138, GW-400, GW-401, GW-402, GW-403, GW-404, GW-453, and GW-468. While these logs provide general descriptions for each of the rock formations (i.e. – Pumpkin Valley, Friendship/Rutledge, Rogersville, etc.) and include details on core recovery, rock quality designation (RQD), and other subsurface data, they do not provide detailed stratigraphic columns for each well. The logs do not graphically or descriptively subdivide the geologic formations into a detailed vertical sequence showing principal lithologies and thicknesses/intervals on a bed by bed basis. They do provide depth specific notes identifying joints, fracture depths/intervals, general bedding plane dips, and other subsurface features forbedrock intervals that encompass hundreds of feet of rock core. Appendix B2 includes boring logs and monitoring well construction logs for 21 individual wells and well clusters in the WBCV area. Appendix C includes rising head slug test data and time/water level recovery plots for 45 slug tests conducted by Golder. The absence of the Task 2 report (Golder 1988a) excludes the presentation of the original data and interpretations that are likely relevant to Site 14 (e.g. - geohydrologic testing results not provided in other Golder reports). Attempts to find the complete Task 2 report with the main report and all appendices through local DOE information repositories and contractor sources (personal communication with D. Ketelle – September 2015) have been unsuccessful.

A pdf file version of the Task 5 report was obtained separately but did not include any Plates or any appendices. The Task 5 report includes results, summary tables, interpretations, and conclusions relevant to Site 14 EMDF planning and design, but important Plates and Appendices are missing that would provide significant additional detail [Missing appendices include: A) rock core logs; B) packer test data and analyses, C) field boring and well installation; D) slug test data and analyses; and E) tracer area pump test data and analyses]. However, well locations, and basic well construction and some water level data are available through the Y-12 subsurface database for BCV (B&W Y-12 2013) maintained and periodically updated by the Y-12 Environmental Compliance Department. In addition, some drilling and well construction logs, well hydrographs, and stream flow data are available for the WBCV area from the *Data Package for the LLWDDD Program Environmental Impact Statement* (see Appendix F, G, and H of ORNL 1988), and from other unpublished electronic data files reviewed below. The following subsections sequentially review some of the key aspects of each of the Golder reports that bear on Site 14.

6.2.1.1 Golder Task 2

As shown by the locations in Figure E-81, the Task 2 and subsequent field efforts included the drilling, logging, and installation of many monitoring wells, cluster wells, and piezometers across the area between SR 95 and NT-14 including the WBCV Site 14 footprint. At and near the Site 14 footprint, fifty seven well locations were drilled within the area between NT-14 and NT-15 north of Bear Creek. However, 40% (23 of the 57) of the locations represent wells that are no longer functional (i.e. - plugged and abandoned, destroyed, etc.), including most of the wells located within the Site 14 waste limits (10 out of 14). These numbers do not include the additional 72 or more locations of wells and well/piezometer clusters within a localized area roughly 250 x 100 ft in size used for tracer testing, K testing, and pumping tests located about 700 ft west of the southwest edge of the Site 14 footprint (see Figure E-81 inset). This area includes one of the most intensively studied subsurface areas on the ORR. In the absence of the Task 2 Golder report, the details and results of the Task 2 investigation remain a data gap for the previous investigations at and adjacent to Site 14.

6.2.1.2 Golder Task 3

The Task 3 investigation (Golder 1988b) included five synoptic water level measurement events (Aug/Nov 1987 and Feb/May/July 1988) conducted manually on a quarterly basis in 113 monitoring wells ranging in depth from 6 to 863 ft, and continuous monitoring in 11 selected wells (16.5 to 398 ft deep). Potentiometric surface contour maps for the “near surface system” (equivalent to the water table interval described by Solomon et al 1992)) were provided for the August 1987 and May 1988 events. Scanned copies are shown in Figures E-82 and E-83 covering the same general area shown in Figure E-81. The Site 14 footprint is centered across the spur ridge underlain by the Dismal Gap/Maryville formation. The water table contours in the eastern half of the figures spans roughly two thirds of the Site 14 footprint. The arrows in the figures are drawn perpendicular to the contours and show generalized flow directions for shallow ground water from upland recharge areas toward discharge areas along the nearby valley floors of NT-14 to the east/southeast, NT-15 to the west/northwest, and Bear Creek to the south. At the local scale, the figures show the likely steep hydraulic gradients from the topographic highs within the Site 14 footprint down toward the northwest into the relatively narrow valley of NT-15, and the local influences of the footprint ravines draining east to NT-14 and south toward Bear Creek. Underdrain networks are recommended for these two ravines in the conceptual design for Site 14. These water table contour maps indicate the strong influence of site topography and the adjacent NT stream channels that constrain the local base level elevations of the water table along the NT valley floors coincident with ground water discharge. These same constraints occur locally at each of the proposed EMDF site in BCV. The contour maps do not, however, clearly reflect the complex and dominant strike-parallel flow paths in saprolite and bedrock fracture networks that are superposed with horizontal and vertical hydraulic gradients as demonstrated from tracer tests and pumping tests in BCV and elsewhere on the ORR. These fracture flow paths tend to transfer ground water more rapidly along strike toward the NT valleys and ravines crossing and adjacent to the Site 14 footprint relative to fractures and joints oriented perpendicular to strike. While the contours reflect the general pathways, the fracture flow (and contaminant) pathways may locally deviate from flow directions suggested by the hydraulic gradients depicted in Figures E-82 and E-83, influenced greatly by the orientation of geologic strike with respect to surface topography.

The Task 3 report includes tables with well construction data for 118 of the original GW-400 series of wells/piezometers (GW-402 through GW-499P). Continuous water level monitoring was conducted in 11 wells instrumented with pressure transducer/data loggers. Eight of the wells were located within the tracer study site just downslope and southwest of Site 14. The other three wells were located in a cluster within a wetland area near Bear Creek roughly 2000 ft further southwest of the tracer well field. Hydrographs were provided for the instrumented wells showing ground water level fluctuations over the continuous monitoring period from March to June 1988.

Golder established a temporary meteorological station at their field trailer just west of NT-15 and Site 14 (near the GW-640 well cluster), to gather data for precipitation, evaporation, air temperature, barometric pressure, and relative humidity. The data were gathered mostly on a daily basis from October 1987 to February 1988. The site specific data were supplemented with data from the NOAA facility in Oak Ridge and precipitation data from the BCBG. The data were used to support water budget analyses conducted under Task 4 and for comparison with the continuous ground water level data. Continuous head data were also used to evaluate previous packer test results from Task 2 (unavailable), and to evaluate hydraulic heads in the deep aquifer system. Golder concluded that the deeper ground water system “*appears to obey gravity flow since higher heads are observed under elevated portions of the site and lower heads are observed under Bear Creek*.” (p. 30 Golder 1988b). Golder provided an Addendum to Task 3 in July 1989 (Golder 1989a) providing additional continuous monitoring data extending the monitoring period through December 4, 1988. The addendum did not include hydrographs, only the raw data.

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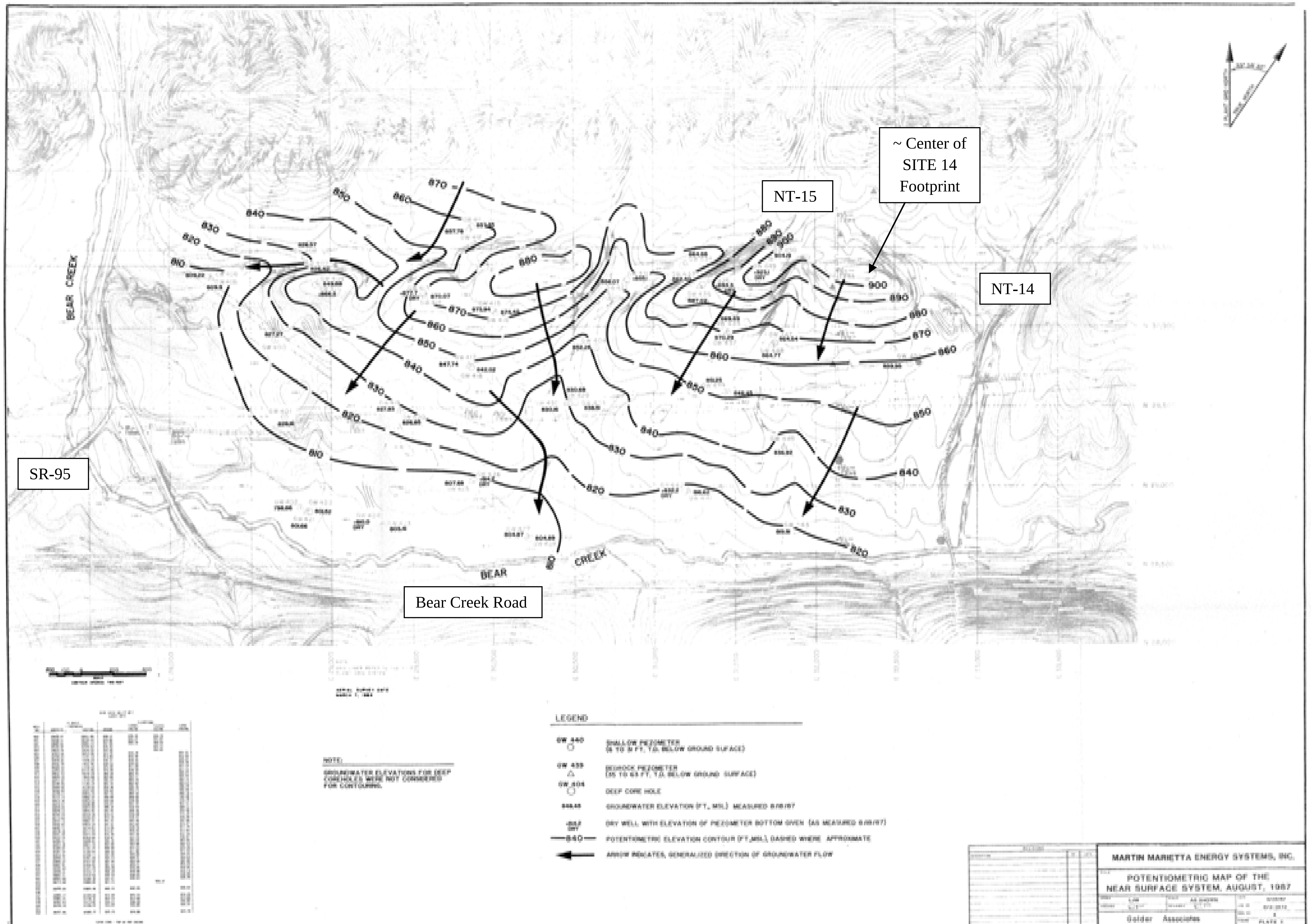

Figure E-82. August 1987 potentiometric surface contour map for the water table interval ("near surface system") at the WBCV site (from Golder 1988b)

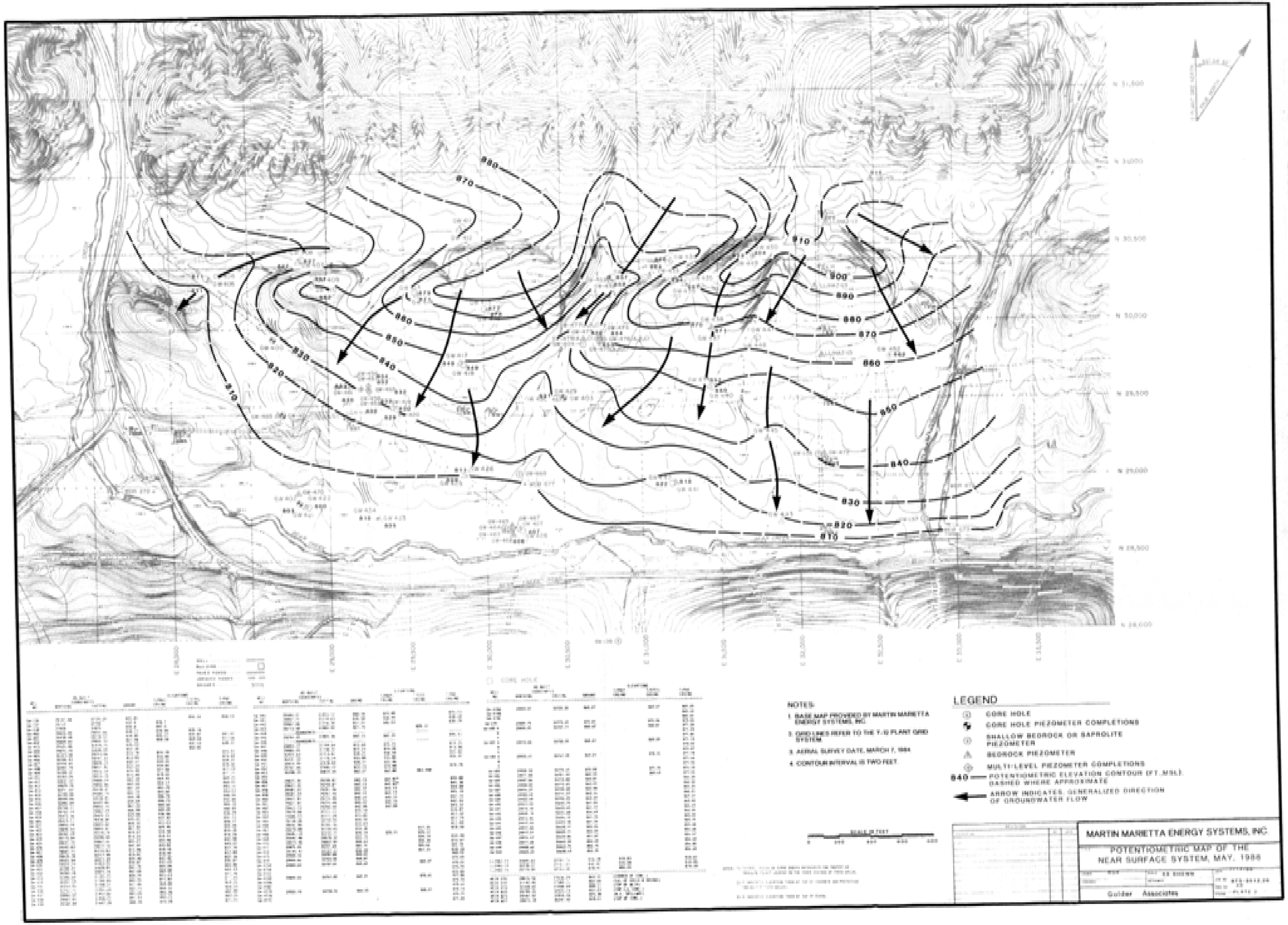

Figure E-83. May 1988 potentiometric surface contour map for the water table interval at the WBCV site (from Golder 1988b)

6.2.1.3 Golder Task 4

Task 4 (Golder 1988c) involved ground water sampling and laboratory analysis in an attempt to differentiate between shallow and deep ground water flow systems and flow paths. The scope included ground water sampling from discrete packer test intervals in bedrock at ten borehole locations. The sample intervals included two locations with relatively shallow depths between 83 and 114 ft, and eight locations with sample intervals from much greater depths ranging between 242 and 470 ft bgs. Laboratory analysis included major ions and gross alpha/gross beta. The well locations were all within the Nolichucky Shale and the low levels of gross alpha and gross beta were attributed to the presence of small quantities of several naturally occurring radioactive elements in the clays of the Nolichucky.

The other major component of the Task 4 scope included quarterly ground water sampling and laboratory analysis from ten wells spread across the site area sampled from different formations ranging from the deep sections of the Rome to the shallow Maynardville limestone (See Figure 3.1 in Golder 1988c). Two of the sampled wells were completed at relatively shallow depths; the remainders were sampled in wells completed in deep intervals ranging from 238 to 760 ft. Lab analysis included priority pollutants (only in the two shallow wells), major ions, radiological parameters, and stable isotopes. The EPA priority pollutant list includes 126 compounds including volatile and semi-volatile organic compounds, pesticides, PCBs, and metals. It is unclear why these compounds were part of the analysis as the report does not indicate that the WBCV was used for waste disposal. One of the ten sampled wells (GW-451) is located near the north corner of the Site 14 footprint and is completed in the deep interval within the Rome formation. Two of the other sampled wells are both located about 600 ft south of the Site 14 footprint; both are completed in the deep interval within the Nolichucky Shale. One other of the deep interval sampled wells is located just east of NT-14 southwest of Site 14 within the Nolichucky Shale. Task 4 results from these wells provide chemical data with potential relevance to Site 14. The ten wells were selected to monitor high flow zones that might represent major ground water pathways and to attempt to define differences in ground water chemistry between recharge and discharge areas. The authors noted (p. 3) that it was "*not completely possible to accurately define the ground water chemistry of a complex flow system such as exists at this site from two sets of data at only ten well locations*." The overall findings and conclusions of the Task 4 report should be referenced for additional details (Golder 1988c).

6.2.1.4 Golder Task 5

Task 5 objectives included field tests to validate contaminant transport models for the site and performance of model validation exercises. The field tests included: 1) bedrock packer testing, 2) pumping tests, 3) slug tests, and 4) tracer tests. The pumping and tracer tests were conducted in the tracer field noted above and shown on the inset of Figure E-81. The packer, pumping, and slug tests are summarized below; the tracer tests are summarized above in Section 2.13.4. The sections below summarize Task 5 results relevant to Site 14 but the original Task 5 report (Golder 1988d) should be consulted for additional details describing field methods, results and interpretations as well as tables, drawings, and other data.

The Task 5 report reviews rock core drilling, logging, and packer testing of core holes GW-404, GW-454/455, and GW-471 (GW-455 was a deeper offset to GW-454 terminated at 57.8 ft). A total of 401 ft of rock core were logged from these deep bedrock coreholes all located within the tracer field. Additional more extensive rock coring is noted in the Task 5 report at several other locations but the detailed rock core logs noted by Golder were not included with the pdf file version of the report, nor have any other detailed rock core logs been obtained for the WBCV LLWDDD area. Lee and Ketelle (1989, p. 12) describe a total of 8700 ft of rock core obtained from the WBCV site area investigated for the LLWDDD program, but detailed logs of this extensive coring were apparently not retained in project archives. This extensive coring program included 13 deep coreholes drilled across the WBCV area as deep as 1252 ft below surface. The cores were used in part to accurately determine the contact boundaries between the geologic formations, and collectively spanned the entire stratigraphic section between the uppermost Rome through the lower part of the Knox Group. Scanned copies of Golder plates are provided in Figures E-84, E-85, and E-86 illustrating the subsurface formation contacts identified in these coreholes and the dip of the bedding planes toward the southeast at angles around 45 degrees. Cross section C-C´ trends north-south across the middle of the Site 14 footprint and illustrates the relatively thin layer of regolith (overburden) soils and saprolite above bedrock. Where encountered, formation contacts are projected among the coreholes and extended updip to the surface. As shown in Figures E-81and E-84, the Site 14 waste limits extend from near the middle of the Pumpkin Valley Shale on the north to the lower Nolichucky Shale on the south.

<u>Golder Packer Tests, Pumping Tests, and Slug Tests at the Tracer Field Near Site 14</u>

Packer Tests

The Golder Task 5 report provides several tables summarizing the test intervals and results of the packer tests completed in GW-404, GW-455, and GW-471. A total of 24 tests were made with a 12 ft packer spacing in vertical profiles across the lengths of the open bedrock boreholes. The geologic formations tested included the upper and middle Dismal Gap/Maryville and the lower Nolichucky (along strike with the same units below the lower third of the Site 14 footprint). K (K) values were determined using semi-log and log-log methods and geometric mean K values were presented based on the two methods. The mean K values ranged between 10^{-4} cm/sec to 10^{-6} cm/sec with only one K value in the order of magnitude range of 10^{-7} cm/sec. The mean K values in GW-471 showed a generally progressive order of magnitude increase with depth; but no similar progressive changes with depth were indicated in the GW-455 and GW-404 results. Results were also tabulated and discussed with respect to core log descriptions and zones of structural deformation (contorted bedding, shearing, steep dips, etc.). Additional details, interpretations, and conclusions are provided in the Task 5 report (Golder 1988d).

Pumping Tests

The Task 5 report also describes two 24 hour pumping tests (described as shallow and deep) conducted among several wells in the tracer field southwest of Site 14. Figures E-87 and E-88 from Golder (1988d) illustrate the main pumping test wells/well clusters in plan and cross sectional views. The tests were performed within the uppermost 100 ft of the saturated zone to determine aquifer characteristics and the nature and degree of anisotropy anticipated to favor higher K along bedding planes and joints parallel to geologic strike. The deep pumping test was intended in part to evaluate a shear zone of structural deformation identified downdip at the same stratigraphic horizon of the open hole interval of the deep pumping test well (See Figure E-88). The pumping and observation wells were screened within the upper section of the Dismal Gap/Maryville formation just below the contact with the Nolichucky. The individual wells and cluster wells were completed at three separate levels vertically designated as A, B, and C (A - deep; B - intermediate, and C – shallow). The shallow level C water table wells were screened within saprolite, while the mid and deeper level wells were completed in fractured bedrock. As shown in Figure E-88 (cross section), the wells at each level were completed at greater depths in the down dip direction to maintain relatively consistent levels for the A, B, C well groups according to the general structural dip of approximately 40-45 degrees to the southeast. Well construction tables provide data for the total depths and screened and open hole intervals of all wells (see Golder 1988d). As shown in Figure E-88, the "shallow" well used for the pumping test was actually completed at the mid level B horizon in bedrock and not in the shallow water table saprolite interval.

The deep test well (GW-473) pumping rate was 0.59 gpm and the shallow test well (GW-474) pumping rate was 0.42 gpm. Four well clusters with three wells per cluster were installed at right angles parallel and perpendicular to geologic strike centered around the two pumping wells.

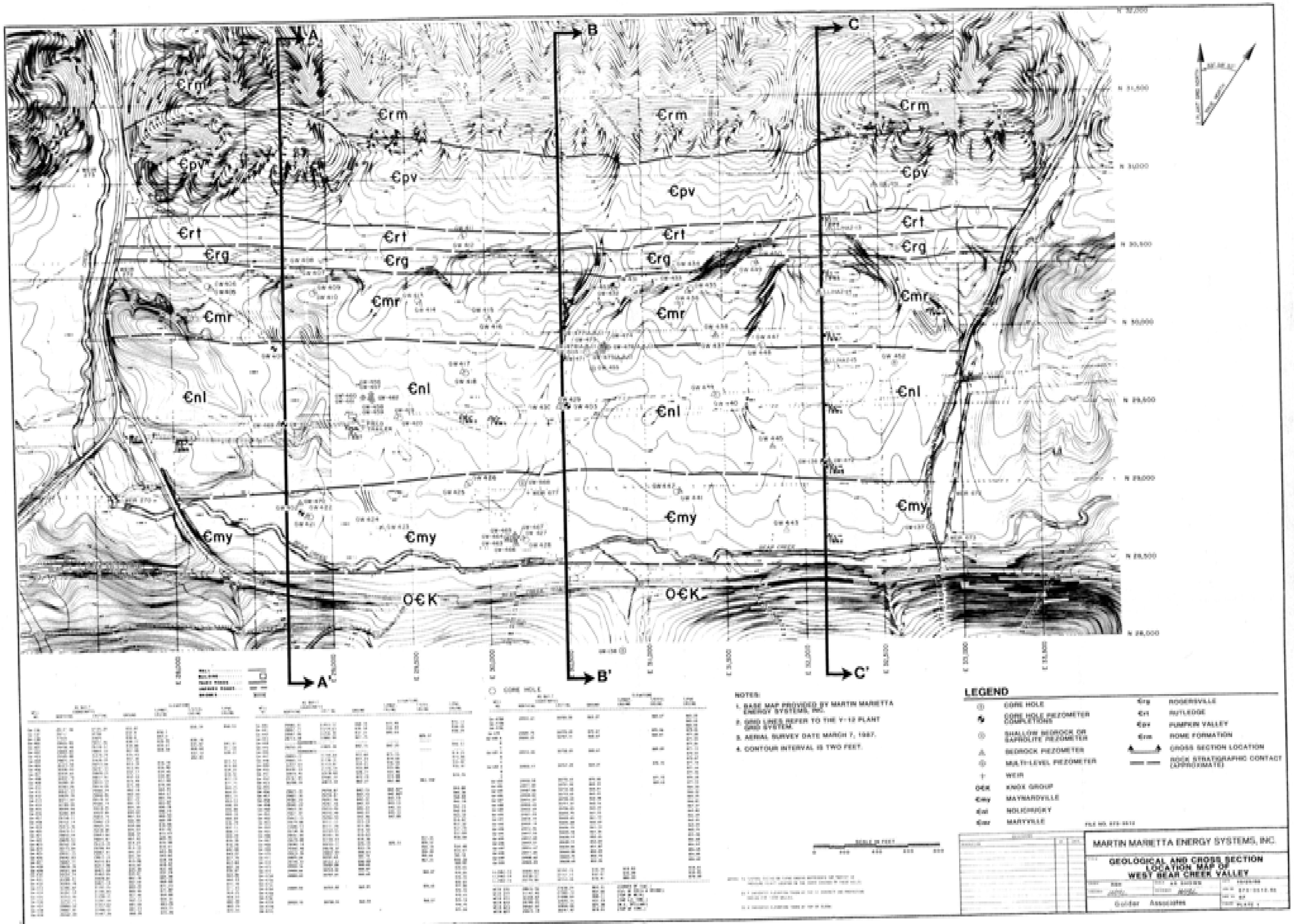

Figure E-84. Index map for deep geologic cross sections across the WBCV site area [from Golder 1988b]

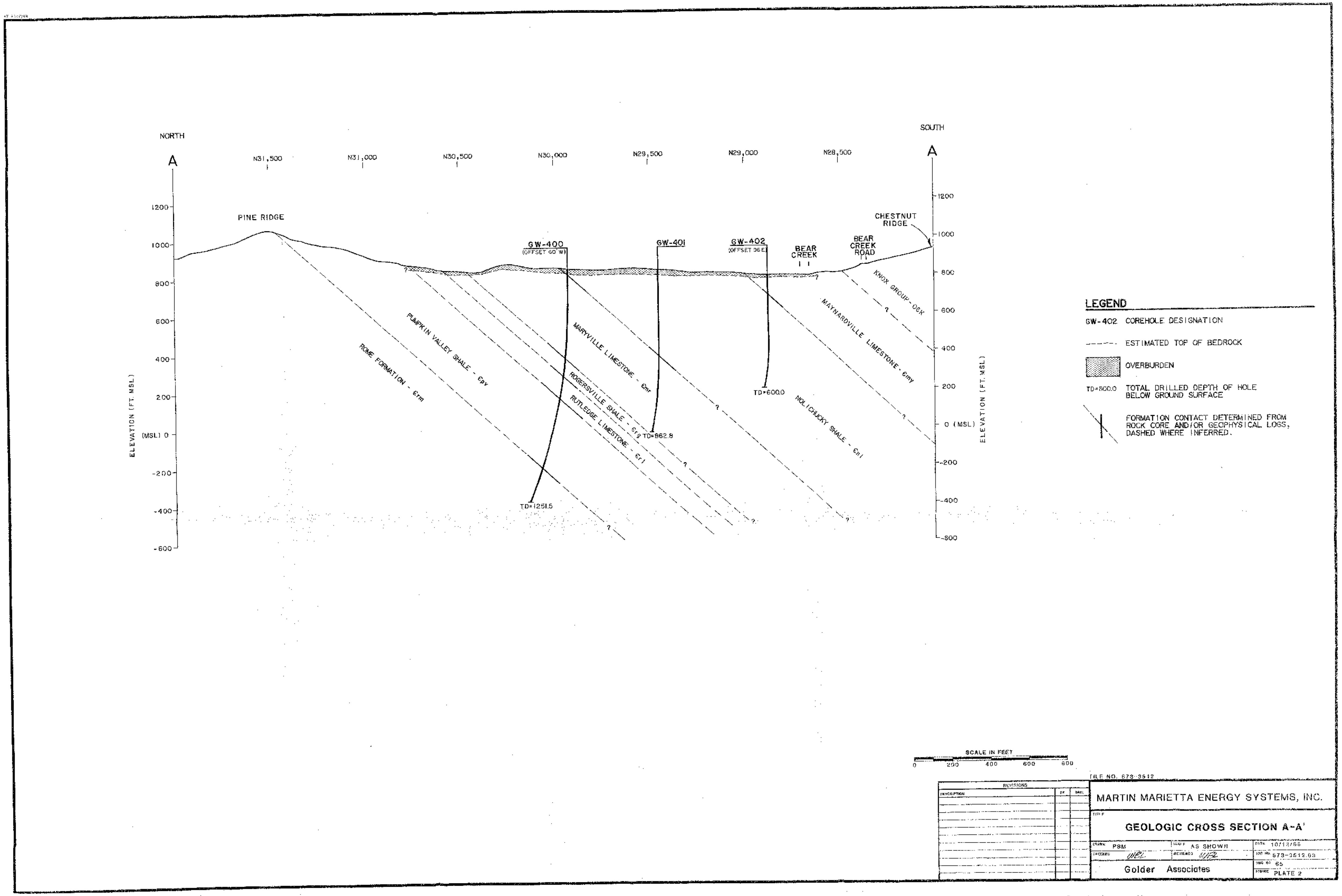

Figure E-85. North-south geologic cross section west of Site 14 and NT-15 [from Golder 1988b]

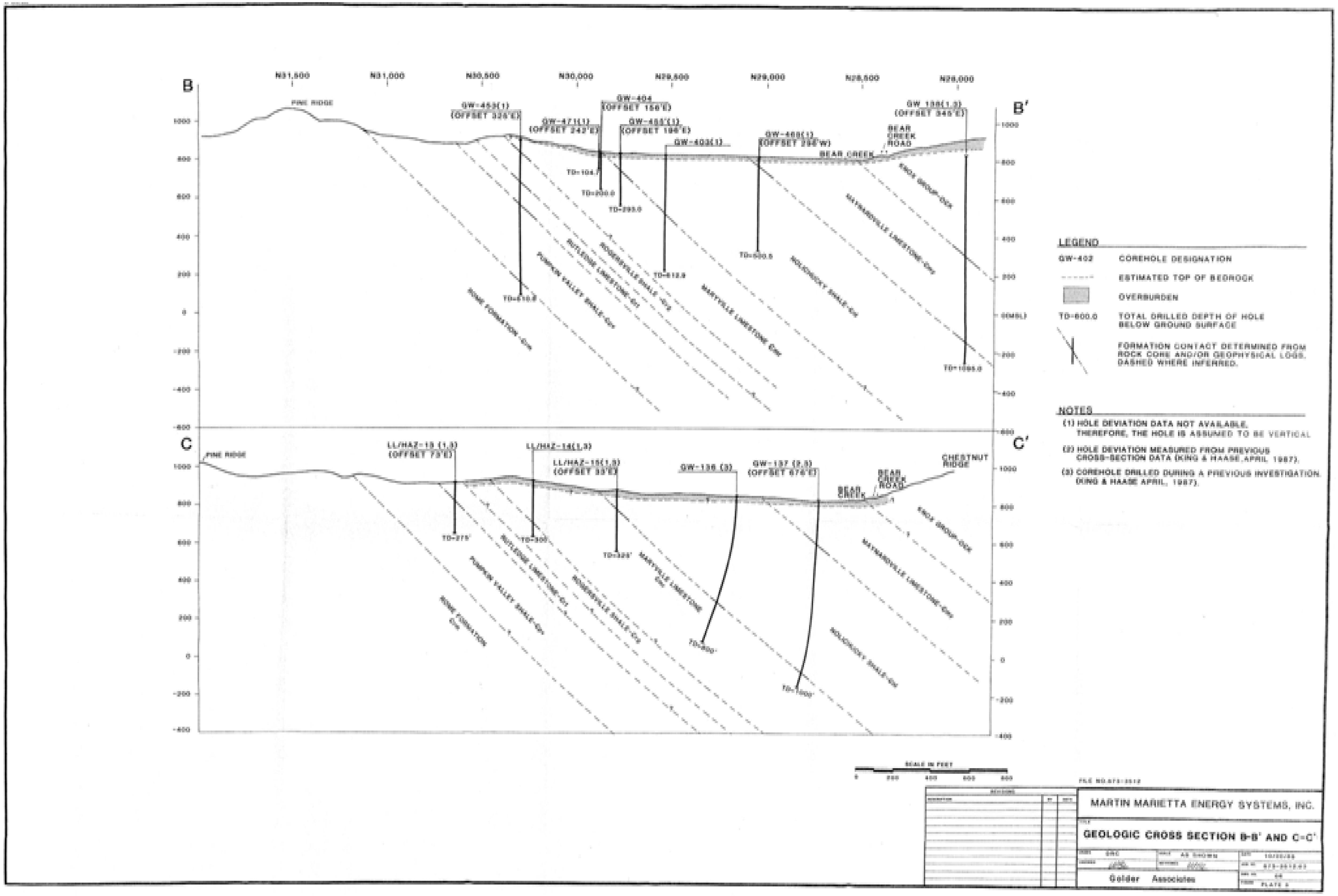

Figure E-86. North-south geologic cross sections just west of (B-B') and across Site 14 (C-C') [from Golder 1988b]

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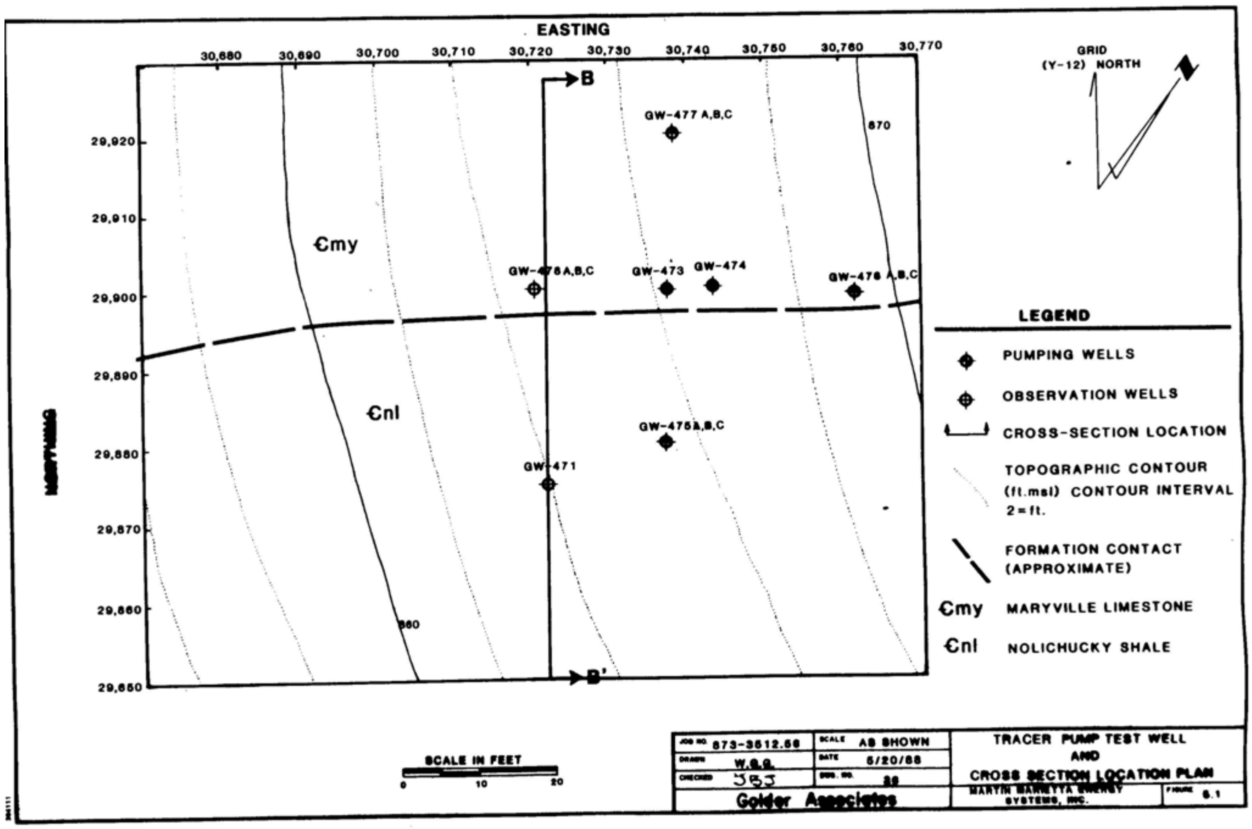


FigureE-87. Layout of wells used in Golder pumping tests at tracer test site area near Site 14 [Golder 1988d]

Water level recovery was monitored over a period of 8 days after each test until greater than 90% recovery of original static levels was achieved. It is important to note that the well clusters used in the pumping tests occur within a 20-25ft radius of the pumping wells and over an approximately 100 ft depth interval vertically. The results therefore reflect the bulk response of flow along in-situ horizontal and vertical fracture flow paths from shallow and deep pumping within a cylindrical area roughly 50 ft wide and 100 ft deep. Test results may therefore differ from those derived from individual well tests such as slug and packer tests where the aquifer response is localized across a much smaller area only around the wellbore or well intake interval. The Task 5 report provides details on the drilling, installation, and well development for the numerous single and cluster wells in the tracer field used for K measurements, and pumping and natural gradient tracer tests. Tables are provided by Golder (1988d) with all well construction and well development data.

Golder provides pre-test potentiometric contour maps for the pump test area based on measurements from the three levels A, B, and C designated for the three-well clusters (A - deep; B - intermediate, and C – shallow). Golder states that the generalized horizontal flow gradients at the test site are primarily toward the west and southwest. They noted strong upward vertical gradients across the <100 ft depths of the well clusters, and reported vertical gradients ranging from 0.10 to 0.31 measured between the shallowest and deepest of the three-well clusters surrounding the pumping wells.

The deep pumping test was conducted before the shallow test. GW-473 was pumped from a 26 ft open hole interval at level A from 68-94 ft below ground surface (bgs). The maximum drawdown in the pumping well was 61.66 ft at the end of the 24 hr pumping period. Golder presents several contour maps showing separate drawdown effects for each of the levels A, B, and C.

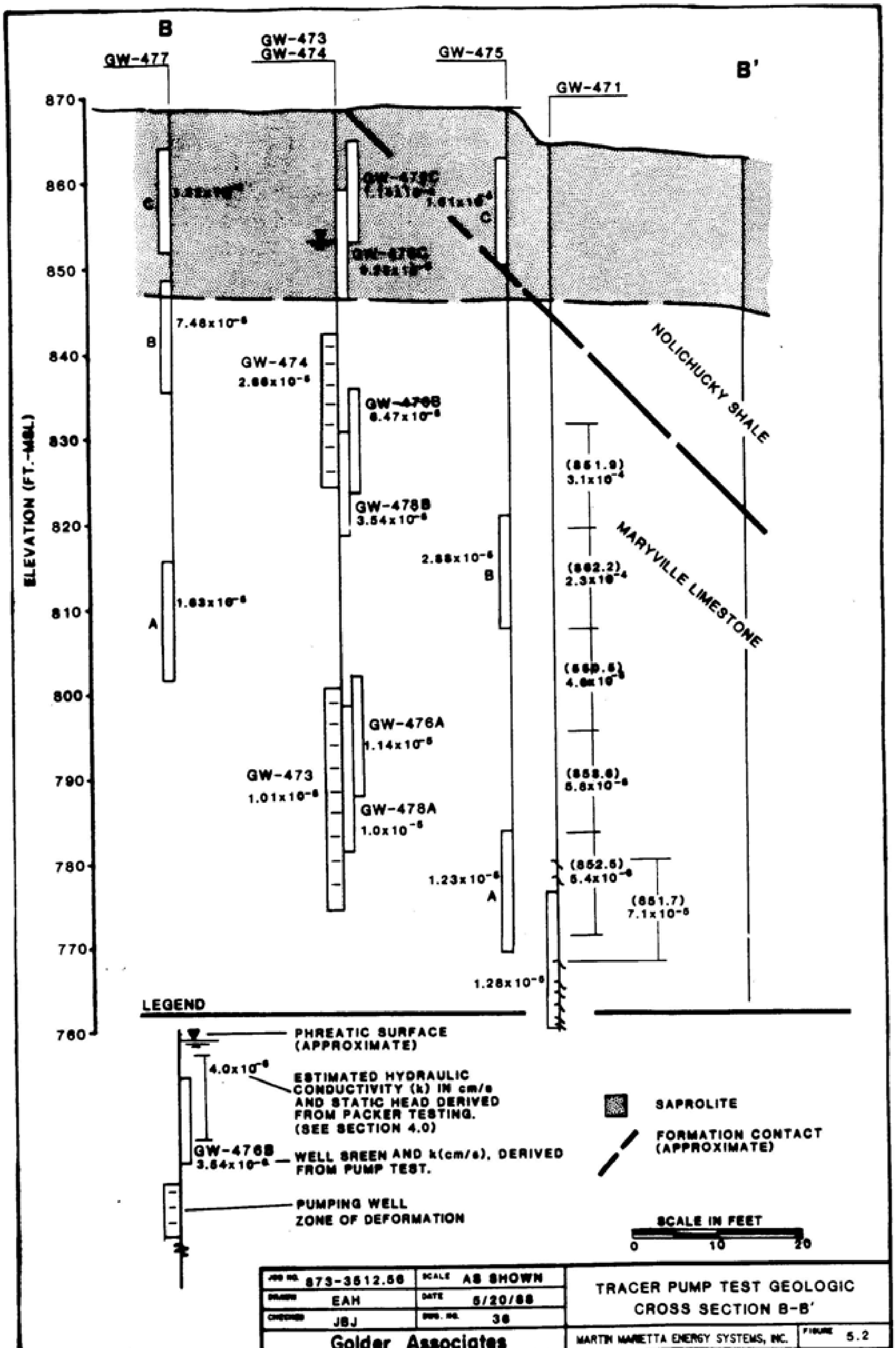


Figure E-88. Cross section B-B' illustrating subsurface conditions at Golder pumping test site [See preceding figure for line of section – Golder 1988d]

The greatest drawdown effects were shown in the deepest level A with progressively less drawdown in the intermediate and shallow level wells. Maximum drawdowns in the level A deep observation wells at 24 hrs ranged from about 25 to 46 ft, suggesting effective fracture flow connections within the 20-25 ft test radius. The potentiometric surface contour map for the level A wells shows a modest elongation parallel to strike indicating some anisotropy associated with higher K along strike parallel fracture flow paths. Golder notes similar non-radial patterns in pumping tests conducted in a Nolichucky Shale pumping test completed as part of Task 2 (for which no report is available). Drawdown response was nearly immediate in all of the deep level observation wells and increased for the first five hours and then approached steady state drawdown in the majority of the deep wells after about 17 hours of pumping. GW-475A was exceptional and continued to have drawdown throughout the pumping period without tapering down to a steady state drawdown condition. Golder also noted significant drawdown at two deep corehole locations more distant from the pumping well in GW-455 and GW-404, located at radii of 150 ft south and 106 ft west/southwest of the pumping well (see Figure E-81). Maximum drawdown in these wells was greater than 0.9 ft in GW-455 and 5.0 ft in GW-404. Golder noted that both of these deeper corehole wells were flowing prior to the start of the test (indicating artesian conditions and upward gradients). They observed that these significant drawdowns at these greater distances suggest that fracture sets are extensive and that anisotropic conditions occur along and perpendicular to strike (Golder 1988d, p. 71-72). Maximum drawdown in the intermediate level B observation wells during the deep test was reported as very uniform, ranging from 0.72 to 0.89 ft. Maximum drawdown in the shallow level C observation wells was reported as ranging from essentially zero to 0.33 ft. The drawdown results suggest that interconnections (and K) among fractures are greater laterally within bedding parallel fracture networks than those vertically across bedding planes. These results are reasonably consistent with the stratabound flow and contaminant transport described by Ketelle and Lee (1992), and with analysis of fracture patterns reported by Hatcher et al (1992) and others on the ORR. Time-drawdown/recovery data were evaluated for all observation wells to determine values for transmissivity (T), storativity (S), and bulk K. Three methods from pump test research literature were used to solve for T and S (those of Theis, Neuman, and Chow - see Golder 1988d for full references to these methods). In addition, two methods from the literature were used to evaluate anisotropic conditions (Papadopulus and Gringarten-Witherspoon – see Golder 1988d for references). It should be noted that individual well time-drawdown/recovery plots for the shallow and deep tests, calculations for determining aquifer characteristics (transmissivity, storativity, K, etc.) by various methods, and a Plate 1 map and cross section for the pumping tests were not included in the pdf file version of the Task 5 report obtained by Pro2Serve. Results are based on summary tables and interpretations presented by Golder. Tables E-16 and E-17 summarize the results for T, S, and bulk K for the deep and intermediate (shallow) level pumping tests by Golder, respectively, based on drawdown and recovery analysis (See Golder 1988d for additional tables presenting results from the Papaadopulus and Gringarten-Witherspoon methods).

For the deep test, the geometric mean of T values derived from level A (deep) wells were in the range of 10^{-5} to 10^{-6} ft^2/sec. The geometric mean of S values derived from level A wells were in the range of 10^{-3} to 10^{-5}. Wells in the intermediate level B depths were reported to show delayed yield response to the deep pumping and vertical leakage from the overlying shallow interval. T values from the intermediate level wells were in the range of 10^{-5} ft^2/sec. Bulk K values were estimated using the calculated T values and assuming a 20 ft aquifer thickness for the level A deep interval (where $T=K\cdot m$, where m is the aquifer thickness). The bulk K values reported by Golder for the level A wells were all in the range of 10^{-5} cm/sec (four of the eleven test wells were exempted from consideration for technical reasons).

Table E-16. Hydraulic characteristics determined by Golder from "deep" pumping test results [Table 9.1 from Golder 1988d]

DEEP PUMPTEST/TRACER AREA
SUMMARY OF RESULTS OF
DRAWDOWN AND RECOVERY ANALYSES

WELL NO.	TRANSMISSIVITY (THEIS DRAWDOWN) (SQ FT/SEC)	TRANSMISSIVITY (THEIS RECOVERY) (SQ FT/SEC)	COEF. OF STORAGE (THEIS DRAWDOWN) (DIMENSIONLESS)	TRANSMISSIVITY (NEUMAN METHOD) (SQ FT/SEC) (1)	COEF. OF STORAGE (NEUMAN METHOD) (DIMENSIONLESS)(2)	TRANSMISSIVITY (CHOW'S METHOD) (SQ FT/SEC)	GEOMETRIC MEAN TRANSMISSIVITY (SQ FT/SEC)	COEF. OF STORAGE (CHOW'S METHOD) (DIMENSIONLESS)	AVG. HYDRAULIC CONDUCTIVITY (CM/SEC) (3)
GW-404	2.76E-05	3.20E-05	1.24E-04	NA	NA	3.01E-05	2.98E-05	1.34E-04	4.55E-05
GW-455	NA	6.94E-05	NA	NA	NA	NA	NA	NA	1.06E-04 (5)
GW-471	7.61E-06	8.92E-06	1.47E-04	NA	NA	8.66E-06	8.38E-06	1.18E-04	1.28E-05
GW-473 (PW)	6.48E-06	6.49E-06	NA	NA	NA	6.83E-06	6.60E-06	NA	1.01E-05
GW-474	NA	NA	NA	9.56E-05	3.26E-02	NA	NA	NA	1.46E-04 (4)
GW-475A	1.48E-05	5.08E-06	1.65E-03	NA	NA	7.00E-06	8.07E-06	7.14E-04	1.23E-05
GW-475B	NA	NA	NA	8.01E-05	5.94E-04	NA	NA	NA	1.22E-04 (4)
GW-476A	8.54E-06	7.14E-06	3.60E-05	NA	NA	6.93E-06	7.50E-06	3.13E-05	1.14E-05
GW-476B	NA	NA	NA	2.00E-05	6.06E-04	NA	NA	NA	3.05E-05 (4)
GW-477A	2.25E-05	7.38E-06	1.51E-04	NA	NA	7.35E-06	1.07E-05	6.66E-04	1.63E-05
GW-478A	7.44E-06	6.32E-06	1.62E-04	NA	NA	6.00E-06	6.56E-06	1.69E-03	1.00E-05
OVERALL GEOMETRIC MEAN	1.16E-05	1.10E-05	1.73E-04	5.35E-05	2.27E-03	8.71E-06	9.51E-06	2.71E-04	1.45E-05

NOTE: (1) Represents the geometric mean of two transmissivity values derived using different type curves and/or match points.

(2) Represents the geometric mean of two coefficient of storage values derived using different type curves and /or match points.

(3) Based on the geometric means of the above transmissivity values and assuming a saturated aquifer thickness of 20.00 feet.

(4) K value not used in determination of overall geometric mean since observation well completed in zone immediately above pumped interval.

(5) K value not included in overall geometric mean due to limited drawdown (0.9 feet), and only the Theis recovery method prove to be a viable method of analysis.

(PW) Pumping well

Table E-17. Hydraulic characteristics determined by Golder from shallow pumping test results Table 9.2 from Golder 1988d]

SHALLOW PUMPTEST/TRACER AREA
SUMMARY OF RESULTS OF
DRAWDOWN AND RECOVERY ANALYSES

WELL NO.	TRANSMISSIVITY (THEIS DRAWDOWN) (SQ FT/SEC)	TRANSMISSIVITY (THEIS RECOVERY) (SQ FT/SEC)	COEF. OF STORAGE (THEIS DRAWDOWN) (DIMENSIONLESS)	TRANSMISSIVITY (NEUMAN METHOD) (SQ FT/SEC) (1)	COEF. OF STORAGE (NEUMAN METHOD) (DIMENSIONLESS)(2)	TRANSMISSIVITY (CHOW'S METHOD) (SQ FT/SEC)	GEOMETRIC MEAN TRANSMISSIVITY (SQ FT/SEC)	COEF. OF STORAGE (CHOW'S METHOD) (DIMENSIONLESS)	AVG. HYDRAULIC CONDUCTIVITY (CM/SEC) (3)
GW-474(PW)	5.93E-05	1.45E-05	NA	1.77E-05	5.53E-02	3.11E-05	2.62E-05	NA	2.66E-05
GW-475B	3.66E-05	2.95E-05	1.35E-04	NA	NA	2.09E-05	2.83E-05	1.31E-04	2.88E-05
GW-475C	2.59E-04	2.94E-05	1.20E-02	NA	NA	5.15E-04	1.58E-04	1.27E-02	1.61E-04
GW-476B	7.46E-05	4.69E-05	2.38E-04	NA	NA	7.39E-05	6.37E-05	2.28E-04	6.47E-05
GW-476C	NA	NA	NA	NA	NA	1.12E-04	1.12E-04	7.09E-02	1.14E-04
GW-477B	7.46E-05	1.28E-04	7.92E-04	NA	NA	4.18E-05	7.36E-05	6.35E-04	7.48E-05
GW-477C	4.30E-04	NA	7.55E-02	NA	NA	3.36E-05	1.20E-04	2.25E-02	1.22E-04
GW-478B	3.66E-05	2.54E-05	1.64E-04	NA	NA	4.52E-05	3.48E-05	1.53E-04	3.54E-05
GW-478C	1.46E-04	3.27E-05	8.01E-03	NA	NA	1.57E-04	9.08E-05	8.39E-03	9.23E-05
OVERALL GEOMETRIC MEAN	9.60E-05	3.49E-05	1.63E-03	1.77E-05	5.53E-02	6.71E-05	6.59E-05	2.17E-03	6.69E-05

NOTE: (1) Represents the geometric mean of two transmissivity values derived using different type curves and/or match points.

(2) Represents the geometric mean of two coefficient of storage values derived using different type curves and/or match points.

(3) Based on the geometric means of the above transmissivity values and assuming a saturated aquifer thickness of 30.00 FT.

(PW) Pumping well

Boundary conditions were evaluated by Golder using conventional methods for semi-log plots of time-drawdown data. None of the deep level A wells exhibited any indications of boundary conditions, however, six wells in the shallower levels B and C did exhibit boundary conditions that were interpreted by Golder as representing depletion of ground water storage in zones above level A as shown by rapid increases in drawdown at late times. The results of the methods applied to evaluate anisotropy are less conclusive and straightforward than those for the other methods used to derive aquifer characteristics and interpret subsurface flow conditions. The Task 5 report should be consulted for further details and discussions.

As noted above, the shallow pumping test was actually conducted by pumping from a mid level "B" well, GW-474 (See Figure E-88). The evaluation and methodologies applied by Golder for the mid level (Golder "shallow") pumping test were equivalent to those for the deep test. GW-474 was pumped from an 18 ft open hole shallow bedrock interval from 26.3 – 44.5 ft bgs, and 23.5 ft above the deep pumping test well. The static water table at the test site was located within overlying saprolite roughly ten feet above the top of the pumping interval in GW-474. The maximum drawdown in the pumping well was 16.36 ft at the end of the 24 hr pumping period. Golder presents several contour maps showing separate drawdown effects for each of the observation wells in levels A, B, and C. The greatest drawdown effects were recorded in the intermediate level B observation wells suggesting higher K along bedding parallel pathways relative to those perpendicular to bedding planes. Maximum drawdown in the mid level wells ranged from 2.8 to 7.3 ft at 24 hrs, with less drawdown in the shallow and deep level wells. Maximum drawdown in the level C shallow observation wells at 24 hrs ranged from 0.12 to 1.08 ft; level A deep wells were more uniform in drawdown ranging from 0.37 to 0.41 ft. The variations in drawdown among the wells reflect variations in K and interconnectivity within the hydraulically stressed 3D fracture flow network of bedrock and saprolite surrounding the pumping well. Golder noted that the drawdown contour map for the level B wells showed little elongation parallel to strike suggesting less strike parallel anisotropy at the intermediate level.

Drawdown response was nearly immediate in the mid level observation wells and increased at a steady rate for the first two hours after which the drawdown rate sharply declined. The B level wells approached steady state drawdown conditions after about 16-17 hours, similar to the deep test. Golder noted that the shorter two hour early period steady rate of drawdown versus the five hour period in the deep test, suggested greater leakage and recharge from the overlying weathered rock and saprolite, relative to the deeper test.

Golder used time-drawdown/recovery data for level B and C wells to determine values for T, S, and bulk K. Golder indicated that the level A deep wells were not used as the level B pumping well was partially penetrating. The methods described above for the deep tests were applied to the intermediate (Golder shallow) level pump test. Results are shown in Table E-17 for T, S, and bulk K. The geometric means of T values derived from level B wells were all in the range of 10^{-5} ft^2/sec. The geometric means of S values derived from level B wells, including the pumping well, were all in the range of 10^{-4}. Golder notes that the T values derived from level C shallow wells ranged from 9.08×10^{-5} ft^2/sec to 1.58×10^{-4} ft^2/sec, that they were in general an order of magnitude higher than those derived from the level B wells, and that they correlated well with results from packer tests. Golder noted that the level B pumping well exhibited a significant delayed yield response indicating vertical leakage or delayed yield commonly observed by gravity flow in unconfined water table aquifers. Bulk K values were estimated using the calculated T values and assuming a 30 ft aquifer thickness (based on 30 ft from the static water table to the bottom of the pumping interval). The bulk K values reported by Golder for the level B wells were all in the range of 10^{-5} cm/sec. The bulk K values reported for the shallow level C wells ranged from 9.23×10^{-5} cm/sec to 1.61×10^{-4} cm/sec.

Slug Tests

The Task 5 report presents the results and interpretations of 21 rising head slug tests conducted at the tracer test site. An additional 45 slug tests were conducted by Golder elsewhere across the WBCV site including several at and near the Site 14 footprint. However, the results and interpretations of those tests are not available as they were apparently included in Volume I of the Task 2 Report which as previously noted could not be obtained. Volume II Appendix C of the Task 2 Report was obtained and includes data, water level recovery plots, and K values calculated for the 45 slug tests, but the K values are not summarized nor interpreted in the appendix. The results are available, however, for potential use if Site 14 is selected for the EMDF development.

The Golder slug tests reported in Task 5 were conducted to determine K values among the many wells included in the well field of the tracer and pumping tests. All the slug tested wells were completed within the Dismal Gap/Maryville formation. Results are presented in Table E-18 and illustrate a range of well depths varying between 24 and 100ft for 19 of the wells, excluding GW-455 and GW-471 which were two deeper coreholes completed at greater depths of 185.8 and 103.4, respectively. The K values were calculated using the Hvorslev method and Golder notes that precautions were taken in the analysis of semi-log plots of water level recovery data to disregard erroneous early data that might reflect sand pack dewatering and not the in-situ K of the natural formations.

Golder states that the water columns were insufficient in the shallow "C" level wells completed in saprolite and could not be slug tested. The results thus do not include important K values for the uppermost part of the water table interval that commonly occurs within the highly weathered fractured bedrock above competent bedrock. Golder summarizes the slug test results within four groups: 1) level A deep wells, 2) B mid level wells, 3) relatively shallow wells completed in saprolite or in the upper ten feet of bedrock, and 4) in the deeper corehole well completions in GW-455 and GW-471. The K values reported for level A wells ranged between 10^{-5} to 10^{-7} cm/sec with a geometric mean of 7.72×10^{-6} cm/sec. The K values for intermediate level B wells were all within the order of magnitude range of 10^{-5} cm/sec with a geometric mean of 3.45×10^{-5} cm/sec. The K values for the shallow wells ranged from 10^{-6} to 10^{-4} cm/sec with a geometric mean of 1.30×10^{-5} cm/sec. The K value for GW-455 was 4.57×10^{-5} cm/sec, and the K value for GW-471 was 1.18×10^{-6} cm/sec. The geometric mean for all wells based on the slug tests was 1.37×10^{-5} cm/sec. Golder also reported a "high degree of consistency" among the K values of the slug, pumping, and packer tests conducted in the tracer area site. Table E-19 presents those results.

6.2.1.5 Golder Task 6

Among the Golder reports, the Task 6 report (Golder 1989b) is the only one that presents a comprehensive and detailed review of surface water and hydrogeological conditions in WBCV, including the Site 14 area. The Task 6 scope included the compilation and interpretation of all geological and hydrogeological data from Tasks 1 through 5 to produce a site conceptual model for ground water flow and contaminant transport. The Task 7 scope involved the actual development of a computer model of ground water flow, supported by the Task 6 site conceptual model and investigation results.

The Task 6 report is organized into three key sections: a geologic evaluation, a hydrogeologic evaluation, and the conceptual flow model. The geologic evaluation includes the regional geologic setting, stratigraphy, surficial deposits, weathering, and structural features. The hydrogeologic evaluation includes the regional hydrogeology, surface water hydrology (including a detailed water budget, and analyses of precipitation and streamflow, critical storm and baseflow, and infiltration and recharge), aquifer characteristics (K, anisotropy, storage, and boundaries, and hydraulic head), and site geochemistry (results from swab and quarterly sampling, piper diagrams, and ground water flow interpretations). The results from the geologic/hydrogeologic evaluation are summarized in a fairly concise summary of a conceptual flow model for the WBCV area.

Table E-18. Hydraulic conductivy data determined by Golder from rising head slug tests in WBCV [Table 8.1 from Golder 1988d]

RISING HEAD TEST SUMMARY

WELL NO.	OPEN INTERVAL TOP OF SATURATED SAND (TOC-FT)	BOTTOM OF SAND PACK (TOC-FT)	FORMATION	K (cm/sec)
GW-455	157.7	185.8	MARYVILLE	4.57E-05
GW-471	89.7	103.4	MARYVILLE	1.18E-06
GW-473	68.4	94.4	MARYVILLE	3.93E-05
GW-474	27.9	45.1	MARYVILLE	3.33E-05
GW-475A	86.4	99.7	MARYVILLE	7.85E-07
GW-475B	49.9	62.9	MARYVILLE	6.96E-05
GW-476A	69.9	83.0	MARYVILLE	6.61E-06
GW-476B	36.9	49.4	MARYVILLE	7.96E-05
GW-477A	54.7	68.7	MARYVILLE	1.37E-05
GW-477B	22.3	34.9	MAY-SAP	1.12E-05
GW-478A	66.9	81.3	MARYVILLE	9.81E-06
GW-478B	35.2	47.2	MARYVILLE	2.35E-05
GW-479	18.4	25.9	SAPROLITE	2.48E-05
GW-480A	33.6	37.6	MARYVILLE	2.86E-06
GW-480B	28.6	32.6	MAY-SAP	5.23E-06
GW-481A	31.4	35.1	MARYVILLE	1.81E-04
GW-481B	28.6	32.6	MAY-SAP	6.76E-06
GW-482A	32.7	36.7	MARYVILLE	1.82E-06
GW-482B	26.2	30.2	MAY-SAP	2.29E-05
GW-483	18.4	28.0	MAY-SAP	3.27E-05
GW-484	17.1	24.3	SAPROLITE	1.75E-05

GEOMETRIC MEANS

ALL (incl SAP) = 1.37E-05
MARYVILLE (excl SAP) = 1.34E-05
SAPROLITE AND MAY-SAP CONTACT = 1.44E-05

Table Note: MAY-SAP are abbreviations for Maryville and saprolite (the Golder report table erroneously indicates May is Maynardville Limestone but none of these wells are anywhere near the Maynardville Limestone)

Table E-19. Hydraulic conductivity data compiled by Golder for slug, pumping, and packer tests. [Table 8.2 from Golder 1988d]

COMPARISON OF SLUG TEST HYDRAULIC CONDUCTIVITY (K) VALUES
WITH PUMP TEST AND PACKER TEST RESULTS

WELL NO.	TESTED INTERVAL (FT. BGS.)	SLUG TEST K (CM/SEC)	PUMP TEST (1) K (CM/SEC)	PACKER TEST (2) K (CM/SEC)
GW-455	157.7 to 185.8	3.61E-05	3.47E-06	4.07E-05
GW-471	89.7 to 105.6	1.05E-06	1.28E-05	NA
GW-473	68.4 to 94.4	3.93E-05	1.01E-05	5.39E-06 (1)
GW-474	27.9 to 45.1	3.33E-05	2.66E-05	4.61E-05 (1)
GW-475A	86.4 to 99.7	7.88E-07	1.23E-05	5.39E-06 (1)
GW-475B	49.9 to 62.9	6.96E-05	2.88E-05	4.61E-05 (1)
GW-476A	69.9 to 83.0	6.61E-06	1.14E-05	5.39E-06 (1)
GW-476B	36.9 to 49.4	7.96E-05	6.47E-05	4.61E-05 (1)
GW-477A	54.7 to 68.7	1.37E-05	1.63E-05	NA
GW-477B	22.3 to 34.9	1.12E-05	7.48E-05	NA
GW-478A	67.9 to 81.3	9.81E-06	1.00E-05	5.39E-06 (1)
GW-478B	35.2 to 47.2	2.35E-05	3.54E-05	4.61E-05 (1)
GW-479	18.4 to 25.9	2.70E-05	NA	NA
GW-480A	33.6 to 37.6	2.86E-06	NA	NA
GW-480B	28.6 to 32.6	5.23E-06	NA	NA
GW-481A	31.4 to 35.1	1.81E-04	NA	NA
GW-481B	28.6 to 32.6	6.76E-06	NA	NA
GW-482A	32.7 to 36.7	1.82E-06	NA	NA
GW-482B	26.2 to 30.2	2.29E-05	NA	NA
GW-483	18.4 to 28.0	3.27E-05	NA	NA
GW-484	17.1 to 24.3	1.75E-05	NA	NA

NOTES (1) PACKER TEST HRDRAULIC CONDUCTIVITY (K) DERIVED FROM COREHOLE GW-471. THE COMPARISON PACKER TEST K IS CORRELATIVE TO THE ALONG-DIP PROJECTION OF TESTED ZONES IN GW-471, ASSUMING A DIP OF 45 DEGREES SOUTH.

As previously noted, the Golder Task 2 report could not be obtained, but the Task 6 report includes a review of the scope and findings from Tasks 2 through 5, and therefore provides information on Task 2 activities and results that are otherwise unavailable. The Task 6 report provides fundamental data and interpretations for surface water hydrology based on meteorological data and stream flow data collected from several weirs located along the lower reaches of NT-14, NT-15, and Bear Creek in the WBCV/Site 14 area. Golder analyzed rainfall/runoff relationships from four storm events and completed a detailed water budget for the 1986-1987 water year. In support of these analyses, Golder provides results of surface infiltration tests in the Task 6 report. The Task 6 report also provides information and analysis of Task 2 drilling and logging, and packer and pumping tests not provided elsewhere. The Task 6 report summarizes Task 2 pumping tests conducted in wells completed in the Nolichucky Shale and Maynardville Limestone, in addition to the Task 5 pumping tests described above that were conducted at the Dismal Gap/Maryville tracer test site. Task 6 report appendices include precipitation and streamflow data and hydrographs for the weir locations, and documentation of the field infiltration tests not provided elsewhere.

Although the broad and detailed scope of the Task 6 report is difficult to concisely summarize, Golder provides a summary of principal conclusions and a conceptual flow model for the WBCV/Site 14 area with implications for BCV as a whole – "*The rock strata strikes about N55°E and dips to the southeast at a relatively uniform dip of about 40°. Results of rock core drilling and logging indicate a relatively uniform dip and thickness of the rock strata across the site. Large-scale thrust or tear faulting does not appear to exist, however, fracturing is prevalent throughout the Conasauga Group. In general, fractures typically occur along bedding planes with some fracturing noted, although to a much lesser degree, roughly normal to bedding. The overlying soils are primarily a result of in-place decomposition of the parent rock. The residual soil exhibits a similar remnant structure as that of the rock from which it is derived. The hydrogeologic significance of the geologic structure and fracturing is that a highly anisotropic flow system prevails.*

Bear Creek and its tributaries play a key role in the shallow and surficial flow systems on site. The average long term water budget for the site consists of about 50 inches of annual precipitation, 20 inches of which is lost to evapotranspiration. The remaining 20 inches is divided into about 9 inches of direct overland runoff, and about 11 inches of infiltration of which about 95% or 10.5 inches returns to the streams as baseflow; the remaining 0.5 inches is lost as deeper aquifer recharge.

Based on the results of 120 straddle packer tests, 66 slug tests, and 4 aquifer pump tests, hydraulic conductivity at the site generally decreases with depth from about 10-4 cm/sec in the upper 100 feet to 10-7 cm/sec at over 500 feet. The site is heterogeneous and anisotropic with the principal value of hydraulic conductivity oriented along strike. Hydraulic head values indicate the the hydraulic gradients in the shallow system (<100 feet) are controlled by local topography. The deeper gradients appear more regionally controlled by Pine Ridge, Chestnut Ridge and, perhaps, the Clinch River.

Based on the data obtained to date, the site conceptual hydrogeologic model can be described as follows. Three dependent flow systems appear to exist called the shallow, transition zone and deep systems.

The shallow system, to depths of about 100 feet, has a geometric mean hydraulic conductivity of about 10-4 cm/sec, appears controlled by local topography, surface drainage features and strong, along-strike, anisotropic flow with discharge into local streams, except in the lower reach of Bear Creek which appears to exhibit losing characteristics.

The transition zone lies between some 100 feet to 500 feet below surface under most of the site and has a mean hydraulic conductivity of about 10-5 cm/sec. The geochemistry of this zone is much different from the shallow system indicating longer residence times, although neither carbon-14, tritium, nor stable isotope information could confirm the age of the waters. The hydraulic head information and geochemistry data from the Nolichucky Shales appear to confirm a significant along-strike component of ground water flow. Most ground water reappears as baseflow to site drainage features and Bear Creek. However, the site water balance indicates losing stream characteristics for Bear Creek at the Western margin of the site.

The deep system, below 500 feet, is difficult to define because of sparse data. However, indications are that several hydraulic heads in this zone are of the same magnitude as the Clinch River elevations, perhaps indicating a lower hydraulic boundary to the Bear Creek system. In addition, there is some evidence for a downward flow component at these depths, rather than upward flow to Bear Creek. The mean hydraulic conductivity for the deep zone is about 10-7 cm/sec." (Golder 1989b – Executive Summary)

The Task 6 report should be reviewed for complete details, interpretations, and conclusions, particularly those related to the geology and hydrogeology of the WBCV area. Selected findings of the report are included in subsequent sections where surface water hydrology and hydrogeology data are summarized for Site 14.

6.2.1.6 Golder Task 7

The Task 7 report by Golder (1989c) documents the results of a preliminary ground water flow model for the WBCV area. Golder notes in the report abstract that the original scope included development of a solute transport model to evaluate leak scenarios and provide dose estimate calculations. The scope was subsequently reduced to development of a calibrated ground water flow code which could be used for pathways analysis. A 3D finite element ground water flow computer model was developed for the site using the DOE FE3DGW code. Six simulations of steady-state ground water flow were completed, with model calibration using measured water table elevations. Among several conclusions cited, Golder reports the following based on model results: 1) the majority of ground water recharge returns to the streams as shallow base flow; 2) general flow directions and velocities could be simulated to approximate field values; 3) along-strike flow in the shallow bedrock flow system dominates the site hydrogeologic regime, with typical resultant flow velocities of 0.5 ft/day, assuming a porosity of 0.10. These velocities indicate typical travel times at various parts of the site in the shallow system on the order of tens of years; and 4) the modeling has confirmed the conceptual flow model described for the shallow system, where flow is topographically and along-strike controlled. The model grid is, however, a site scale model and is too coarse to examine small scale features, such as discrete fracture sets, small scale interlayered variable K features and small streams. Subsequent fate and transport modeling conducted for the PA by ORNL (1997) employed a different 3D finite difference model, FTWORK, developed by GeoTrans, Inc.

6.2.2 ORNL Reports and Performance Assessment

Several specialized reports presenting the results of other field investigations, research, and a PA were published by ORNL in relation to the WBCV area and plans for developing the proposed tumulus facility. Results are summarized in the following subsections. Original documents are referenced for greater detail.

6.2.2.1 Soils, Surficial Geology, and Geomorphology By Lietzke et al 1988

Lietzke et al 1988 documented results of extensive mapping of soils for the WBCV area as part of the investigations conducted for the LLWDDD program. They mapped and provided descriptions of soil residuum and saprolite, and colluvium and alluvium (modern and ancient) across BCV from the outcrop belt of the Rome Formation through the Conasauga Group and for the Knox Group underlying Chestnut Ridge. Deep pits were dug in four of the Conasauga Group formations (Pumpkin Valley, Rogersville, Dismal Gap/Maryville, and Nolichucky) to characterize soils and saprolite. Pits and trenches were excavated along two major transects through shallow soils/residuum with detailed descriptions and photographs from the test pits which were typically 2-2.5 m deep. Transect B-B' (Figure E-89) runs north-south across the current footprint of Site 14 providing an indication of near surface soils and saprolite conditions.

They specifically note problems in locating the LLWDDD footprint in the Nolichucky Shale related to: 1) shallow depth to the water table, 2) shallow depth to relatively unweathered saprolite, and 3) nearness to the outcrop belt of the Maynardville limestone where rock outcrops and shallow depth to rock "provide a potential short circuit in the natural ability of the soil-regolith mantle to filter and purify vadose water before it reaches saturated zones at depth" (Lietzke et al 1998).

The report includes detailed maps for Site 14 and adjacent areas illustrating the extent of modern and ancient alluvium along the floodplain areas of Bear Creek and NT-14/NT-15, and along smaller sub-tributaries cross cutting the Site 14 footprint. The geomorphology and geomorphic history (from the Pleistocene to Holocene) of the WBCV area is also described and illustrated in maps and 3D drawings illustrating relationships among residuum, colluvium, alluvium, saprolite, and bedrock from Pine Ridge across BCV to Chestnut Ridge.

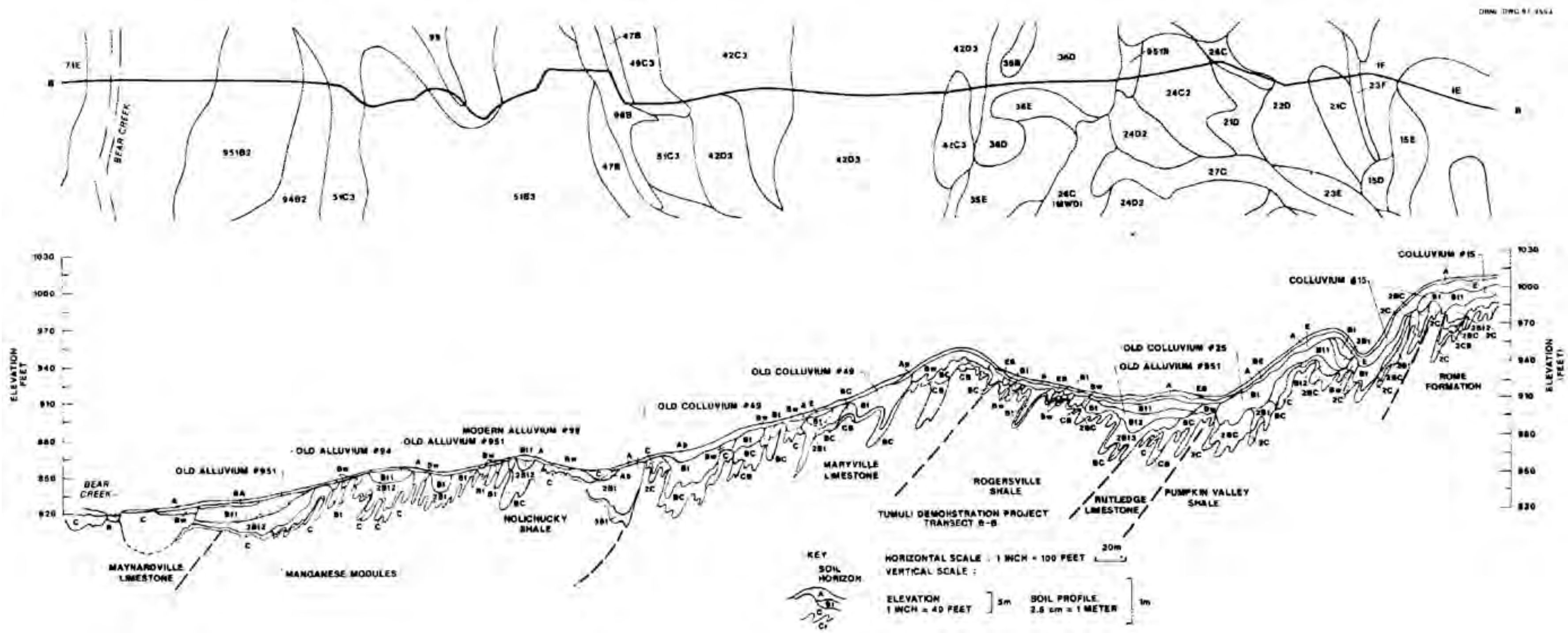


Figure E-89. North-south transect across the center of Site 14 illustrating shallow soils, saprolite, alluvium, and colluvium [Source: Lietzke et al 1998; Note the greatly exaggerated vertical soil profile highly distorted relative to surface topography]

For the EMDF Site 14, the detailed descriptions and mapping of alluvium and descriptions of saprolite may have significance for landfill design and design characterization. The detailed descriptions and mapping of soil residuum is probably not significant as most of the relatively loose near surface topsoil and residuum layer will probably be removed during initial construction for structural stability. Figure 10 in Lietzke et al (1988) maps potential problem areas for Site 14 including: 1) slopes higher than 25%, 2) shallow soil areas, 3) engineering problems with high silt and clay content (high soil erodibility factor (k), high plasticity, low weight–bearing capacity), 4) wetness and flood hazard, 5) limestone rock outcrops, and 6) the approximate boundary between the Nolichucky Shale and Maynardville Limestone. Unfortunately, the quality of the scanned image is poor and some of the potential "problem" areas are difficult to identify. But the map does accurately illustrate several ravines cross cutting the Site 14 footprint and the floodplain areas along the adjacent NT-14/NT-15 tributaries, and the floodplain areas and limestone outcrops along and north of Bear Creek. Figure 12 in the Lietzke report illustrates variations in topographic slope across the WBCV site from Bear Creek to the crest of Pine Ridge. The infiltration characteristics of soils were also mapped across the site area (See their Figure 13), distinguishing between areas with high infiltration and deep percolation into rock from those with poor to intermediate infiltration and lateral flow and runoff characteristics. The north-south transects A-A' and B-B' (the latter running directly across the center of the Site 14 footprint) are provided in Appendix C to the report. Transect B-B' is illustrated in Figure E-89 for its relevance to the Site 14 footprint. The transects accurately illustrate relationships between surface topography/elevations, surficial soils, modern and old alluvium, colluvium, and underlying bedrock formation contacts and southeast dips extending from the Rome formation below Pine Ridge southward to Bear Creek (Note however, the highly exaggerated vertical scale of the soil profiles on these transects which misrepresents the thickness of near surface layers with respect to the overall scale of the cross section).

6.2.2.2 Geology of the West Bear Creek Site - Lee and Ketelle 1989

Lee and Ketelle (1989) published a report on the geology of the WBCV site during the same year of the Golder Task 6 and 7 reports. The report addresses: 1) the extensive rock coring (total of 8,698 ft of rock core) and borehole geophysical logging program completed at that time; 2) relatively detailed geologic descriptions for each of the Conasauga Group formations from the Rome Sandstone through the Maynardville Limestone; and 3) geologic structures (fracturing, deformation, and potential tear faults). The report also provides a geologic map and generalized cross sections for the WBCV area addressed under the LLWDDD investigations.

The report indicates that the rock cores were logged to the nearest 0.1 ft and "represented graphically" at scales from 1inch = 5 ft to 1 inch = 10 ft for detailed evaluation and correlation purposes across the site. However, the detailed logs are not provided in the report, nor are details represented on site cross sections (the report notes that core logs and geophysical logs were filed in the author's offices). The report also notes that the cores were stored at Building 7041 at ORNL, but their existence and current location have not been verified. Three north-south trending cross sections are provided in the report that are very similar to those provided by Golder, except that a zone of shear deformation is shown parallel with bedding plane dips that occurs stratigraphically between the upper half of the Dismal Gap/Maryville formation and the lower half of the Nolichucky Shale. Figure E-90, from Lee and Ketelle (1989; Fig. 8), illustrates this zone in the north-south cross section located across the center of Site 14 (equivalent to Golder's cross section C-C' above, but viewed in the opposite direction – See Figure E-91 for well locations). The actual correlated deformation features logged in the rock cores at Site 14 are shown at depth in GW-136 and GW-137.

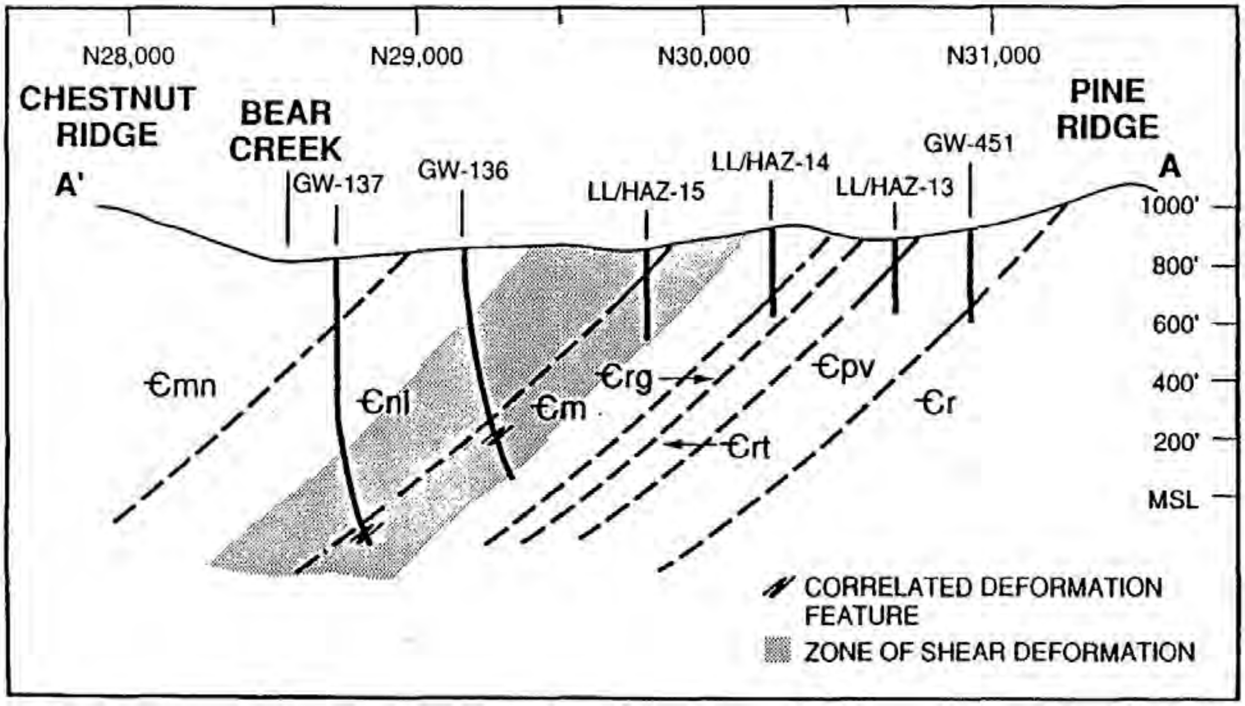


Figure E-90. North south cross section through Site 14 illustrating a zone of shear deformation within portions of the Nolichucky Shale and Dismal Gap/Maryville formation.

[Fig. 8 from Lee and Ketelle 1989]

Figure E-91 illustrates the portion of the geologic map prepared by Lee and Ketelle covering the Site 14 area from Pine Ridge to Bear Creek and between NT-14 to NT-15. The map shows the locations of core holes and test pits at Site 14 and the detailed surface topography, and ravines and drainage patterns across the site illustrated by 2 ft contours based on a 1984 aerial survey of the site. The outcrop patterns shown in Figure E-91 vary somewhat from those in Figure E-81 based on King and Haase (1987) for all of BCV.

Lee and Ketelle (1989) reported a geologic strike for the WBCV area typically varying between N56°E and N67°E with bedding plane dips generally from 41° to 45° southeast with values from 37° to >50° occurring locally. They attempted to determine the presence of tear faults purported to exist within BCV as suggested by slight offsets in the crest of Pine Ridge by King and Haase (1987). However, through a combination of analysis of core log/stratigraphic data, and relationships of formation contacts measured in test pits north and south of NT-15 near the center of the site they concluded that "*a tear fault does not exist near the perennial stream (NT-15) near the center of the site, and it is considered unlikely, based on topography and rock core data, that such a fault exists elsewhere on the site*".

To analyze fracture orientations, Lee and Ketelle gathered data from four test pits excavated into saprolite along a north south transect near the center of Site 14 and in the outcrop belts of the Nolichucky, Dismal Gap/Maryville, Rogersville and Pumpkin Valley (pits used in the soil survey by Lietzke) underlying the Site 14 footprint. Two orthogonal fracture sets were identified, oriented roughly parallel and normal to geologic strike (stereogram plots of poles to bedding and fractures are provided in Fig. 10 of the report). Three types of intermediate-scale structural features were identified by Lee and Ketelle in the clastic rocks of the Conasauga Group: 1) folded bedding considered to be drag folds, 2) heavily fractured beds resembling fault gouge, and 3) discrete shear fractures with high and low angle orientations with respect to core axes.

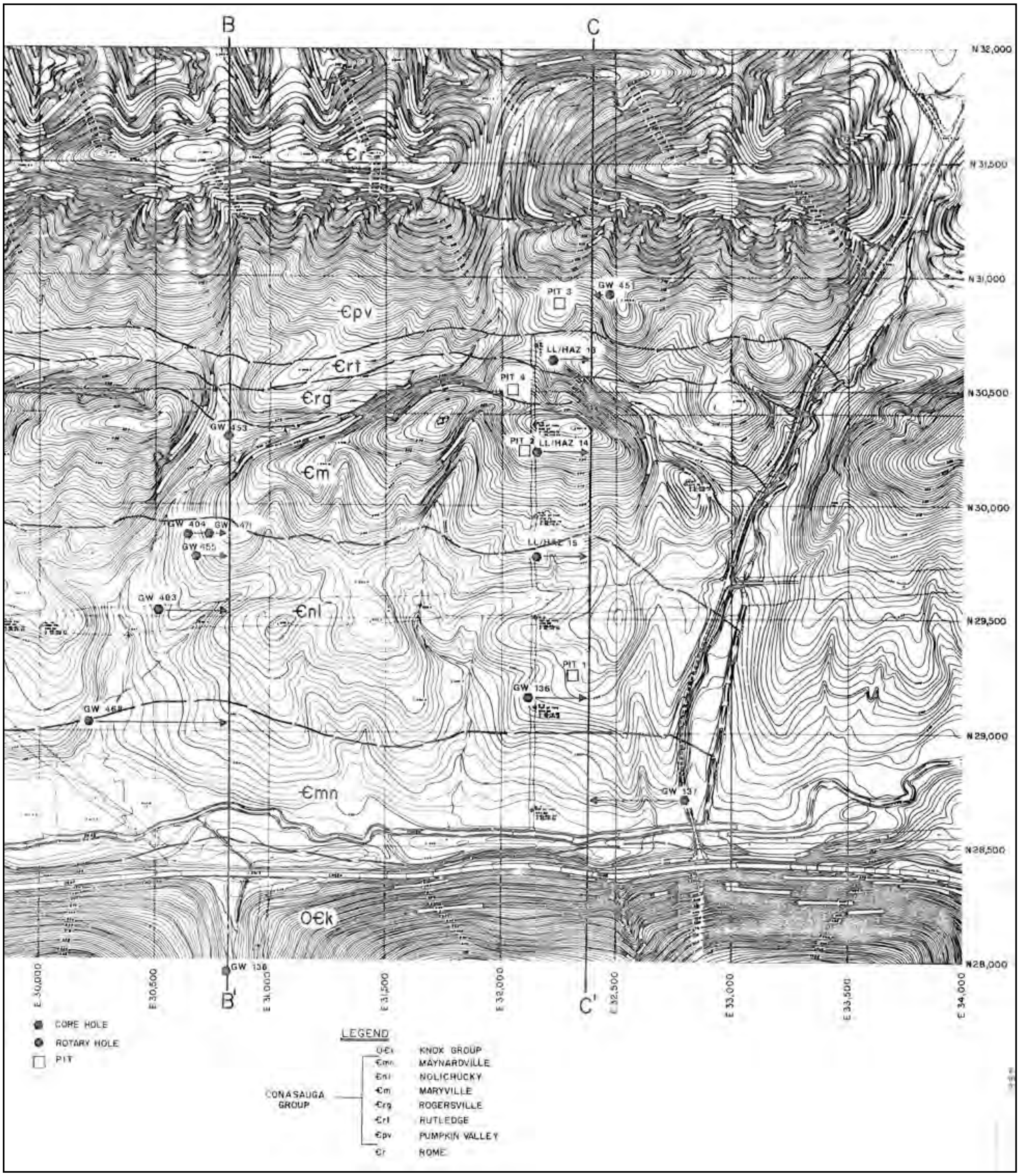


Figure E-91. Portion of the detailed geological and topographical map for the Site 14 area presented by Lee and Ketelle (1989 - Fig. 9)

Their analysis indicated that the deformation style is related to lithologic homogeneity and bedding thickness. Except for LL/HAZ-15, they identified one intermediate scale zone of drag folding, gouge, or vertically extensive shears in all core holes across the WBCV site localized within the upper Dismal Gap/Maryville formation. The zone varied from "several inches to several feet thick" and is illustrated conceptually in Figure E-92 (from Lee and Ketelle (1989) - Fig. 11). This zone apparently occurs across most of the subsurface footprint of Site 14, except at the LL/HAZ-15 location near the southern margin of the footprint. This zone was also noted by Golder in the deep level "A" pumping tests at the tracer test site just southwest of Site 14 as a stratigraphic interval with greater fracture density and potentially higher K (See Figure E-88 – pump test site cross section).

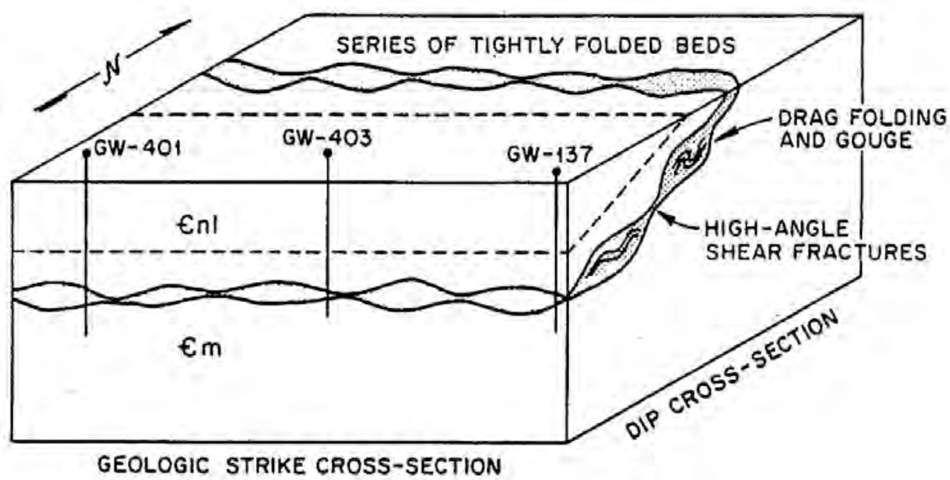


Figure E-92. Conceptual block diagram of deformation zone within the upper Dismal Gap/Maryville stratigraphic interval at Site 14

[Fig. 11 from Lee and Ketelle 1989]

6.2.2.3 Maynardville Exit Pathway Monitoring Program – Shevenell et al 1992

The Maynardville Limestone, which underlies the southern portion of BCV, was recognized in the 1980s as the primary pathway for ground water contaminants leaving BCV. In the early 1990s, a monitoring well program was developed to construct new wells that would intersect and monitor these important pathways in BCV. The results of the program were reported by Shevenell et al (1992) and provide the most detailed account of the hydrogeology of the Maynardville Limestone in BCV. The monitoring program included a series of "Pickett" wells (23) installed along four north-south transects in BCV. From west to east along Bear Creek, the transects were identified as W, A, B, and C (See locations on Figure E-2). The pickett location nearest to Site 14 is W, and is located roughly 4000 ft upstream along Bear Creek near its intersection with NT-11. Figure E-93 is a north-south cross section through the Picket W wells illustrating the depths of fractures, cavities, water bearing zones, and monitored intervals within the various hydraulic zones and members of the Maynardville identified by Shevenell et al (1992).

While the W picket and other upstream pickets are some distance from Site 14, the results of the report provide information and interpretations of the stratigraphy, hydrogeology, and subsurface flow characteristics of the Maynardville that are relevant to evaluating the potential for ground water contaminant transport downgradient of Site 14 and the other proposed EMDF sites in BCV. The report includes detailed descriptions, boring logs, borehole geophysical logs, and picket cross sections that identify the fractures, cavities, and other major transmissive zones that provide preferential pathways for ground water flow in the Maynardville (and adjacent Copper Ridge Dolomite underlying Chestnut

Ridge). The report also includes the results and analysis of purging and flow measurements while drilling and during well development/purging. Correlations of the seven zones applied to the Maynardville (and upper Nolichucky) were made with the two deep coreholes GW-137/138 near Site 14. This report provides an important reference for understanding karst flow conditions in the Maynardville at and near

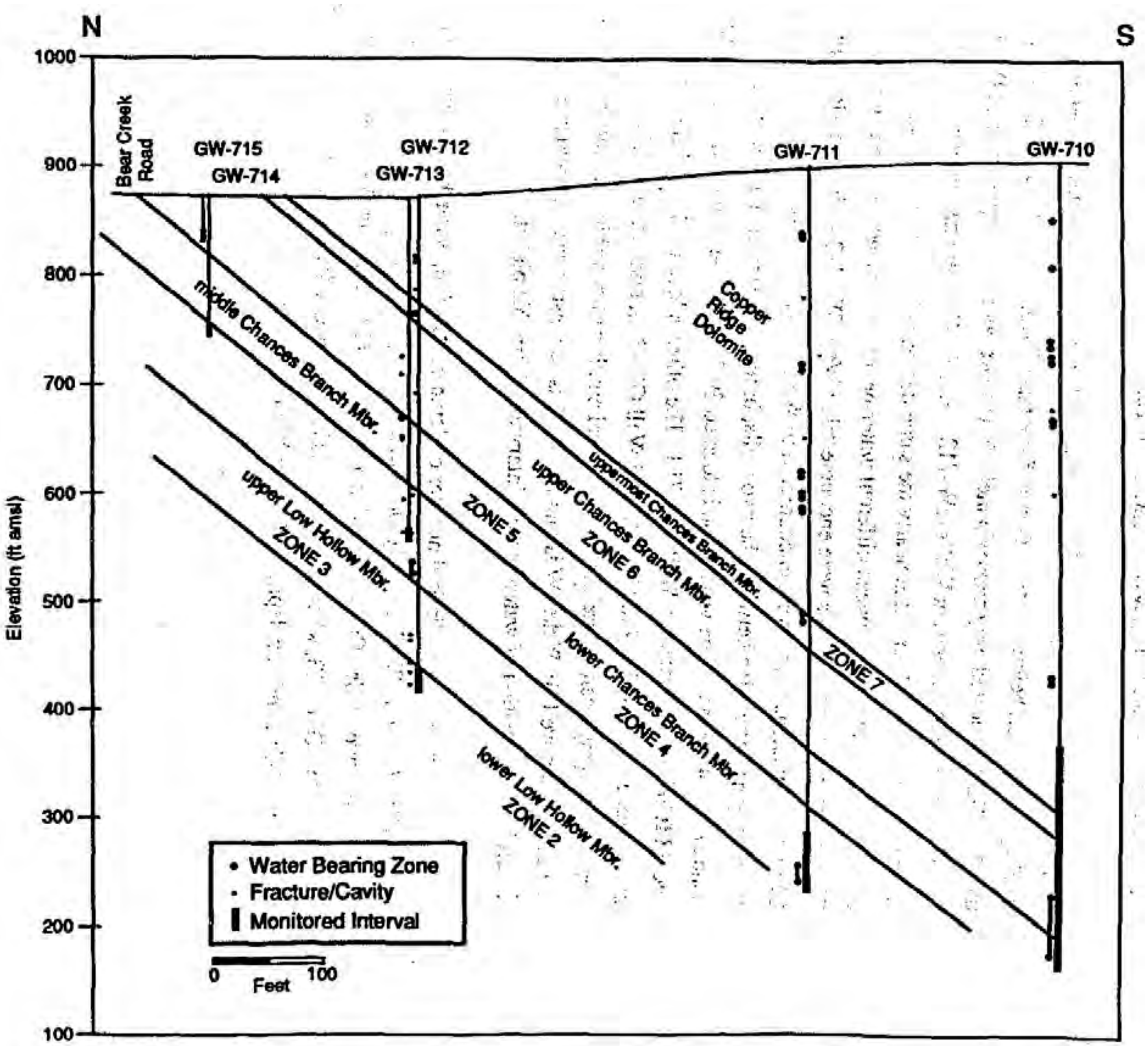


Figure E-93. Cross section through Picket W in the Maynardville Limestone east of Site 14 near the junction of NT-11 and Bear Creek

[Fig. 3.8 from Shevenell et al 1992]

Site 14, and for further evaluation of the many wells drilled within the Maynardville south and west of Site 14 if the site is selected as the EMDF location.

The Maynardville outcrop belt and the stream channel and floodplain areas of Bear Creek occur downslope to the south of and hydraulically downgradient from the various EMDF footprints. The potential thus exists that future contaminant releases to ground water from below the footprints could reach the Maynardville and Bear Creek where karst flow conditions exist, particularly where the footprints are located in closer proximity to the Maynardville subcrop. The distance between the southern waste limit margins of the various footprints and the Maynardville/Nolichucky contact varies between 593 ft at Site 7a to 1270 ft at Site 5 (Distances are 656 ft at Site 14, and 597 ft at Site 6b), suggesting that Sites 6b, 7a, and 14 offer the greatest risk of contaminants to reach the Maynardville and Bear Creek.

6.2.2.4 Well Installation and Testing West of Site 14 - Moline and Schreiber 1996

A field research program reported by Moline and Schreiber (1996) was conducted using two new monitoring wells (GW-821 to GW-823) adjacent to three existing well pairs located roughly 1500 ft west of the main tracer field near Site 14. The study site is located within the Nolichucky Shale along strike with the southern margin of Site 14 (See Figure E-81). The new wells were drilled, logged, tested and completed in 1994 and used in conjunction with the existing wells for various purposes including: 1) testing of rotasonic drilling and core logging; 2) hydraulic head measurements and helium and bromide tracer tests (See tracer test section above for a summary of tracer test results); 3) borehole tests including downhole videos, electromagnetic borehole flowmeter tests, and point dilution tests, and 4) multilevel well installations. The report should be referenced for complete details but the results of the study have relevance to Site 14 with regard to site characterization methods such as rotasonic drilling and borehole flowmeter tests, as well as the interpretation of hydrogeological conditions at Site 14.

6.2.2.5 EIS Data Package for LLWDDD Program – ORNL 1988

A data package report was prepared by ORNL (1988) to support an Environmental Impact Statement (EIS) to be written to evaluate the effects of future disposal of low-level waste at four sites on the ORR as part of the LLWDDD program, including the WBCV area. The data package provided information on geology, soils, ground water, surface water and ecological characterization for each of the four alternative sites in the LLWDDD program. The summary descriptions are concise and do not include results or interpretations, and reference back to reports by Golder and others noted above. However, several appendices to the report include site-specific data for the Site 14 footprint and adjacent areas. Appendix G, Part 1, to the report includes drilling/boring and well construction logs for 48 wells (GW-405 through GW-452 and LL/HAZ-13, -14, and -15) including many completed at and near the Site 14 footprint. Ground water level data and hydrographs were also provided in Appendix G, Part 2, and surface water quality data in Appendix D (1987-1988), and streamflow data in Appendix H (Appendix F included the full report on soils and saprolite by Lietzke et al 1988, referenced above). The streamflow data are only tabular and not provided as streamflow hydrographs and thus not easily evaluated. The data package report does provide some important characterization data for Site 14 not included in the Golder reports or available elsewhere.

In addition, the document provides more detailed descriptions of ecological conditions at the WBCV site. Terrestrial flora is described including unusual communities or species and rare plants based on extensive surveys conducted at the site from June 1 to July 13, 1988. Information on terrestrial fauna is referred to Appendix O – Ecology of the ORR. Aquatic biota are briefly reviewed, but the report notes that a report in preparation by Southworth et al (referring to Southworth et al, 1992) "*will provide the most current data on the ecological status of Bear Creek*". Appendix N includes the results of small mammal sampling (trapping) at the WBCV site including several White footed mice and one Golden mouse.

The final element of the EIS data package report of value to Site 14 is an annotated bibliography of LLWDDD characterization studies provided as the final Part III of the report. The bibliography provides a listing of 42 reference documents in no apparent order but associated with characterization of the various disposal sites proposed in the LLWDDD program with single paragraph summaries of each.

6.2.2.6 ORNL Performance Assessment 1997

A draft radiological PA was published by ORNL in 1997 for the proposed but never constructed Class L-II Disposal Facility (Tumulus) for low level waste disposal. The footprint of the proposed facility was located within the current larger Site 14 footprint. Although the physical characteristics of the proposed tumulus facility differ from those of the proposed EMDF, the PA provides information on site hydrology, hydrogeology, conceptual models of fate and transport mechanisms and pathways, and other information relevant to Site 14 (See ORNL 1997 for complete details).

6.2.2.7 USGS 1994 Seep, Spring, Stream Flow Inventory

A valley wide inventory and assessment of base flow from seep, spring, and stream channel locations throughout BCV included many locations within and adjacent to the Site 14 footprint. These data were limited to single base flow measurement events in March and September 1994 during periods not influenced by storm runoff pulses, when base flow conditions prevailed. In addition to single event point measurements of stream flow, the USGS also recorded field measurements of pH, specific conductance, temperature, and dissolved oxygen. Although the USGS hydrologic data are limited to just two time events, they provide the most comprehensive runoff data across the entire watershed of BCV and the area at and surrounding Site 14. Results are presented below as part of the review of surface water hydrology for Site 14 and the other proposed EMDF sites.

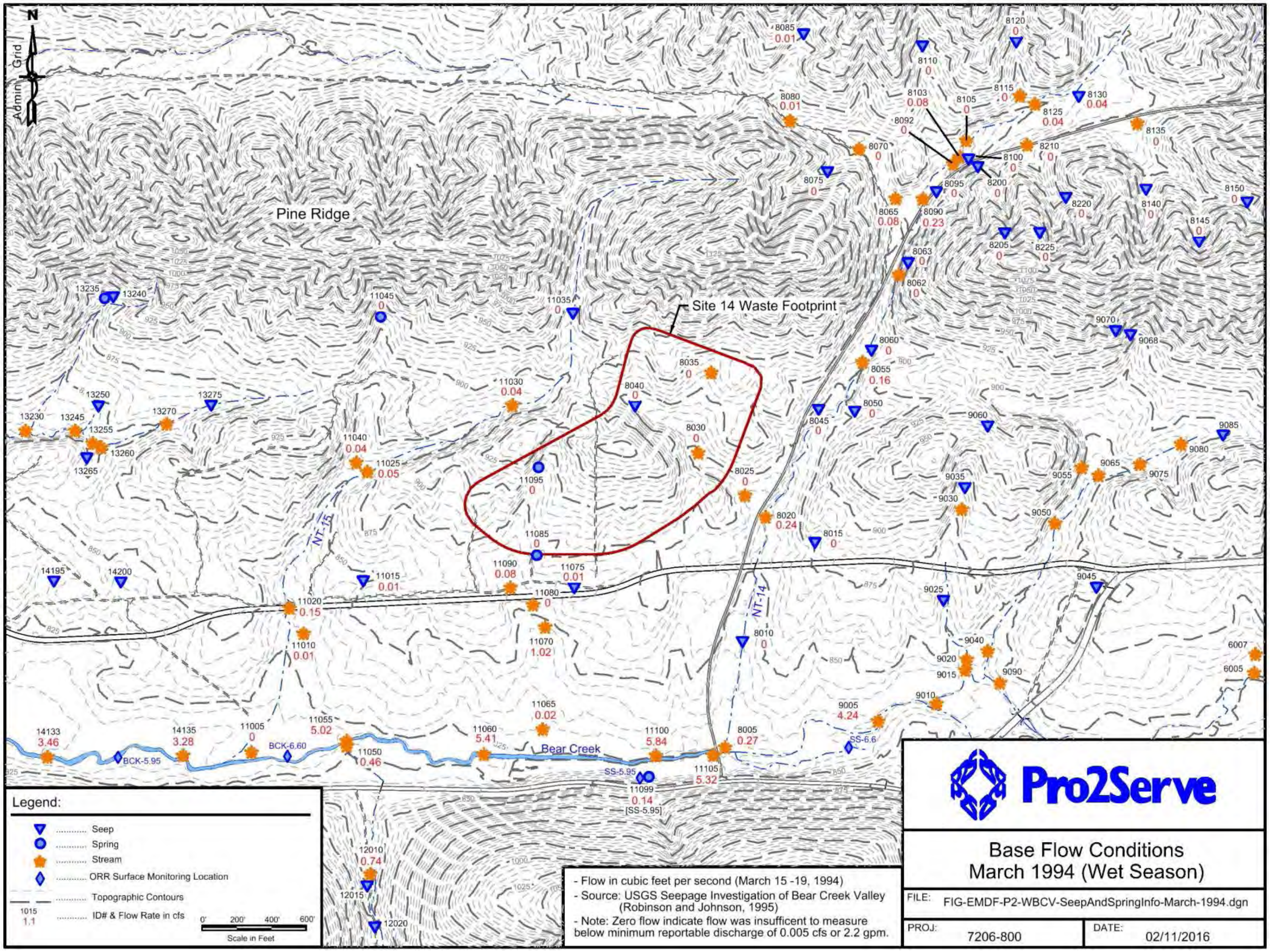
6.3 SITE 14 SURFACE WATER HYDROLOGY

This section reviews the general aspects of surface water hydrology and hydrological data available for Site 14. The Site 14 footprint occurs within the upland area between NT-14 on the east and NT-15 on the west. Runoff from the Site 14 footprint drains east and west along several ravines to NT-14 and NT-15, and toward the south along other ravines that drain directly into Bear Creek to the south.

6.3.1 USGS Data

Figures E-94 and E-95 present the USGS base flow point measurements in cfs for seep, spring, and stream channel locations for March and September 1994, respectively. The March measurements represent base flow conditions during the typical spring wet season and the September measurements represent base flow conditions during the typical late summer/fall dry season. The locations cover the primary ravines cross cutting the Site 14 footprint and the watersheds of NT-14 and NT-15, as well as the section of Bear Creek draining all of BCV to the south of Site 14. The zero values reported by the USGS do not indicate the stream channels were necessarily dry but that stream flow rates were extremely low and immeasurable using typical equipment used to gage stream flow (i.e.- <0.005 cfs or 2.2 gpm). The USGS GPS coordinates were used to plot locations on the site drawings, but where the GPS locations were grossly inconsistent with site topography, stream channels, and the locations shown on the USGS schematic drawings, the locations were adjusted. The USGS locations of springs and seeps have not been verified in the field at Site 14 (or for Sites 6b and 7a; only at Site 5).

For March and September 1994, the USGS data show zero flow at the one seep (8040) and three stream channel locations for the ravines cross cutting the northeast third of the Site 14 footprint. For the other major set of ravines and stream valleys draining southward from the southwest third of the footprint, the September data indicate zero flow across the entire watershed for this sub-tributary of Bear Creek. The March data, however, indicate zero flow from the two headwater springs (11085 and 11095) but a flow of 0.01 cfs (4.5 gpm) at seep location 11075 near the southern footprint margin. Stream channel flow is also indicated in March 1994 along this sub-tributary ranging between 0.02 and 1.02 cfs. But the stream channel flow rates do not increase incrementally in the downstream direction but vary by location. A relatively low flow of 0.02 cfs (9 gpm) near the mouth of this sub-tributary is much less than the 1.02 cfs (458 gpm) flow rate measured roughly 500 ft or more upstream.



FigureE-94. USGS flow rates measured under base flow conditions in March 1994 from locations at and surrounding Site 14

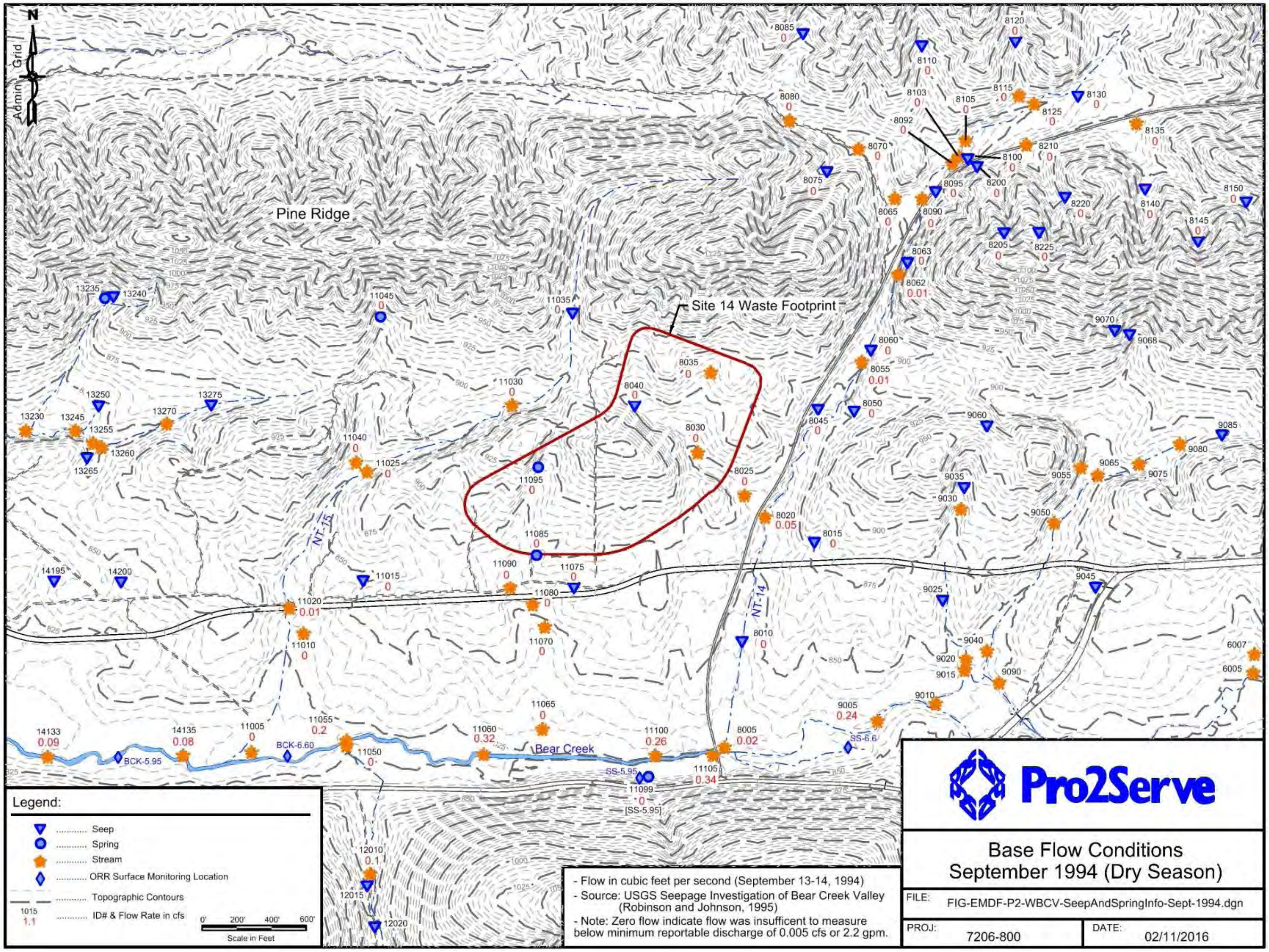


Figure E-95. USGS flow rates measured under base flow conditions in September 1994 from locations at and surrounding Site 14

This significant change in flow could indicate loss of surface water in the stream channel to karst conduits in the Maynardville limestone as the tributary flows across the predominantly clastic Nolichucky upstream across the soluble limestone of the Maynardville near the floodplains of Bear Creek. Alternatively, the reduced flow could merely represent loss to floodplain alluvium from one location to another. The identification of seep and spring locations within the Site 14 footprint with "zero" flow in both the wet and dry season measurement events indicates that the USGS identified these features even without measurable flow. Their identification suggests that at least the wet season flow rates may have been obvious even though they were below the 0.005 cfs (2.2 gpm) "zero" values that were recorded. These results are consistent with headwater spring and seep locations at Site 5 originally identified by the USGS and monitored weekly during the Phase I investigation with extremely low flow rates that fall in the range of 2.2 gpm or less. Field reconnaissance has not been conducted at Site 14 to accurately identify, photograph, and otherwise characterize the features of the springs and seeps at and near the Site 14 footprint, but these actions may be warranted if Site 14 is selected for disposal.

The USGS data also indicate wet and dry seasonal base flow conditions along the lengths of NT-14 and NT-15 bordering Site 14. The March stream channel data indicate flows along NT-14 (with a larger watershed than NT-15) ranging from 0.01 cfs in the uppermost sub-tributaries north of Pine Ridge to flow rates ranging from 0.16 to 0.27 cfs along the main trunk of NT-14. The flow rate of 0.27 cfs (121 gpm) near the mouth of NT-14 merges with flow rates of 5.32 cfs (2388 gpm) along Bear Creek just below the NT-14 confluence. In contrast the September data for NT-14 shows zero flow across the entire upper most headwaters of NT-14 with flow along the main trunk ranging from 0.01 to 0.05 cfs, an order of magnitude less than flows in March. The September flow rate of 0.02 cfs (9 gpm) near the mouth of NT-14 merges with a flow rate of 0.34 cfs (153 gpm) along Bear Creek just below the NT-14 confluence.

The USGS data for NT-15 reflect similar flow conditions ranging from zero flow at the headwater tributary seep and spring locations in both the March and September events to stream channel flow that increases progressively along downstream sections. The stream channel flow rates are much lower for NT-15 relative to NT-14 reflecting the smaller watershed area of NT-15. March stream channel flow rates along NT-15 range from 0.04 cfs (18 gpm) along the northwest side of the Site 14 footprint to 0.15 cfs (67 gpm) downstream. September stream channel flow rates on NT-15 were zero at all locations except at location 11020 where the rate was 0.01 cfs. The data suggest that typical dry season base flow along NT-15 is <0.005 cfs for the majority of the watershed area.

6.3.2 Golder/MMES Hydrologic Data (1985-1988)

The Golder Task 6 report (Golder 1989b) includes two main types of hydrologic data applicable to Site 14: 1) continuous stream flow data plotted and analyzed for specific storm events, and 2) daily mean stream flow data tabulated for the weirs noted above. Golder also obtained precipitation and other meteorological data for use with the hydrologic data. The daily mean stream flow data reported by Golder were apparently acquired separately by the USGS and MMES. Six weir locations were identified by Golder in the WBCV area. The weirs relevant and closest to Site 14 identified by Golder included (See locations on Figure E-81):

- **Bear Creek - Weir 270** on Bear Creek downstream and southwest of Site 14 near the middle of the triangular intersection of SR 95 and Bear Creek Road (at or near the current BCK 4.55 monitoring location),
- **Bear Creek - Weir 673** on Bear Creek 20 ft downstream of the mouth of NT-14,
- **NT-14 - Weir 672** on the lower reaches of NT-14 at a point 170 ft upstream of its junction with Bear Creek, and
- **NT-15 - Weir 677** on the lower reaches of NT-15 at a point 220 ft upstream of its junction with Bear Creek.

Four storm events reflecting pulses of stream channel flow in late summer (September 12 and 28, 1987), winter (January 19, 1988), and spring (April 18, 1988) storm events were evaluated by Golder. Hydrographs for the Bear Creek weirs 270 and 673 are provided in Appendix B of the Task 6 report (Golder 1989b), but no hydrographs are provided for the two weirs 672 and 677 along NT-14 and NT-15 draining the upland areas at and near Site 14. Precipitation data are not provided on the hydrographs or mean daily stream flow tables so relationships between streamflow and precipitation duration and intensity are not clear. However, the relatively rapid rise and fall in stream flow rates documented elsewhere in BCV and on the ORR are evident among the Golder hydrographs for the lower reaches of Bear Creek south of Site 14. Golder states that hydrographs indicate little baseflow in winter and late summer, but significant base flow during spring rains. While baseflow recharge to streams is less likely during typical late summer/fall dry seasons, recent detailed hydrograph and baseflow analysis from upper NT-3 tributaries at Site 5 indicates that baseflow is not limited only to Spring rainfall events but occurs over a broader nongrowing season that encompasses winter and spring seasons. The analysis further indicates that baseflow at any location depends on several variables including antecedent soil moisture conditions, air temperature, evapotranspiration rates, and the spatial and temporal variations in the frequency, duration, and intensity of precipitation events, and the overlapping runoff and baseflow effects of closely spaced sequential precipitation events. The Site 5 data suggests that baseflow ground water recharge to stream channels may even be possible during short term unusually wet atypical periods during the normal dry season. Attachment B provides details of water budget analyses and baseflow recharge to streamflow based on the complete year of continuous stream flow monitoring at Site 5. Conditions at Site 5 are similar enough to those at Site 14 that the conclusions are applicable to Site 14.

The daily stream flow data for Weirs 270 and 673 along Bear Creek and Weirs 672 and 673 on the lower reaches of NT-14 and NT-15 provide basic stream flow data close to Site 14. The stream flow data tables provide mean daily flow rates in cfs with minimum, maximum, and mean flow rates presented for each month. Data for Weir 270 spans the three year period from March 1985 through April 1988 encompassing two full years for 1986 and 1987; the Weirs at 672, 673 and 677 cover the approximately 1.5 year period from September 1986 through April 1988, including all of 1987. An example of the data set for 1987 at Weir 672 (lower NT-14) is provided in Table E-20 from Golder (1989b). Daily precipitation records from the BCBG are provided in Appendix H of the EIS data package for the LLWDDD covering the same period of weir stream flow data that allow for correlation between precipitation events and mean daily flow rates at the weirs.

Although these weir data are from locations over 1200 ft south and southwest of Site 14, they provide insight into continuous daily flow conditions along the lower reaches of NT-14 and NT-15, and for Bear Creek. The results include both base flow conditions between significant rainfall events and those related to pulses of rapid runoff in response to storm events that are not provided in the 1994 USGS single point measurements. The data along the lower reaches of NT-14 and NT-15 also provide benchmarks for upstream locations where stream flow rates would decrease along upstream flow paths relative to the downstream weir locations.

For Weir 672 (lower NT-14), analysis of the daily mean stream flow data from late September 1986 through early April 1988 indicates the following (See Table E-20 for the 1987 portion of the data at Weir 672):

- Daily minimum and maximum flow rates ranged from 0.00 to 11.00 cfs (4937 gpm)
- Monthly mean flow rates ranged from 0.00 in October and November 1987 to 0.67 cfs (301 gpm) in January 1987
- Daily mean flow rates for the dry season from August through December 1987 indicated zero (0.00) cfs for nearly all of September, October, and November, and about half of August and December 1987.

Table E-20. Example of 1987 stream flow data available for lower reaches of NT-14 and NT-15 near Site 14

[Data shown from Golder (1989b) are from Weir 672 on lower reach of NT-14 located ~1000 ft southeast of Site 14 footprint]

SURFACE DISCHARGE SUMMARY, JANUARY -- DECEMBER 1987
BEAR CREEK TRIB ABOVE BEAR CREEK ROAD NR WHEAT,TN: ALIAS=GS10
USGS SITE ID = 035382672
Flow in cfs

DAY	JAN87	FEB87	MAR87	APR87	MAY87	JUN87	JUL87	AUG87	SEP87	OCT87	NOV87	DEC87
1	0.11	0.22	2.40	0.22	0.11	0.06	0.03	0.01	0.00	0.00	0.00	0.00
2	0.10	0.27	1.00	0.23	0.09	0.05	0.03	0.01	0.00	0.00	0.00	0.00
3	0.09	0.26	0.59	0.28	0.10	0.04	0.04	0.01	0.00	0.00	0.00	0.00
4	0.08	0.23	0.41	0.35	0.53	0.05	0.05	0.02	0.00	0.00	0.00	0.00
5	0.08	0.20	0.33	0.48	0.23	0.04	0.07	0.02	0.00	0.00	0.00	0.00
6	0.07	0.18	0.27	0.69	0.16	0.03	0.08	0.03	0.00	0.00	0.00	0.00
7	0.07	0.18	0.23	0.62	0.14	0.03	0.12	0.02	0.00	0.00	0.00	0.00
8	0.07	0.16	0.22	0.47	0.12	0.03	0.07	0.02	0.00	0.00	0.00	0.00
9	0.07	0.13	0.23	0.35	0.11	0.02	0.05	0.01	0.00	0.00	0.00	0.00
10	0.07	0.13	0.18	0.28	0.09	0.02	0.04	0.04	0.00	0.00	0.05	0.00
11	0.07	0.12	0.17	0.25	0.08	0.02	0.04	0.01	0.00	0.00	0.01	0.00
12	0.07	0.12	0.18	0.22	0.07	0.02	0.03	0.02	0.09	0.00	0.00	0.00
13	0.07	0.11	0.17	0.18	0.06	0.03	0.03	0.01	0.01	0.00	0.00	0.00
14	0.07	0.12	0.17	0.28	0.06	0.03	0.03	0.00	0.00	0.00	0.00	0.00
15	0.09	0.11	0.17	1.60	0.03	0.03	0.02	0.00	0.00	0.00	0.00	0.04
16	0.08	0.52	0.19	1.20	0.03	0.07	0.02	0.00	0.00	0.00	0.00	0.01
17	0.07	0.70	0.17	1.00	0.05	0.08	0.02	0.01	0.00	0.00	0.04	0.01
18	0.37	0.62	0.26	0.67	0.05	0.05	0.02	0.01	0.00	0.00	0.01	0.00
19	11.00	0.48	0.66	0.46	0.04	0.04	0.02	0.00	0.02	0.00	0.00	0.00
20	1.50	0.38	0.58	0.35	0.09	0.06	0.02	0.00	0.00	0.00	0.00	0.01
21	0.69	0.34	0.43	0.28	0.09	0.06	0.02	0.00	0.00	0.00	0.00	0.00
22	0.50	0.65	0.33	0.22	0.09	0.09	0.01	0.00	0.00	0.00	0.00	0.00
23	0.35	1.50	0.27	0.18	0.06	0.09	0.02	0.00	0.00	0.00	0.00	0.00
24	0.27	0.87	0.24	0.27	0.06	0.06	0.02	0.00	0.00	0.00	0.00	0.02
25	0.84	0.53	0.23	0.19	0.20	0.05	0.02	0.00	0.00	0.00	0.00	0.12
26	1.60	0.42	0.18	0.17	0.15	0.04	0.02	0.00	0.00	0.00	0.00	0.08
27	0.83	4.10	0.17	0.15	0.09	0.03	0.01	0.00	0.00	0.01	0.00	.
28	0.52	3.60	0.15	0.14	0.07	0.03	0.01	0.00	0.00	0.00	0.00	0.11
29	0.38	.	0.14	0.13	0.05	0.02	0.01	0.00	0.02	0.00	0.00	0.06
30	0.32	.	0.20	0.12	0.07	0.02	0.01	0.00	0.02	0.01	0.00	0.03
31	0.25	.	0.24	.	0.09	.	0.01	0.00	.	0.00	.	0.02
	======	======	======	======	======	======	======	======	======	======	======	======
MIN	0.07	0.11	0.14	0.12	0.03	0.02	0.01	0.00	0.00	0.00	0.00	0.00
MAX	11.00	4.10	2.40	1.60	0.53	0.09	0.12	0.04	0.09	0.01	0.05	0.12
MEAN	0.67	0.62	0.36	0.40	0.11	0.04	0.03	0.01	0.01	0.00	0.00	0.02

- In contrast, daily mean flow rates for the dry season data from late August through December 1986 indicated only 4 days with zero flow, suggesting a drought period in the late summer/fall of 1987.
- For the period of record, ten relatively larger runoff events [arbitrarily bracketed by grouping all daily mean flow rates ≥0.50 cfs (224 gpm)] occurred over the ~1.5 year period of record and only between the relatively wetter months of November through April. No runoff events with flow rates ≥0.50 cfs occurred between the relatively drier months from May through October.

For Weir 677 (lower NT-15), analysis of the daily mean stream flow data from late September 1986 through early April 1988 indicates the following:

- Daily minimum and maximum flow rates ranged from 0.00 to 5.00 cfs (2244 gpm)
- Monthly mean flow rates ranged from 0.00 cfs in August through October 1987 to 0.33 cfs (148 gpm) in January and February 1987
- Daily mean flow rates for the dry season from August through December 1987 indicated zero (0.00) cfs for nearly all of August and nearly all of September through December 1987, reflecting apparent drought conditions similar to that seen in Weir 672 but more extreme, apparently from the small watershed acreage of NT-15.
- The same runoff events noted above for Weir 672 are present at Weir 677 with reduced flow rates reflecting the smaller watershed of NT-15 relative to NT-14.

For Weir 673 (on Bear Creek 20 ft below NT-14 confluence), analysis of the daily mean stream flow data from late September 1986 through early April 1988 indicates the following:

- Daily minimum and maximum flow rates ranged from 0.01 cfs in August and September 1987 to 110.00 cfs (49,368 gpm) in January 1988, ten times greater than the maximum flow rate measured at Weir 672 on the lower reaches of NT-14.
- Monthly mean flow rates ranged from 0.05 cfs (22 gpm) in August 1987 to 7.21 cfs (3236 gpm) in January 1987
- Zero daily mean flow rates were not recorded for the dry season but very low flow rates as low as 0.01 cfs were recorded for two separate three day periods in August and September 1987 where Bear Creek flow was reduced to rates of about 4.5 gpm.
- The runoff events noted above for Weirs 672/677 are reflected in flow rates at Weir 673, although with orders of magnitude greater flow, reflecting the collective watersheds for all of BCV above Weir 673. The data for Weir 270 further downstream along Bear Creek were not analyzed but probably reflect incremental increases in Bear Creek flow from NT-15 and other tributaries entering Bear Creek below Weir 673.

Historical streamflow data spanning even longer periods of record are available for several weir locations along the course of Bear Creek from upstream areas near NT-1 down to SR 95 (See Figure E-2), including BCK 4.55 that appears to be coincident with Weir 270. Flow rates and water quality are also monitored at springs SS-7 and SS-8 located on the south side of Bear Creek in the vicinity of BCK 4.55, and from SS-6.6 located about 500 ft upstream of the mouth of NT-14 and also located along the south side of Bear Creek (and therefore more likely to discharge ground water from below Chestnut Ridge). These data are publicly available in the OREIS database for the ORR but were not analyzed for Site 14.

The meteorological data, streamflow data, watershed areas were combined by Golder to complete water balance calculations for the BCV watershed. Three different analyses were used which they stated were related and consistent: a standard water budget method, a water balance method based on streamflow and precipitation, and a baseflow calculation method. According to their water budget analysis, the upper and lower reaches of Bear Creek behave very differently; in the upper reaches the ground water flows to the stream, but in the lower reaches the stream recharges the ground water. As previously noted, Golder concluded that on an annual average basis, 95% of ground water recharge returns to Bear Creek (and its tributaries) as baseflow to the stream channels. They also concluded that "no deep ground water recharge to Bear Creek occurs" (Golder 1989b).

The available data suggests that stream flow along NT-14 and NT-15 and the sub-tributaries cross cutting the Site 14 footprint is intermittent, but may be continuous along portions of the drainage paths during the typical nongrowing wet season from approximately December through April. The wetland delineation report by Rosensteel and Trettin (1993) does not specifically address stream flow determinations for the Site 14 area, but based on field observations, stream flow data, and stream determinations for upper NT-3 tributaries at Site 5 similar to those at Site 14, it is likely that NT-14 and NT-15 support constant flow throughout the Winter/Spring wet season up through their headwater reaches above the footprint area. In addition, the available data suggests it is possible that portions of NT-14 and NT-15 may support periods of continuous or intermittent stream flow during the warmer and drier seasons. Both of these NTs actually extend into headwater areas north of the crest of Pine Ridge expanding the size of their watersheds relative to those at the other proposed EMDF sites.

6.3.3 Wetland Delineation

The wetlands shown in Figure E-81 delineated by Rosensteel and Trettin (1993) reflect areas of ground water discharge that drain slowly toward and support baseflow along the stream channels and ravines at and near Site 14. The most prominent ravine cutting across the footprint occurs near the saddle area between the base of Pine Ridge and the knoll near the center of the footprint underlain by the Dismal Gap/Maryville formation. That ravine drains toward the southeast into NT-14 and is sufficiently deep to warrant an underdrain system to promote and sustain the natural drainage of ground water underflow below the footprint into the NT-14 stream channel. Two wetlands located along this ravine indicate that much of this ravine is a zone of natural ground water discharge to surface water, at least during the wet season. The USGS 8040 seep location probably occurs within or near the upper wetland in this ravine but the seep location has not been field verified since located by the USGS using GPS equipment in 1994. The other major ravine cutting across the footprint is located along the southwest third of Site 14. The USGS spring 11095 is located in the upper part of that ravine which drains southward directly toward Bear Creek. The depth of this ravine also warrants an underdrain network to facilitate the drainage of ground water to surface water and a sustained low water table below the footprint. The configuration and relatively deep drainage paths of these two drainage features are well displayed in Figure E-91 above, emphasized by the detail shown with the 2ft topographic contours. This figure also illustrates the relatively steep slopes along NT-15 immediately west of the Site 14 footprint. The area along NT-15 below these steep slopes is also identified as a wetland that may be fed in part from ground water discharge draining from the adjacent uplands at Site 14.

Other than the water balance analyses conducted by Golder, the stream flow data from the weir locations (1985-1988), the 1994 USGS inventory measurements, and the wetland delineations, little else has been done to quantify surface water hydrology at the local scale of Site 14. No site reconnaissance or flow measurements have been reported near Site 14 since the investigations in the 80's and 90's. If Site 14 is selected for the EMDF, additional characterization of surface water hydrology may be warranted to support engineering design and fate and transport modeling.

6.4 SITE 14 HYDROGEOLOGY

More wells have been drilled within and directly adjacent to the Site 14 footprint than at any of the other proposed EMDF sites. While the investigations were not targeted directly toward the engineering design or modeling needs of the EMDF, the data provide a strong foundation for the conceptual design that can be readily expanded upon if Site 14 is selected for the EMDF. Much effort has been made to compile, organize, and complete the preliminary evaluation of the data and reports available for the WBCV area that are relevant to Site 14. Additional work will be required, however, to further organize, evaluate, and present the detailed hydrogeological data for Site 14 if selected for the EMDF. The following subsections review preliminary findings based on the assessment completed for the current stage of the RI/FS process.

6.4.1 Site-specific Subsurface Data for Site 14

Other than the generalized cross sections presented in preceding sections, detailed site cross sections and maps have not been developed to accurately depict and thoroughly evaluate subsurface hydrogeological conditions across and adjacent to the proposed Site 14 footprint. As summarized in previous sections however, data from over 57 wells (excluding the greater number in the tracer field) are available to allow for the construction of accurate and detailed drawings across the Site 14 area, if selected as the new EMDF. The detailed site cross sections and maps would consolidate available data from the previous investigations summarized above, and facilitate site planning for additional characterization and detailed design. Fundamental hydrogeological data available for Site 14 include:

- survey coordinates and elevations for wells/piezometers;
- boring logs with descriptions and depths of residual soils, saprolite, and bedrock;
- monitoring well/piezometer construction diagrams and data indicating open hole and screen intervals, isolation casing depths, filter pack/bentonite seal intervals, etc.;
- water level data from manual synoptic measurements, continuous monitoring devices, and statistical averages and max/min values; and
- results of slug, packer, pumping and flowmeter tests to determine aquifer hydraulic characteristics such as K, T, and S.

Table E-21 lists 57 active and inactive wells/piezometers at and near Site 14, located north of Bear Creek, south of Pine Ridge, and between NT-14 and NT-15, for which some combination of either boring logs, well construction logs/data, and/or water level hydrographs/data may be available. These locations do not include the tracer test area shown on Figure E-81, where an additional ~72 individual and cluster wells/piezometers occur. Among the wells in Table E-21, most of the logs are available from among appendices to the Golder reports and the EIS Data Package, and from other independent pdf information/data files. Other well construction data and ground water level data are provided in the Y-12 subsurface data base for BCV maintained by the Y-12 Environmental Compliance Department (B&W Y-12 2013). Well data are also available in spreadsheet formats in miscellaneous unpublished data files in Excel and pdf formats. If Site 14 is selected as the EMDF, these logs and data will warrant compilation, organization, and detailed evaluation, along with presentation of results in maps and cross sections to more thoroughly evaluate the site-specific subsurface hydrogeological conditions at and adjacent to Site 14.

6.4.2 General Subsurface Conditions at Site 14

General conclusions that can be made for Site 14 are similar to those presented above for the EMDF sites and general conditions in BCV. The Site 14 footprint is located across the outcrop belts of the upper Pumpkin Valley Shale on the north, southward across the Friendship/Rutledge, Rogersville, Dismal Gap/Maryville formations, and the lower Nolichucky Shale along its southern margins. A regolith zone of unconsolidated overburden materials occurs across the footprint that normally includes a thin topsoil layer (<1ft thick) that grades into an interval of residual soils (typically clay/silty clay across much of the Conasauga group formations) a few feet thick, followed by a saprolite layer of weathered and fractured bedrock that may be a few feet to a few tens of feet thick.

Table E-21. Active and inactive monitoring wells/piezometers at and near Site 14 with major types of available data

Monitoring Well	Boring Log	Well Construction Log	WL Hydro graphs	Slug Test Data /Plots	Active	Inactive		Monitoring Well	Boring Log	Well Construction Log	WL Hydro graphs	Slug Test Data /Plots	Active	Inactive
GW-136	Y*	Y**		Y	Y			LL/HAZ-04		**				Y
GW-137	Y*	Y**		Y	Y			LL/HAZ-05		**			Y	
GW-403	Y*	Y**		Y	Y			LL/HAZ-06		**				Y
GW-427	Y	Y**	Y	Y	Y			LL/HAZ-07		**			Y	
GW-428		Y**	Y	Y	Y			LL/HAZ-08		**			Y	
GW-429		Y**	Y		Y			LL/HAZ-09		**			Y	
GW-430	Y	Y**	Y	Y	Y			LL/HAZ-10		**			Y	
GW-435		Y**	Y		Y			LL/HAZ-11		**				Y
GW-436	Y	Y**	Y	Y	Y			LL/HAZ-12		**				Y
GW-437	Y	Y**	Y	Y	Y			LL/HAZ-13		Y**			Y	
GW-438		Y**	Y		Y			LL/HAZ-14		Y**				Y
GW-439	Y	Y**	Y	Y	Y			LL/HAZ-15		Y**				Y
GW-440		Y**	Y	Y	Y			OR-03		**				Y
GW-441	Y	Y**	Y	Y	Y			OR-04		**			Y	
GW-442		Y**	Y		Y			OR-05		**			Y	
GW-443	Y	Y**	Y		Y			OR-06		**				Y
GW-445	Y	Y**	Y		Y			OR-21		**				Y
GW-447		Y**	Y			Y		OR-22		**				Y
GW-448	Y	Y**	Y	Y		Y		OR-23		**			Y	
GW-449		Y**	Y		Y			M-04		**				Y
GW-450	Y	Y**	Y	Y	Y			M-05		**				Y
GW-451	Y	Y**	Y	Y	Y			M-06		**				Y
GW-452		Y**	Y	Y		Y		M-07		**				Y
GW-466	Y	Y**		Y	Y			M-08		**				Y
GW-472	Y	Y**		Y	Y			M-09		**				Y
GW-499A	Y	Y**			Y			M-10		**				Y
LL/HAZ-01		**			Y			42-DC		**				Y
LL/HAZ-02		**			Y			44-DC		**			Y	
LL/HAZ-03		**				Y								

Notes: Y – indicates Yes status – blank cells indicate No; * - indicates rock core log is available for these deep bedrock coreholes
**Well coordinates, construction, water level, and other fundamental well data are available for all wells at Site 14 in the Y-12 Subsurface Database
Inactive – inactive/plugged and abandoned or otherwise unusable as shown on Y-12 subsurface database drawings for BCV
WL Hydrographs – water level hydrographs available in Appendix G of EIS Data Package for LLWDDD
Slug test data and water level recovery plots are provided in Appendix G of EIS Data Package for LLWDDD
Green shading indicates well is within Site 14 footprint; Orange shading indicates well is within ~300-400 ft radius of footprint perimeter

The regolith materials may also include surficial deposits of unconsolidated colluvium along lower slopes of valleys, and alluvium along valley floor/floodplain areas at and adjacent to the footprint. Lietzke et al (1988) described and mapped surficial soils and shallow saprolite, and areas with both ancient and recent alluvium and colluvium across the WBCV area. The deeper levels of soils, saprolite, and bedrock are described primarily in boring logs and rock cores, and through the various test methods summarized above used to determine aquifer characteristics. The detailed hydrogeology and hydraulic characteristics of alluvial materials, and the relationships between ground water discharge and surface stream flow have not been fully characterized, but may be important to the design of the proposed underdrain networks at Site 14. Lietzke et al (1988) does review the general soils characteristics of alluvium at Site 14 where encountered in pits and shallow trench transects across the site.

6.4.3 Ground Water Occurrence and Flow at Site 14

The general configuration of the water table or potentiometric surface for shallow wells at Site 14 is illustrated in Figures E-82 and E-83 (prepared by Golder 1988b). Golder provides no indication of whether these data and contours are representative of seasonal high and low ground water conditions. However, they do provide some indication of water table elevations across and adjacent to the Site 14 footprint that can be used in general to infer relationships between conceptual design base level elevations and the water table. The 1987 map illustrates water levels measured on August 18, 1987, shown to the nearest 0.01 ft. The drawing notes that water levels in deep coreholes were not used in contouring. In contrast, the contour map for May 1988 does not specify a measurement date and the control data are shown only to the nearest 1 ft. Golder does not explain these differences, but in general the contours are shown to reflect the influence of the primary NT-14 and NT-15 stream channels bordering the Site 14 footprint as well as the apparent influence of some of the deeper ravines cross cutting the footprint. The contours indicate horizontal gradients and generalized flow directions for shallow ground water from upland areas of Site 14 toward zones of ground water discharge along NT-14, NT-15, and Bear Creek. In particular, steep gradients are shown toward the northwest of the footprint that would in conjunction with dominant strike-parallel flow paths direct shallow to intermediate level ground water flow toward the mid to upper reaches of NT-15. Likewise similar gradients and conditions would convey ground water along dominant strike-parallel fracture pathways to the east and southeast toward NT-14, and particularly along the sub-tributary to NT-14 that cross cuts the northern third of the Site 14 footprint. Hydraulic gradients across the southern part of the footprint suggest ground water migration to the south directly toward Bear Creek. However, tracer test results suggest that ground water flow (and contaminant migration) along hydraulic gradients that are perpendicular to strike may be relatively slower than areas of the site where hydraulic gradients are parallel to subparallel with geologic strike.

Available cross sections through the tracer test site located just southwest of the Site 14 footprint suggest that the water table probably occurs up within the saprolite zone above competent bedrock within the lower elevation areas to the southwest and south of Site 14. It is unclear though, whether or not the water table below the higher elevation areas of Site 14 occurs within the saprolite zone or at deeper levels within bedrock. The available cross sections across the broader areas of WBCV do not illustrate water table conditions with respect to regolith and bedrock. Recent Phase I data from Site 5, however, show that the water table below the spur ridge underlain by the Dismal Gap/Maryville occurs in bedrock well below the base of saprolite. This condition may occur along the ridge crest at Site 14 near the location of LL/HAZ-09 and other wells below the ridgeline crests at Site 14. The range of fluctuations in the depth of the water table and the depth to competent bedrock across these higher elevation crest areas of the site significantly influence the base elevations for the landfill floor and underlying liner system and geobuffer which must occur within the unsaturated zone. Available data are sufficient to allow for preliminary mapping of the bedrock surface at Site 14, and the available contour maps by Golder provide a reasonable approximation of the water table across the site that can be used to refine the basal elevations and configuration beyond the conceptual landfill design at Site 14 if the site is selected for construction.

The geologic contact between the Nolichucky Shale and Maynardville Limestone occurs about 656 ft south of the southernmost edge of the Site 14 waste footprint (See Figure E-81). South of this contact, the relatively lower average hydraulic conductivities in the fracture dominant flow to the north are enhanced by karst flow conditions in the Maynardville south of the contact. In the area south of this contact within the Maynardville along and adjacent to the floodplain area of Bear Creek, ground water has been shown throughout BCV to move more quickly toward the southwest predominantly along geologic strike. The ground water migrates within a complex network of floodplain alluvium, saprolite and bedrock fractures, and open conduits and commingles to some degree with surface water along Bear Creek. Several wells south and southwest of Site 14 provide data that may be used to assess the hydrogeological characteristics within the outcrop belt of the Maynardville. Well logs and subsurface testing of those wells offer the potential for site-specific data that could be used for modeling fate and transport along downgradient flow paths if Site 14 is selected as the EMDF. The USGS spring 11099 (also identified as SS-5.95) is located along the south side of Bear Creek about 500 ft downstream of the NT-14/Bear Creek junction. Like many other springs along the lower north slopes of Chestnut Ridge, this spring may be fed entirely or in part from ground water recharge and discharge below the carbonates of Chestnut Ridge. Springs SS-7 and SS-8 occur along the south side of Bear Creek well downstream of Site 14 (near SR 95 around 2000 ft southwest of the NT-15/Bear Creek junction). The springs discharging to Bear Creek that are fed from ground water below undisturbed and uncontaminated areas along the middle and north sides of Chestnut Ridge may introduce uncontaminated ground water to the stream channel of Bear Creek and act to naturally attenuate ground water and/or surface water contaminants entering from areas north of Bear Creek such as those historically migrating from existing source areas in Zone 3.

The conceptual model for Site 14 and the other EMDF sites in BCV suggests that the majority of ground water flux occurs within the shallow water table interval, with significantly less flux occurring within the intermediate and deeper intervals (See Section 2.8 above and several technical papers and research supporting the conceptual model). The conceptual model suggests that ground water contaminants reaching the water table below the Site 14 footprint would be conveyed along strike dominant flow paths toward discharge zones along NT-14 and NT-15, and that contaminants would also migrate along fracture flow paths south and southwest of Site 14 towards Bear Creek where subsurface karst flow conditions and interactions with surface water along Bear Creek complicate the overall flow regime.

6.4.4 Aquifer Test Data

Among the sites in BCV, the WBCV area at and near Site 14 offers probably the most extensive testing and data for basic aquifer characteristics such as K, S, T, and anisotropy. Data, findings, and interpretations from the pumping tests, packer tests, slug tests, flowmeter tests, and tracer tests are summarized in previous sections. All provide significant site characterization information for evaluating and modeling subsurface conditions at and near Site 14.

6.4.5 Geotechnical Data

Among the data obtained for the WBCV area for the LLWDDD program, little geotechnical data are available. Among the available Golder and other boring logs, blow counts are not provided in overburden soils and saprolite. Air rotary drilling methods were commonly used with drill cuttings collected at 5ft intervals or unspecified intervals as the basis for describing general subsurface intervals such as “saprolite”, or broad intervals encompassing tens of feet of bedrock sequences that are assigned very generalized descriptions noting basic lithologies, colors, etc. Rock core logs from the deep bedrock coreholes include percent rock quality designation data (RQD) and measures of fracture index per foot. Conventional blow counts and Shelby tube sampling with geotechnical laboratory analysis for soil and rock engineering properties and parameters appear to be absent from the site characterization data in WBCV area and Site 14.

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APPENDIX E – ATTACHMENT A:
PHASE I CHARACTERIZATION REPORT
OF THE ENVIRONMENTAL MANAGEMENT DISPOSAL
FACILITY SITE IN EAST BEAR CREEK VALLEY (SITE 5)

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CONTENTS

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FIGURES

TABLES

EXHIBITS

PLATES

ACRONYMS

Alliant	Alliant Corporation
API	Antecedent Precipitation Index
ARAP	Aquatic Resources Alteration Permit
ASTM	American Society of Testing and Materials
ATV	accoustic televiewer
BCV	Bear Creek Valley
BWSC	Barge, Waggoner, Sumner, and Cannon, Inc.
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980
DOE	U.S. Department of Energy
D	Draft
DQO	Data Quality Objective
EM	Office of Environmental Management
EMDF	Environmental Management Disposal Facility
EMWMF	Environmental Management Waste Management Facility
EPA	U.S. Environmental Protection Agency
FFA	Federal Facility Agreement
FY	Fiscal Year
HPF	heat pulse flow
HSA	hollow-stem auger
K	hydraulic conductivity
LLLDDD	Low Level Waste Disposal, Development, and Demonstration
M&W	M&W Drilling, LLC
NGR	Natural Gamma Ray
NNSA	National Nuclear Security Administration
NT	Northern Tributary
NWP	Nationwide Permits
NWS	National Weather Service
ORAU	Oak Ridge Associated Universities
ORP	oxidation/reduction potential
ORR	Oak Ridge Reservation
OTV	optical televiewer
Pro2Serve	Professional Project Services, Inc.
PVC	polyvinyl chloride
RI/FS	Remedial Investigation/Feasibility Study
RQD	rock quality designation

SP	spontaneous potential
SpC	specific conductivity
SOP	standard operating procedure
SWG	surface water gaging
SWL	static water level
TDEC	Tennessee Department of Environment and Conservation
TDS	total dissolved solids
TOC	top of casing
U.S.	United States
UPF	Uranium Processing Facility
USACE	U.S. Army Corps of Engineers
USCS	Unified Soil Classification System
USGS	U.S. Geological Survey
VOC	volatile organic compound
WBCV	West Bear Creek Valley
Y-12	Y-12 National Security Complex

1. INTRODUCTION

This report documents the results of a limited Phase I site characterization at the proposed Environmental Management Disposal Facility (EMDF) site on the Oak Ridge Reservation (ORR). The report is provided as Attachment A to Appendix E of the current Draft (D3) version of the Remedial Investigation/Feasibility Study (RI/FS) Report for the EMDF. The Phase I site characterization activities were conducted in response to concerns voiced by the local United States (U.S.) Department of Energy (DOE) Oversight Office of the Tennessee Department of Environment and Conservation (TDEC) about site suitability. The TDEC comments were presented to DOE in response to the Draft (D2) RI/FS Report (DOE 2013a) and relate in part to concerns regarding springs, seeps, and the shallow water table at and near the footprint of the proposed EMDF.

The overriding objective of the limited Phase I site characterization activities was to provide data to demonstrate the suitability of the site as a viable on-site Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) disposal facility, similar to the existing adjacent Environmental Management Waste Management Facility (EMWMF). As the primary parties in the Federal Facilities Agreement for CERCLA activities on the ORR, TDEC and the U.S. Environmental Protection Agency (EPA) must concur with DOE on the suitability of the EMDF. Limiting the Phase I site characterization scope was viewed by DOE as a prudent step to avoid investing heavily in extensive site characterization until the site is deemed suitable and approved by TDEC and EPA. If the proposed EMDF site *is* approved by TDEC and EPA, then the DOE would proceed with a much more detailed Phase II site characterization program to thoroughly characterize the site and provide the extensive data required for development of a complete and rigorous engineering design for the proposed landfill. If TDEC and EPA reject the proposed EMDF site then DOE would not have invested unwisely in extensive site characterization.

The conceptual design for the EMDF includes the installation of underdrain systems beneath the landfill to ensure surface water and ground water diversion, drainage, and lowering of the water table below the waste cells. The results of the Phase I site characterization are presented in relation to the existing site topography and proposed conceptual design for the landfill and underdrain system. The results support the concept that the water table can be effectively managed and lowered during and after construction to ensure that the water table does not encroach on the geologic buffer or waste materials placed above the buffer and liner systems.

1.1 DRIVERS

The proposed site is undeveloped and lacks site-specific characterization information, although there is abundant data on geology and hydrogeology from adjacent areas. The lack of site-specific characterization data was raised as a concern by TDEC representatives at a workshop held in Oak Ridge on August 14, 2013. TDEC also offered several comments on the D2 RI/FS regarding site suitability and the lack of site characterization data for the selected site, noting that the agency would not approve the site unless site characterization was conducted. The cost and schedule for full site characterization, including a full year of monitoring, which is intended to support final design, monitoring and performance assessments, could not be justified by DOE unless the site was approved by the Federal Facility Agreement (FFA) parties (i.e., TDEC and EPA) as the preferred disposal site. Discussions between senior DOE Oak Ridge Office of Environmental Management (EM) managers and senior TDEC managers on September 13, 2013, produced an informal agreement that a limited Phase I site characterization, resulting in satisfactory findings, would be adequate to support a preferred site approval decision. DOE acknowledged that TDEC and EPA can disapprove the site or the action at several points after the RI/FS is approved if subsequent more detailed characterization data, or protectiveness evaluations, warrant disapproval. DOE subsequently prepared a work plan entitled *Limited Phase I Site Characterization Plan for the Proposed Environmental Management Disposal Facility Site as Requested by the Tennessee*

Department of Environment and Conservation (DOE 2013b) to document the original proposed scope of work. TDEC reviewed the work plan and provided comments. Based on TDEC comments, DOE made slight revisions to the work plan and proceeded with plans for the Phase I effort. EPA did not provide formal comments on the work plan.

1.2 OBJECTIVES

As noted above, the primary goal of the limited Phase I site characterization was to provide initial data on surface water and ground water conditions at the proposed EMDF site. These data will allow for a more informed decision on landfill site suitability so the project could move forward with a more complete Phase II characterization to follow upon approval. Secondary goals were to acquire initial data and make observations on seasonal changes in ground water level fluctuations, stream flow, springs, and seeps at the site in order to assess ground water/surface water interactions and to demonstrate that the conceptual design will be adequate to handle hydrological conditions at the proposed EMDF site.

1.3 REPORT ORGANIZATION

Sections 2 through 4 review the scope and detailed field methodologies of the Phase I investigation, as these have not been previously documented. Section 5 summarizes previous investigations near and along strike with the EMDF with references to documents and important data relevant to the EMDF. Section 6 presents a site-specific hydrogeological conceptual model for the EMDF. Section 7 presents the Phase I results under the general headings of surface water hydrology and hydrogeology (subsurface hydrology). Section 8 provides conclusions and recommendations based on the Phase I results addressing site suitability and general recommendations for follow on Phase II investigations. Section 9 lists all references cited. Plates with detailed large scale site drawings and cross sections are provided as attachments. Supporting documentation for the Phase I investigation (completed field forms, boring and geophysical logs, test results, calculations, monitoring data, etc.) are provided in various attached Exhibits.

1.4 BACKGROUND SITE AND CONCEPTUAL LANDFILL DESIGN INFORMATION

Numerous investigations have been completed for existing and planned waste sites within Bear Creek Valley (BCV) and across the ORR. Reports from these investigations provide a considerable amount of detailed surface and subsurface information dating back from the 1970s to the present. Much of the information is available from sites directly adjacent to the proposed EMDF providing a unique resource and opportunity for planning investigations at the EMDF. Relevant data from adjacent sites is briefly summarized in Section 5.0 and elsewhere in conjunction with the Phase I results as appropriate. Background information is also summarized in Appendix E of the current RI/FS report (D3 Version, On-site Disposal Alternative Site Description). A review of Appendix E and source documents referenced in the current Phase I report is encouraged and important in providing a more complete context for the results of this Phase I report.

Section 6 of the current RI/FS Report (D3) presents a review of the proposed engineering conceptual design for the EMDF. The conceptual design includes descriptions and drawings of the proposed underdrain system, geologic buffer and compacted engineered fill, the landfill liner/leachate system, waste and overlying cap/cover system and stormflow drainage/diversion systems for the landfill. These design elements and their relationships with the existing surface and ground water flow systems are critical to understanding and acceptance of the site as a suitable location for waste disposal and warrant review along with the Phase I site characterization results. Cross sections presented in Plates 2 through 4 accurately present Phase I results in relation to key design elements such as the underdrains, geobuffer, and liners.

1.5 COMPLIANCE WITH APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

It was recognized that the proposed Phase I characterization efforts would make minimal impacts to waters of the State; and certain permitting, including U.S. Army Corps of Engineers (USACE) pre-construction notices and Tennessee Aquatic Resources Alternation Permit (ARAP) requirements, might be relevant and appropriate. However, because this is a CERCLA action, only the substantive requirements of permits must be met.

A summary of the 2012 Nationwide Permits (NWP) of the USACE Nashville District Regulatory Branch, indicates that the Phase I characterization field activities would fall under NWP #5 (Scientific Measurement Devices) under statutory authority 10/404, with limits of 25 yd^3 for weirs and flumes. The 2012 NWP added meteorological stations, current gauges, and biological observation devices to the list of examples and added a requirement that devices and any associated structures or fills be removed upon completion of use and restored to pre-construction elevations to maximum extent practicable [http://www.usace.army.mil/Portals/2/docs/civilworks/nwp/2012/NWP2012 _sumtable_15feb 2012.pdf]. According to these statutes, a Pre-Construction Notification would not be required for the scope of the Phase I investigation. Flow monitoring is not included in the actions requiring a TDEC ARAP.

CERCLA documentation meets the substantive requirements of the National Environmental Policy Act of 1969. The proposed Phase I field work is therefore covered under DOE's categorical exclusion B3.1, applicable to site characterization, monitoring, and general research. Specific activities included in this categorical exclusion that apply to the Phase I scope of work include:

- Geological, geophysical, geochemical, and engineering surveys and mapping, and the establishment of survey marks.
- Installation and operation of field instruments (such as stream-gauging stations or flow-measuring devices).
- Drilling of wells for sampling or monitoring of ground water or the vadose (unsaturated) zone, well logging, and installation of water-level recording devices in wells.
- Aquifer and underground reservoir response testing.

This Phase I site characterization is performed in partial fulfillment of the requirements of 40 CFR 264.97(a)(1) to determine background water quality. The results of this work will also be used to fulfill requirements for Site Evaluation and Low-Level Waste Disposal Facility Design given in DOE O 435.1A, as defined in DOE G 435.1, Chapter IV.

1.6 KEY SITE FEATURES

No hazardous or radioactive contamination was expected or found at the site through field screening activities. Review of available historical topographic maps and air photos indicated that the site had probably not been used for agricultural or industrial purposes since before World War II. Existing ground water contaminant plumes from the S-3 Ponds and former Bone Yard/Burn Yard and Oil Landfarm are all hydraulically downgradient of the EMDF.

A downburst (tornado-like wind) that occurred during a storm on May 19, 2013, toppled trees across much of the proposed EMDF site, as well as on the north side of Pine Ridge. Timber recovery started in the EMDF area in mid November, 2014, and was completed by mid July 2014. Figure 1 illustrates key site features in relation to the EMDF footprint. Features include Phase I monitoring locations, topographic contours, Northern Tributary (NT) drainage paths, approximate geologic formation outcrop boundaries, and the approximate layout of roads constructed to access drilling locations. A large portion of the footprint area has now been cleared of timber as shown in the aerial photo in Figure 2 taken on

September 3, 2014. The logging and road construction work have modified the original forested conditions and natural drainage features in some areas of the site. Potential influences on surface water and stormflow zone ground water flow conditions are discussed elsewhere in this report.

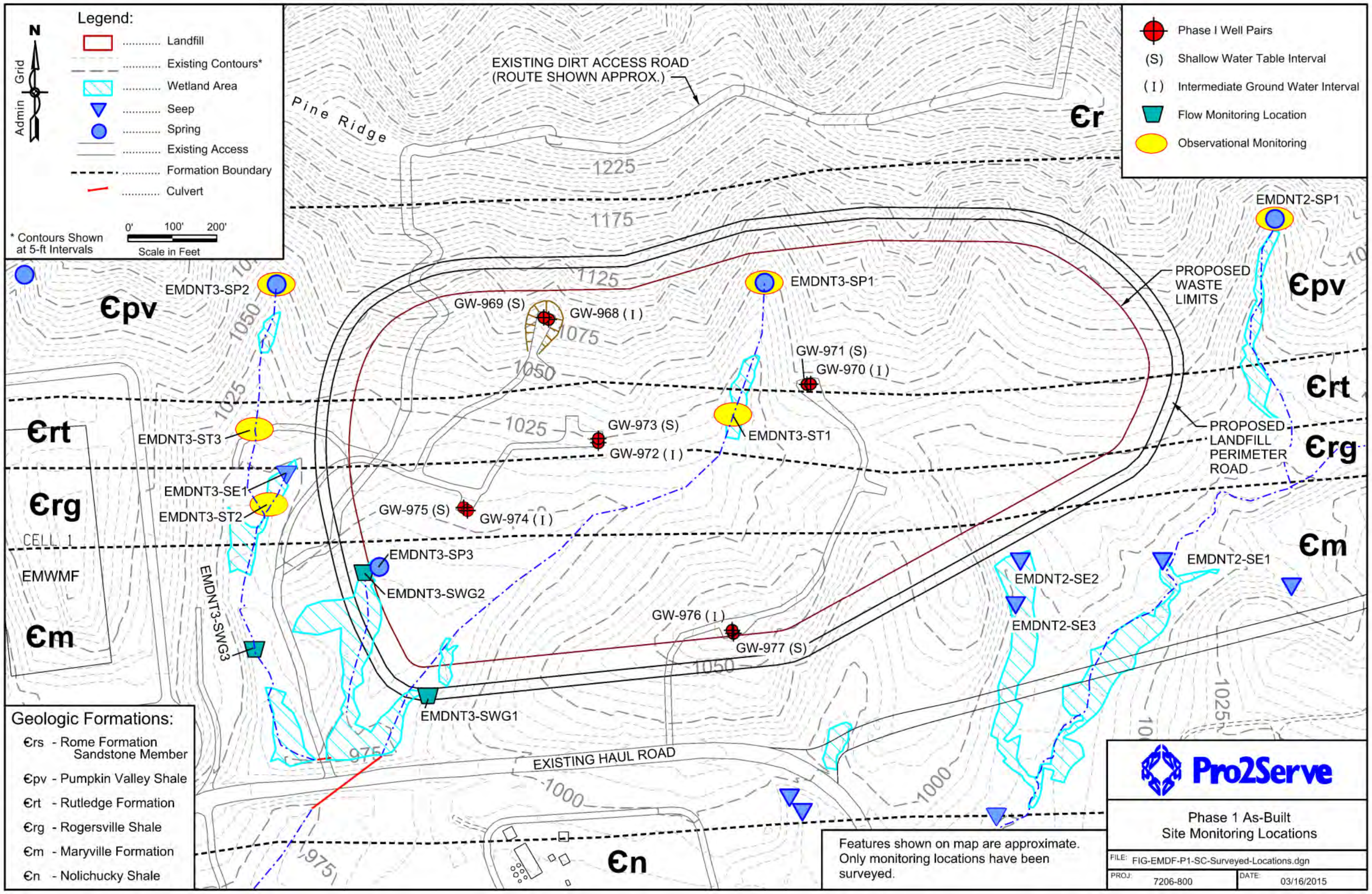
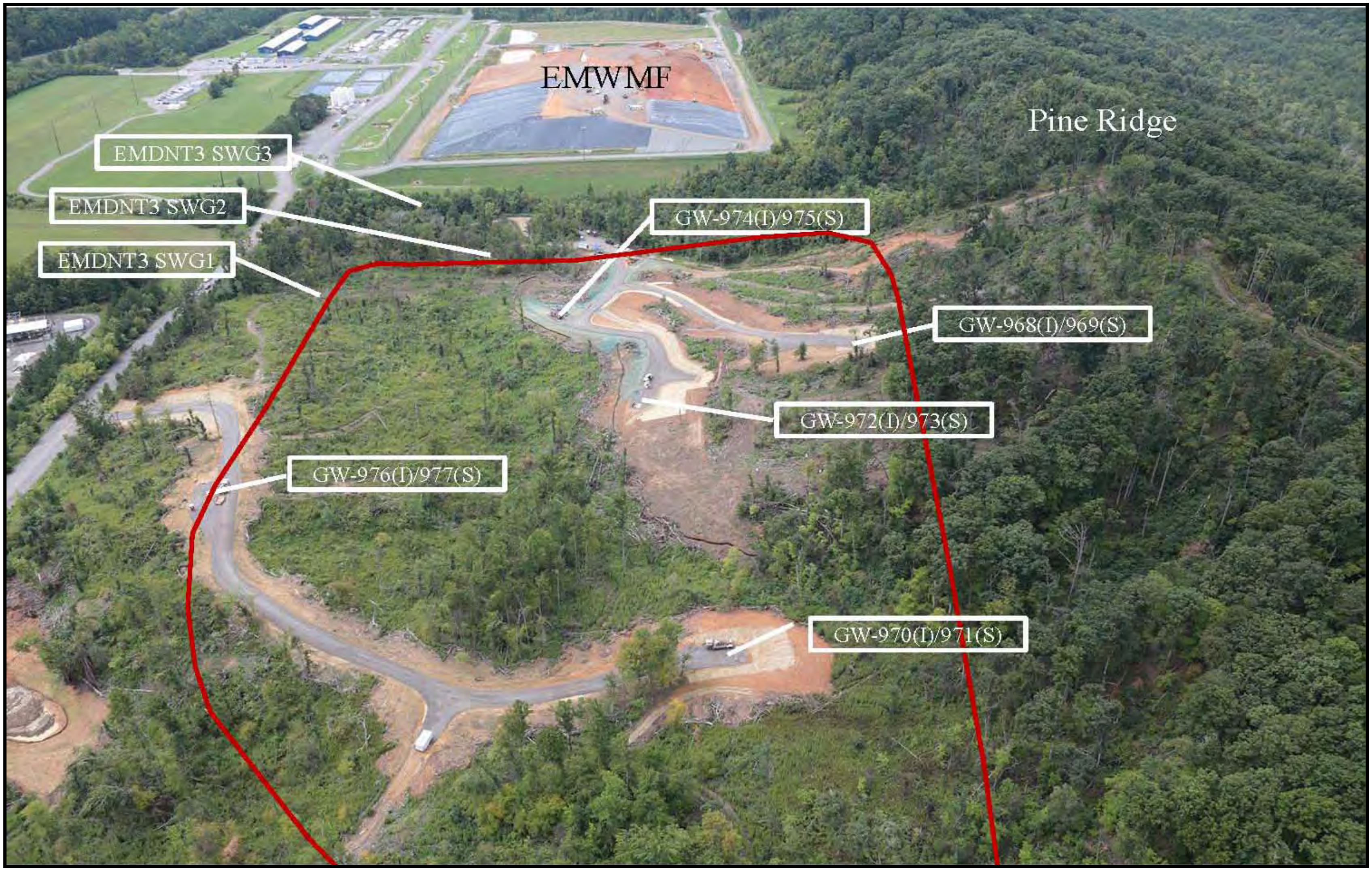


Figure 1. Phase I Monitoring Locations at the Proposed EMDF Site



Note: Trees removed from blowdown areas, Phase I well pair/flume locations; red line indicates approximate outline of waste limits.

Figure 2. View toward the Southwest of the Proposed EMDF Site on September 3, 2014

2. SITE PREPARATIONS AND PROCUREMENT

Because the proposed EMDF site covers areas inside and outside of the Y-12 National Security Complex (Y-12) 229 perimeter fence, a memorandum of understanding was developed between DOE EM and the National Nuclear Security Administration (NNSA) to facilitate site activities and effective coordination between DOE EM staff, NNSA staff, adjacent EMWMF staff (URS | CH2M Oak Ridge LLC), and other contractors working at and near the EMDF site. Excavation/penetration permits (including utility clearances) were required prior to road construction, drilling, and placement of flumes at stream gaging stations, and were obtained through the Y-12 permitting process.

In preparation for the Phase I field work, DOE employed an existing contract with ES&H, Inc., to construct road access to each of the proposed monitoring well locations. The road construction began on July 21, 2014, and was completed during the first week of September 2014. The construction included storm water routing and erosion control measures to prevent soil erosion into the neighboring NT tributaries at and beyond the site. Of note the road construction resulted in a reconfiguration of the former natural surface water drainage patterns (wet weather conveyances) in the vicinity of the roads leading to the three well clusters on the northwest side of NT-3. A portion of the intermittent surface runoff that had formerly followed natural drainage paths and been more evenly absorbed across the surface is now focused during significant precipitation/runoff events downhill toward and into the middle tributary of NT-3. The potential impacts of this reconfiguration in surface water runoff are discussed in Section 7.1 below.

Implementation of the Phase I field work was completed by DOE via procurement through existing DOE Blanket Purchase Agreement contracts for environmental work. DOE prepared a statement of work reflecting the scope and requirements of the approved Phase I work plan and a contract was awarded in late Spring of 2014 to Alliant Corporation (Alliant) to complete the Phase I field work and provide results to DOE. Alliant subcontractor team members included: M&W Drilling, LLC (M&W) for drilling, soil sampling, rock coring, packer testing, and well completions; Oak Ridge Associated Universities (ORAU) for radiological control/health physics support; URS Corporation for geophysical logging and packer test support; and Barge, Waggoner, Sumner, and Cannon, Inc. (BWSC) for site surveying. The interim results were provided to DOE for separate report preparation and integration with the current revised RI/FS report and to facilitate the FFA regulatory approval process for the site.

DOE conducted the procurement and managed the contract for the Phase I effort with intermittent technical oversight from Professional Project Services, Inc. (Pro2Serve) Portions of the Phase I results were provided as interim deliverables to support decision making during the fieldwork, and to provide data for the current Phase I Report. The results of continued Phase I surface and ground water monitoring through the end of Fiscal Year (FY) 2015, will be provided to DOE by Alliant over the coming months.

3. PROJECT PLANS, FIELD SCHEDULE, AND SCOPE CHANGES

Alliant developed a set of detailed project-specific work plans, standard operating procedures (SOPs), and other plans to address waste management and environmental, safety, and health requirements for completing the Phase I field work. The project plans were reviewed, revised, resubmitted, and approved by DOE before commencement of the field work. Because the limited Phase I field program was not formally recognized by the FFA parties as a primary or secondary FFA document, the Alliant work plans did not undergo regulatory review and approval by EPA or TDEC.

The final project plans were submitted on August 21, 2014, and field mobilization and drilling began on August 26. Drilling, soil sampling, rock coring, geophysical logging, packer testing, monitoring well installations, slug testing, and the installation of three stream flow monitoring stations were conducted from September through November 2014. Continuous monitoring equipment was installed in each of the ten monitoring wells and at the three stream flow monitoring stations in late November 2014. Continuous monitoring and weekly equipment inspections, data downloads, and observational monitoring of springs and seeps began around December 1, 2014. Interim data were provided to DOE and Pro2Serve for the preparation of this Phase I report. The monitoring data included in this Phase I report includes the approximately three-month period from late November 2014 through February 26, 2015. Alliant will continue stream and ground water monitoring activities through the end of September 2015, with weekly checks and data downloads to ensure significant breaks in data are avoided. Monitoring may continue beyond the end of FY 2015 if DOE receives regulatory approval of the EMDF site, and if funding is available. Results from the continued monitoring will be shared with the FFA parties in concert with regularly scheduled project team meetings where EMDF progress is reviewed.

4. PHASE I SCOPE SUMMARY AND FIELD METHODS

The limited Phase I site characterization plan (DOE 2013b) did not include detailed descriptions of field methods, typically provided in RI/FS work plans, sampling and analysis plans, and quality assurance/quality control plans prepared for remedial investigations under CERCLA. Section 4, therefore, provides a summary of actual field methods, standards, and requirements employed by Alliant for the Phase I site characterization based on DOE contractual requirements and the project-specific Alliant work plans, SOPs, etc., noted above.

The limited Phase I scope of work included the following major field tasks in their general sequence of implementation:

- Monitoring well drilling, logging, sampling, testing, and well completions
- Construction of stream flow monitoring stations
- Monitoring of ground water and surface water

Details of field methods for implementing these three primary tasks are reviewed below. Phase I results with interpretations are presented in subsequent sections.

The following noteworthy scope changes were made from the original Limited Phase I Site Characterization Plan (DOE 2013b):

1) **Additional Well Pair:** One additional monitoring well pair was added to intercept and monitor ground water conditions within the outcrop belt of the Rutledge Limestone bringing the total number of well pairs from the originally proposed four well pairs to five (ten total wells).
2) **Deletion of Fourth Surface Water Gaging Station and Addition of Limited Observational Spring/seep Monitoring:** The originally proposed continuous stream gaging station to be located below the haul road culvert on NT-3 was removed from the scope because of the constricting plate welded onto the upstream side of the culvert. This plate significantly constrains natural flows resulting in unnatural flow conditions downstream of the culvert. Weekly “observational” monitoring of selected spring and stream locations was added to the scope.
3) **Rock Coring:** Continuous rock coring was added for two of the deeper wells located in the outcrop belt of the Rutledge Limestone (GW-972[I]) and Maryville Limestone (GW-976[I]) to obtain more direct data on the physical characteristics of these formations that are reported to include limestone interbedded with shales that might include dissolution features with higher hydraulic conductivity.
4) **Revised Location of the Upgradient Well Pair:** The upgradient well pair (GW-968[I]/GW-969[S]) originally located on top of Pine Ridge within the outcrop belt of the Rome Formation was moved downslope to a much lower position within the outcrop belt of the Pumpkin Valley Shale. This change was required because of the difficulties and expense associated with the construction of an access road up the very steep slopes of Pine Ridge. The

revised location was coordinated with and approved by TDEC staff with the understanding that TDEC would want future monitoring wells higher up slope within the Rome Formation if and when the EMDF site were approved for more detailed Phase II site characterization (see attached TDEC trip report dated July 29, 2014, in Exhibit A.1).

4.1 MONITORING WELLS

Five shallow/deep well pairs were installed at the locations shown in Figure 1. Each shallow well was drilled to auger refusal depth. Each deep well was drilled initially to auger refusal for placement of isolation casing and then drilled to a total depth of 100 ft below ground surface (bgs). The shallow well total depths range from 10–25 ft bgs, and the five deep wells were each completed at the nominal 100 ft depth. Each of the ten wells was assigned a unique number according to protocols established for subsurface data compiled and maintained by the Y-12 Environmental Compliance Department (per email correspondence from Steve Jones). The well locations were placed to intercept each of the four geologic formations that underlie the EMDF conceptual design footprint (i.e., Pumpkin Valley, Rutledge, Rogersville, and Maryville formations).

Originally an upgradient well pair was to be located along the top of Pine Ridge within the Rome Formation. As noted above, however, the location was moved downslope within the outcrop belt of the Pumpkin Valley Shale. The wells were numbered sequentially from north to south with the odd number in each well pair designating completion in the water table (or shallow - S) interval of the saturated zone and the even number in each pair designating completion in the intermediate interval (I) of the saturated zone. These designations are consistent with those described in the hydrologic framework for the ORR (see Solomon et al, 1992), and in the hydrogeological site conceptual model applied to the EMDF (see Appendix E and Section 6.0 below) and other sites on the ORR. The “deep interval” described by Solomon et al (1992) and applied to the EMDF, refers to a much deeper ground water interval occurring below depths of around 328 ft bgs, well below the 100 ft maximum depths of the deeper Phase I wells. Methodologies and standards for the drilling, sampling, logging, testing, completion, and development of the wells are reviewed in the subsections below.

4.1.1 Contaminant Field Screening

As previously noted, the EMDF site was anticipated to be uncontaminated; however, precautions were taken by Alliant to screen for any potential contaminants during the Phase I field work. The drilling pads and all subsurface materials (soil and rock cuttings/cores and water) were screened for radiological contaminants using alpha, beta, and gamma detection instruments, and for volatile organic contaminants using a photo-ionization detector.

The radiological screening equipment used by ORAU included:

- Ludlum Model 44-9 (otherwise known as a GM pancake probe) - Beta, Alpha, Gamma. This was paired with a Ludlum Model 12 Ratemeter.
- Ludlum Model 26 Integrated Pancake Frisker - Beta and Alpha. This unit is a self-contained detector/ratemeter.
- Ludlum Model 43-92 ZnS(Ag) scintillator - Alpha. This detector was paired with a Ludlum Model 12 Ratemeter.
- Ludlum Model 44-10 NaI wide-energy - Gamma. This detector was paired with a Ludlum Model 2221 Ratemeter.

Alliant used two instruments for field screening:

- Horiba Model U52 Multi Water Quality Checker (U-50 Series)
- RAE Systems MultiRAE PLUS, Model RAE-20 Photoionization Detector

Field screening indicated no evidence of contamination in any environmental media (i.e., surface or subsurface soils, ground water, or surface water). The rock core boxes stored on site were all green tagged. Drilling rigs, drill rods, and downhole geophysical instruments were all scanned before and after use to ensure contaminants were not introduced to or removed from the site and to ensure no human health exposure hazards. Personnel, soil and rock samples/cuttings, and all downhole field equipment were screened to ensure rapid detection and response for any anomalous conditions. Alliant documentation for radiological screening and equipment/core green tagging is provided in Exhibit A.2. Screening data for volatile organic compounds (VOCs) during drilling and sampling were recorded on boring logs.

4.1.2 Drilling Methods, Sequencing, and Borehole Water Table Assessment

Two drilling rigs were used for the Phase I subsurface investigation. A Diedrich D120, hollow-stem auger (HSA) drilling rig was used for the initial drilling through unconsolidated overburden materials down to auger refusal at each of the five deeper well locations. A second rig (Schramm T40W air rotary rig) followed behind the HSA rig to expand the initial borehole diameter and set shallow isolation casing required for each of the deeper wells. The HSA rig was also used for rock coring of bedrock at two of the five deeper well locations (GW-972[I] and GW-976[I]) and for drilling and installation of the five shallow monitoring wells. The air rotary rig was also used to drill through bedrock at three of the deeper well locations (GW-968[I], GW-970[I], and GW-974[I]) with no rock coring, and for widening (reaming) the borehole diameter at the rock cored locations prior to geophysical logging and packer testing.

The nature and sequencing of the drilling allowed for a better assessment of water table conditions prior to installation of shallow well casing and screen. After the initial overburden drilling at each of the five well pair locations, the auger flights were removed from the borehole allowing natural ground water levels to recharge and equilibrate in the open borehole. Observations and measurements of the depth to standing water were made after at least an overnight period, and the open boreholes were temporarily covered to prevent rainfall from entering the boreholes. The water level data in the open boreholes were then used to identify appropriate target depths for Shelby Tube sampling and appropriate depths and screen lengths for the shallow monitoring wells. Water level measurements were made (with consistent reference to the ground surface) after the drilling process upon reaching total depth using an electronic water level indicator to ensure that a sufficient saturated zone was encountered before well installation.

Topsoil materials (i.e, root zone) were removed at each of the drill locations during site grading for access road construction. Except for the GW-976/977 location where topsoil removal was minimal, all of the other drilling pad locations were cleared and graded down in excess of two or more feet below the original ground surface. Organic rich topsoil material was therefore not identified in the Phase I boring logs even though topsoils and a greater thickness of underlying clayey residuum were originally present at the well locations before road grading and well pad leveling. Pre-drilling elevation surveys were not completed to quantify differences between pre and post ground surface elevations. However, pre-drilling elevations were estimated based on the current topographical map for the east end of BCV, including the EMDF site.

4.1.3 Shallow Interval Drilling, Sampling, and Logging

Overburden soil and weathered bedrock (saprolite) samples were collected and logged to auger refusal during the initial HSA drilling at each deeper well pair location. Because of the close proximity of each well pair, no soil samples (except for single Shelby tube samples) were collected during the drilling at each adjacent shallow well location. After bedrock drilling was completed at each of the deeper well locations, the HSA rig was used for drilling and placement of an adjacent 4 in. diameter shallow well within the saturated zone of the unconsolidated overburden materials. The shallow wells were each bored to auger refusal at the top of competent unweathered or less weathered bedrock. Because of the nature and sequence of the drilling, sufficient time was allowed for natural recharge of the borehole and water level monitoring of the recharge rate to ensure that the saturated conditions encountered were reasonably close to equilibrium (i.e., at least for an overnight period and typically greater than 24 hours before drilling and placement of the isolation casing for the deeper wells).

4.1.3.1 Disturbed Soil Sampling

Soil samples in the initial boreholes (drilled for placement of the 10 in. diameter overburden isolation casing) were collected and logged at 5 ft intervals to auger refusal. Starting at the ground surface and at subsequent 5ft intervals thereafter (e.g., 0–2 ft, 5–7 ft, 10–12 ft, 15–17 ft, etc.), the samples were collected using an automatic hammer and split-barrel sampling of soils according to standard penetration testing per American Society for Testing and Materials (ASTM) D 1586 *Penetration Test and Split-Barrel Sampling of Soils*, with the exception that the split-spoon sampler was driven a total distance of 24 in. (four 6 in. increments), instead of 18 in. (three 6 in. increments) as required by ASTM D 1586 [at some locations Alliant collected 18 in. split-spoons rather than 24 in. split-spoon samples). The split-barrel sampling devices have a nominal outside diameter of 2 in. and were 6 in. longer than the sample interval to lessen the potential for over-compacting the sample in the split-barrel. Blow counts per 6 in. increments were recorded on field logs and N values were determined using the sum of the blow counts from the second and third 6 in. intervals. Soil consistency (i.e., stiffness and hardness) was found to increase with depth at each location as indicated by increasing blow counts with depth moving from shallow clayey residuum to increasingly less weathered saprolite with depth to auger refusal atop more competent bedrock. Because the shallow /deep well pairs were drilled in close proximity, (i.e., about 10–15 ft apart), split tube sampling was not conducted in the adjacent augered borehole drilled for shallow well installation.

4.1.3.2 Undisturbed Shelby Tube Sampling and Testing

The scope of work prescribed that one undisturbed Shelby tube sample be collected within the saturated interval at each shallow well location. As noted above, the water level measurements in the open boreholes were used to determine appropriate depths for Shelby tube sample collection. The recovery of suitable Shelby tube samples is often limited by the hardness and stiffness of site soils (i.e., residuum and saprolite) which at the EMDF site naturally increase with depth. The depths selected for the Shelby tube samples were therefore made at depths only slightly below the water level depths measured in the open boreholes before isolation casing was installed. Shelby tube samples were collected, preserved, and transported according to ASTM methods D 1587 *Thin-Walled Tube Sampling of Soils*, and D 4220 *Preserving and Transporting Soil Samples*.

The Shelby tube samples were collected during the drilling of the boreholes for shallow wells at each location based on the results of split tube sampling and logging of the soils and saprolite and water levels in the initial boreholes drilled for the deeper well pairs. The Shelby tube samples from each shallow well were laboratory tested according to the latest version of the following ASTM Methods:

- D 422 – *Standard Test Method for Particle Size Analysis of Soils*
- D 5084 – *Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter*
- D 2487 – *Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)*
- D 854 – *Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer*
- D 4318 – *Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils*

Geo/Environmental Associates, Inc., of Knoxville, Tennessee, conducted the laboratory analyses. Results of the laboratory analysis are presented in Section 7.2.4.1. Laboratory data sheets are provided in Exhibit A.3.

4.1.3.3 Field Logging

Soils were classified and logged in the field according to: (1) ASTM method D 2488 *Description and Identification of Soils (Visual-Manual Procedure),* and (2) Section III of the USACE Geology Section Field Manual (Nashville Engineer District). ASTM Method D 2487 (*Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System*) was also used in concert with D 2488 for field classification of soils (and for laboratory classification purposes of Shelby tube samples). These standards were incorporated into an Alliant SOP to identify consistent and detailed field logging protocols for the Phase I subsurface investigation. Subsurface materials, water level and drilling conditions, and other drilling and field logging activities were logged on a standardized field form (ENG Form 1836) for each well. This field form is specifically designed for use in geotechnical drilling applications suitable for landfill hydrogeological investigations. Munsell color charts were used to accurately and consistently define soil (and rock) colors. Sequential photographs were taken of each split-barrel sample and representative auger/air rotary cuttings to facilitate documentation of subsurface conditions. Completed boring logs for overburden materials are provided in Exhibit A.4, based on logging of the deeper well pair borehole at each of the five well pair locations. Field photographs of split tube soil samples are provided in Exhibit A.5.

In addition to the boring logs, the on-site field geologist recorded the progress of drilling, testing, and well completion activities using a field logbook and a well drilling and construction activity/progress report obtained from the Y-12 Environmental Compliance Department. The logbook and field forms were used to document the sequential progress of drilling, logging, testing, and well installation activities (e.g., mobilization/setup, initial and changing drilling conditions, subsurface water conditions, sounding of depths during well installation, cuttings/drill fluid disposition, demobilization, etc.). The form was also used to supplement information on the boring log where space was limited. Copies of the completed well activity/progress reports are provided in Exhibit A.6.

In as much as possible, augered cuttings before the first split barrel sample and between additional split barrel samples were evaluated and characterized on field logs. Logging of soils/rock was conducted by a professional geologist registered in Tennessee with experience and familiarity with: drilling and well installation, scientific/industry accepted logging methods, and ASTM methods for subsurface characterization.

4.1.4 Intermediate Interval Well Drilling, Sampling, and Logging

For each of the five deeper intermediate interval wells, 10 in. diameter polyvinyl chloride (PVC) casing was first placed across the shallow unconsolidated regolith to isolate the water table interval from deeper ground water zones occurring within fractures of more competent bedrock. Two of the five deeper intermediate zone well pairs (GW-972[I] and GW-976[I]) located within the outcrop belt of the Rutledge Limestone and Maryville Limestone, respectively, were continuously cored through the bedrock interval from auger refusal to depths of 100 ft bgs. Based on boring logs and geological descriptions from other sites in West Bear Creek Valley (WBCV), these formations were reported to include interbeds of limestone and shale. The intent of the continuous rock coring was to obtain more detailed information on the characteristics of these formations, particularly any evidence of dissolution of the limestone beds that might suggest larger aperture fractures or conduits with relatively higher hydraulic conductivity.

The remaining three deeper well pairs (GW-968[I], GW-970[I], and GW-974[I]) located within the outcrop belt of predominantly clastic formations (Pumpkin Valley Shale and Rogersville Shale) were each drilled in bedrock using an air rotary rig from near the auger refusal depth to a total depth of 100 ft bgs. During this air rotary drilling, cuttings were directed to the side of the drilling rig and very generalized logging by the field geologist was recorded on a boring log. Depth occurrences and general rates of ground water production in bedrock were also recorded during drilling, where observed. After removal of the drill string, water levels were monitored periodically within the open bedrock boreholes to assess recharge, relationships to water levels in adjacent shallow wells, and to ensure saturated conditions were suitable for well installation. Because of the nature and sequencing of the drilling operations, the deeper open uncased boreholes were left open for a period of days until borehole geophysical logging and packer testing were completed.

4.1.5 Rock coring Methodology, Logging, and Photography

A double-tube HQ (2.5 in. inner diameter) core size barrel was used to continuously core bedrock at GW-972 and GW-976 after isolation casing was set across the overburden section of each hole. Core drilling, sampling, and logging was conducted according to the following ASTM standard methods: (1) D 2113 *Standard practice for Rock Core Drilling and Sampling of Rock for Site Investigations*, (2) D 5079 *Standard practices for Preserving and Transporting Rock Core Samples*, (3) D 5434 *Standard Guide for Field Logging of Subsurface Explorations of Soil and Rock*, and (4) D 6032 Standard Test Method for Determining Rock Quality Designation (RQD) of Rock Core. The rig geologist followed the requirements for core logging, RQD, core boxing, and other relevant standards defined in Sections III, VII, VIII, IX, and XII of the ASACE Geology Section Field Manual (Nashville Engineer District), and the Alliant SOPs: Regolith and Bedrock Drilling Procedure (AC-4301-001-RBD) and Description of Geologic Materials (AC-4301-001-DGM). Munsell color charts were used to accurately and consistently define rock colors. Dilute hydrochloric acid (10% HCl) was used in the field to confirm and document individual beds of limestone or dolomite in each core run to distinguish between clastic and carbonate beds/lamina.

Core pulls (individual segments of cored intervals) were commonly 5ft in length, but depending on the drilling conditions and the discretion of the driller, shorter intervals were sometimes retrieved. Sturdy wooden core boxes were used for storage of rock cores. Core boxes were labeled and pull blocks were placed between each core run to clearly define each pull, depths, loss, gain, etc. After filling and marking, each core box was digitally photographed with photos of the entire box and additional sequential overlapping close-up photos suitable for a photographic assessment of key core features. Each photo includes a tape measure consistently located adjacent to the length of the box for reference and scale. Higher resolution photographs of the rock core boxes were made using a digital SLR camera. The photographs were made in sequence from top to bottom in overlapping one foot increments under natural light, with closeup photos of selected lithologic/structural features. The high resolution photos were compressed and the lower resolution photos were stitched together to represent each core box for purposes of the Phase I report. However, the high resolution photos are available from DOE upon request.

The core boxes were green tagged and temporarily stored at a climate controlled storage locker to allow for more detailed evaluation and lithologic description. The core boxes were subsequently returned to the proposed EMDF site in late October 2014, placed on wooden pallets, and covered with plastic sheeting. They are currently located near the GW-972(I)/973(S) well pair at the EMDF. The rock cores were made available to TDEC and EPA for their independent evaluation. TDEC/EPA representatives reviewed the cores on October 22, 2014. TDEC representatives also reviewed the cores on February 11, 2015. Photographs of the rock cores with notes and depth indicators highlighting key aspects of the cores are provided in Exhibit A.7. Boring logs based on the rock cores are provided in Exhibit A.4.

4.1.6 Borehole and Well Testing

The following additional characterization activities were completed at each well pair location:

- Borehole geophysical logging: conducted in the five deeper bedrock open boreholes to characterize subsurface lithologic, stratigraphic, and hydrogeologic conditions.

- Slug tests to determine hydraulic conductivity (K) of the saturated screened interval in the shallow monitoring wells.
- Packer tests to determine K values for depth discrete bedrock intervals in the deeper boreholes.

Details of the methodologies for these field tests are summarized in the following subsections.

4.1.6.1 Borehole Geophysical Logging

Borehole geophysical logs were run in the uncased open bedrock boreholes at each of the deeper well locations (GW-968, GW-970, GW-972, GW-974, GW-976). The borehole logs included:

- 3-Arm Caliper
- Natural Gamma Ray (NGR)
- Spontaneous Potential (SP)
- Fluid Temperature/Delta Temperature
- Fluid resistivity
- Acoustic televiewer (ATV)/Deviation
- Optical televiewer (OTV)/Deviation
- Heat pulse flowmeter

Within the limitations inherent to borehole geophysical methods, the suite of logs were chosen with the following objectives: (a) identify subsurface stratigraphy/lithology and contacts, (b) identify the nature and density of fractures/fracture zones/intervals, bedding planes, joints, conduits, (c) identify approximate ground water flow intervals, and (d) identify the orientation of fractures/joints/bedding planes/conduits (strike, dip, relative to true/magnetic north).

The geophysical work was subcontracted by Alliant to a geophysicist with URS Corporation with previous experience on the ORR. The results and additional details of the geophysical logging, equipment, etc., are presented below in Section 7.2.5. A separate report of the geophysical logging prepared by URS is provided in Exhibit A.8.

4.1.6.2 Packer Tests

Packer testing was performed within the open uncased boreholes in each of the deeper well pairs (GW-968[I], GW-970[I], GW-972[I], GW-974[I], GW-976[I]) to determine K values within selected bedrock intervals. Rock cores, synoptic water level measurements in the shallow wells and deep boreholes, and results from the borehole geophysical logs were used to identify discrete intervals for packer testing. The Phase I budget was limited to a total of nine tests, and the packer testing interval was set at 10 ft (i.e. the distance between the bottom of the upper packer and the top of the lower packer). In the three borings without rock core data, the intervals were selected based strictly on geophysical features suggesting fractures or other anomalous features that might be indicative of higher permeability. In the two borings with rock core data (GW-972 and GW-976), the intervals were selected based on both rock core and geophysical features. The testing intervals were focused on determining K values for potential fractured zones and not on determining K values for unfractured intervals likely to have very low K values.

Packer tests were performed in accordance with a testing methodology, field forms, protocols, and equipment prescribed in an Alliant SOP (AC-4301-001-SPT – Straddle Packer with Transducers Testing Procedure), and DOE-contract requirements, as part of the Phase I project-specific work plans. This methodology was based on the following standards for packer testing: (a) ASTM D 4630 *Standard Test Method for Determining Transmissivity and Storage Coefficient of Low-Permeability Rocks by In Situ*

Measurements Using the Constant Head Injection Test, (b) the USACE RTH 381-80 *Suggested Method for In Situ Determination of Rock Mass Permeability Using Water Pressure Tests*, and (c) packer testing methods described in the U. S. Bureau of Reclamation *Earth Manual* (1974). Just before the field testing, the SOP methodology, field forms, and Microsoft Excel™ algorithms were modified slightly to address the use of pressure transducers above, within, and below the isolated packer test interval.

The general testing process for packer testing included the following steps: (1) lowering of the packer testing equipment down to the selected depth interval within the open borehole; (2) inflating the packers to seal off the test interval from intervals above and below the test zone; (3) introducing potable water into the test interval under a constant pressure and measuring the rate of water flow (logging injection flow rates and pressure readings over time). For each test interval, the testing was normally conducted under at least three different increasing test pressures (e.g.,10 lb per square in. [psi], 20 psi, 30 psi), below a maximum calculated injection pressure designed to prevent hydraulic fracturing. During each test, pressure data were recorded electronically using transducers (In-situ® TROLL devices) connected to a laptop computer with In-situ® software, while flow data were recorded manually using field forms/logbooks. Four transducers were employed: one within the packer test interval, one each above and below the upper and lower packers, and one at the surface to measure surface barometric pressures. A Moyno™ pump on the drilling rig was used to inject potable water under controlled flow rates to the isolated packer interval. A conventional in line flow meter with flow rates measured in gallons per minute (gpm) was used to visually monitor and record flow rates. The in line flow meter was incapable of accurate measurements below approximately 0.5 gpm over the typical time scale of the tests. This limited the ability of the packer tests to measure order of magnitude K values at and below 10^{-6} centimeters per second (cm/sec). The piping system also included a visible analog pressure gage (in psi) for assessing flow line pressures against pressures measured by the downhole transducers. Field data were entered into Excel™ spreadsheets to calculate K values for each test interval.

The maximum injection pressure (not to be exceeded during packer testing) for each deep well was calculated as the sum of pressures above and below the potentiometric surface; assuming 1 psi/ft of depth from the ground surface to the potentiometric surface depth, plus 0.57 psi/ft of depth from the potentiometric surface to the midpoint of the packer test interval depth (e.g., for a packer test interval from 25 to 35 ft bgs and a potentiometric surface at 10 ft bgs the maximum injection pressure would be 21.4 psi).

The equation used for determining K based on the packer test field data is:

$$\mathbf{K = Q/2\pi LH^* \ln(L/r) * 0.06797}$$

where:

K = hydraulic conductivity in cm/sec

Q = constant rate of flow into the borehole in gpm

L = length of test section (10 ft in all the EMDF packer tests)

H = total head (in ft) on the test section – based on pressure transducer reading located within packer test interval

ln = natural logarithm

r = radius of borehole (4 in.; 0.33 ft), and

0.06797 is a conversion factor translating field measured units to cm/sec

This equation is applied where $L \geq 10r$. Results of the packer tests are reviewed below in Section 7.2.3.5. Complete documentation for the packer tests is provided in Exhibit A.9.

4.1.6.3 Slug Tests

Slug tests were conducted in each of the shallow wells (except for GW-977[S], which is dry) to determine K values after well installation and development, and after water levels had stabilized to local equilibrium. The tests were conducted by Alliant over a three day period from October 28 to 30, 2014. The test methodology was documented in an Alliant SOP (AC-4301-001-STP – Slug Testing Procedure) as part of the Phase I project-specific work plans. The slug tests were conducted using commercially available pressure transducers (In-situ® TROLL devices; non-vented, using separate barometric TROLL devices) and data loggers with field laptop computer data storage and retrieval capabilities, and recording of rapid water level fluctuations and recovery periods. Alliant used a large diameter solid plastic slug for the tests to induce a rapid and instantaneous water level change up or down for the tests. The pressure transducer sits below the slug during the tests and records the rate of change in the water level in seconds

Determinations of K were made using the commercially available AQTESOLV software (developed by RockWare™) which provides a systematic and consistent process for data plotting, interpretations, and calculation of K values. K values were determined using the method of Bouwer and Rice (1976) and Bouwer (1989). Results of the slug testing are presented in Section 7.2.3.5 below. Slug test data plots, interpretations, calculations, and references are provided in Exhibit A.10.

4.1.7 Well Construction and Development

Because all monitoring wells were located within the proposed EMDF footprint, the wells were all completed with PVC casing/screen to facilitate ultimate plugging and abandonment (as opposed to steel commonly used for long-term permanent installations and sampling). The only exception was for stainless steel casing near and above surface at GW-968(I) as described below. Details related to shallow and deep well construction and well development in the shallow wells are reviewed in the following subsections. Table 1 summarizes key boring/monitoring well construction data for the ten Phase I wells. Monitoring well construction diagrams illustrating as-built components for each of the ten Phase I monitoring wells are provided in Exhibit A.11, along with material specification cut sheets used in well construction.

4.1.7.1 Shallow Well (Water Table Interval) Construction

All shallow wells were drilled to and completed at auger refusal depths and constructed of nominal 4 in. diameter ASTM Schedule 40 PVC flush-joint casing and slotted screen (0.010 in. slots). Screen intervals were 10 ft in length, except for two wells (GW-969[S] and GW-975[S]) where depth to auger refusal was so shallow that a shorter 5 ft screen length was required. Shallow wells were completed through the HSA casing with placement of screen and riser followed by careful removal of auger flights as annular materials were placed. The depths of key completed features (i.e., hole bottom, filter pack bottom and top, bentonite seal, and grout depths) were tagged using a weighted tape to ensure accurate depth placement. Measurements were recorded on field forms and in field logbooks to document field quality control.

Artesian ground water flow overflowing the top of the well casing at GW-969(S) was first observed on December 31, 2015. DOE was immediately notified of the need to extend the existing riser pipe and the top of casing (TOC) to contain the overflow in order to provide accurate continuous water level data using the downhole instruments (In-situ® TROLL devices). Continuous water level monitoring data subsequently provided by Alliant, indicated that GW-969(S) had begun overflowing the TOC elevation (1,072.98 ft) on December 24, 2014. Alliant/M&W installed an additional 10 ft of PVC riser pipe to the existing TOC on February 11, 2015, extending the new TOC elevation to 1,082.98 ft (extending the original stick up of 2.31 ft above the ground surface to12.31ft). The PVC casing was installed in 2.5 ft sections such that upper sections could be removed as appropriate, depending on the most likely seasonal maximum water levels.

Table 1. Boring/Monitoring Well Construction Data

Well Number	Geologic Formation	Estimated Natural Pre-Ph I Surface Elevation[1]	Surveyed Elevation TOC[2]	Surveyed Elevation Top Concrete Well Pad	Surveyed Elevation Top of Ground Surface	Well Casing Stickup	Estimated Topsoil Removed	Auger Refusal Depth (ft bgs)	Bedrock Isolation casing depth [see note for GW-974] (ft bgs)[3]	Difference between isolation Casing and AR Depths	Length Rock Cored Bedrock Interval (ft)	Maximum Total Drilling Depth (ft bgs)	Latest Final Total Depth Measurement in Deep Open Holes	Length of Borehole Bottom Collapse (ft)	Screened or Open Hole Interval (ft bgs)		Screen or Open Hole Length (ft)	Filter Pack Interval (ft bgs)		Filter Pack Length (ft)
															Top	Bottom		Top	Bottom	
GW-968(I)	Cpv	1077.4	1082.56	1070.39	1070.21	12.35	7.19	10.0	10.0	0.0	No rock coring - air rotary drilling in BR	100.0	92.6	7.4	12.7	82.7	70.0	9.0	92.7	83.7
GW-969(S)	Cpv	1075.1	1082.98	1070.67	1070.45	12.53	4.65	13.5	NA	NA	NA	13.5	NA	NA	8.4	13.4	5.0	5.5	13.5	8.0
GW-970(I)	Cpv	1045.3	1043.17	1041.20	1040.93	2.24	4.37	25.6	34.1	8.5	No rock coring - air rotary drilling in BR	101.0	97.4	3.6	34.1	97.4	63.3	NA	NA	NA
GW-971(S)	Cpv	1045	1043.11	1040.81	1040.69	2.42	4.31	23.8	NA	NA	NA	23.8	NA	NA	13.2	23.2	10.0	11.9	23.8	11.9
GW-972(I)	Crt	1022.4	1026.20	1023.75	1023.55	2.65	-1.15	24.2	23.8	-0.4	75.9	101.0	99.6	1.4	23.8	99.6	75.9	NA	NA	NA
GW-973(S)	Crt	1025	1026.96	1024.68	1024.46	2.50	0.54	23.0	NA	NA	NA	23.0	NA	NA	12.9	22.9	10.0	10.3	23.0	12.7
GW-974(I)	Crg	1003.1	1005.38	1003.19	1002.80	2.58	0.3	12.5	10" csg @ 0-12.5'; 8" csg @ 0-15.0'	2.5	No rock coring - air rotary drilling in BR	101.0	97.9	3.1	15.0	97.9	82.9	NA	NA	NA
GW-975(S)	Crg	1003.3	1005.16	1003.01	1002.52	2.64	0.78	10.0	NA	NA	NA	10.0	NA	NA	4.9	9.9	5.0	3.9	10	6.1
GW-976(I)	Cm	1067.5	1068.41	1066.15	1065.84	2.57	1.66	24.4	27.8	3.4	71.8	101.0	100.3	0.7	27.8	100.3	72.6	NA	NA	NA
GW-977(S)	Cm	1067.5	1068.17	1065.84	1065.63	2.54	1.87	25.1	NA	NA	NA	25.1	NA	NA	15.0	25.0	10.0	12.1	25.1	13.0

Notes and Abbreviations:

[1] Estimated natural pre-Phase I surface elevations are based on the BWSC surveyed well locations and the current surface topographic contour map for the EMDF site utilized in AutoCad for the conceptual design (5ft contour intervals).

[2] Artesian flow in wells GW-968(I) and GW-969(S) resulted in extensions to the original TOC elevations. The original professionally surveyed TOC Elevation at GW-968(I) was 1072.52; a 5ft SS 4 in. diameter casing extension was added on 12/23/14 making the new TOC elevation 1077.52; an additional 5.04 ft SS casing extension was added on 2/9/15 making the final TOC elevation 1082.56.

[2] The original professionally surveyed TOC Elevation at GW-969(S) was 1072.98; a 10ft 4 in. diameter PVC casing extension was added on 2/11/15 making the new TOC elevation 1082.98

[3] Original 10 in. PVC isolation casing at GW-974 was retrofitted with 8 in. diameter PVC casing grouted inside the 10 in. casing after driller broke shallow portion of 10 in. surface casing.

- All deep boreholes drilled w/ air rotary 8" diam hole (for GW-972/976 after rock cores acquired).
- GW-974(I) - specific total depth of 10 in. PVC isolation casing apparently not recorded - assumed to be at 12.5 ft bgs.
- Isolation casing was set in three of the five deep wells at auger refusal depth.

AR	auger refusal	NA	not applicable
bgs	below ground surface	PVC	polyvinyl chloride
BR	bedrock	SS	stainless steel
Csg	casing	TOC	top of casing (inner casing of riser pipe)
ft	feet		

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4.1.7.2 Deep Well (Intermediate Ground Water Interval) Construction

Except for GW-968(I), each of the deep wells was completed as an open hole from the depth of the 10 in. diameter PVC isolation casing to the approximately 100 ft total depth of each deep well (natural borehole collapse in each of the five deep boreholes ranged from 0.7–7.4 ft bgs, see Table 1). 10 in. diameter Schedule 40 PVC casing was placed from the ground surface to depths at or near auger refusal in each of the five deep wells. This isolation casing was seated and sealed with pressure grouting methods to variable depths in each well ranging between 0 and 8 ft into the top of bedrock. The objective of this casing is to isolate the shallow ground water associated with the water table interval within the relatively unconsolidated surficial materials (regolith), from the deeper intermediate interval of the saturated zone located within fractured, less weathered or unweathered bedrock.

An exception to the 10 in. diameter isolation casing exists at GW-974(I) where an 8 in. diameter casing was seated just below and grouted inside of the original 10 in. diameter casing. A skid steer accident resulted in a break in the upper part of the 10 in. PVC isolation casing. This warranted the placement of an inner 8 in. isolation casing before drilling of the deep open borehole section of bedrock. The DOE contract for the Phase I work included an option for completing the deep wells with screen and casing over discrete intervals. However, the results from the limited number of packer tests and geophysical logs were insufficient to clearly identify depth discrete intervals yielding ground water to the deeper open boreholes within wells GW-972(I) and GW-974 (I). The relatively rapid response of water levels in the shallow/deep well pairs at these two locations with respect to a heavy rainfall event in mid October 2014, indicated that ground water was recharging the bedrock interval over a fairly short timeframe. Completing these open holes by isolating a particular screen interval of 10–20 ft might result in inadvertent isolation of fractures yielding water to these deep wells. Therefore, the decision was made to leave the deep wells with open hole (uncased) intervals so that further testing could be made during a Phase II effort if desired (an exception was made for GW-968[I] as described below). With additional testing to clearly identify water producing depth intervals, the deep open hole wells could be completed within relatively common depth intervals relative to the water table intervals at each well pair. Consideration could also be given to completing the open holes as nested piezometers to evaluate permeability differences, vertical gradients, and variations in pressure heads between the depth discrete, vertically separated, completed intervals.

Rationale for completing GW-968(I) with conventional well screen and riser pipe was provided to DOE by Alliant/M&W and was primarily based on concerns relating to the potential for artesian water flow to freeze and break PVC casing near and above the ground surface during cold winter months. To prevent this occurrence, Alliant/M&W proposed completing the open hole interval with 4 in. diameter PVC well screen and riser pipe extending up through the 10 in. isolation casing, and topped with stainless steel casing near the surface where freezing might occur. The completion also included conventional filter pack sand around the screen interval with a bentonite plug and overlying grout to a depth near ground surface.

At GW-968(I), 70 ft of 4 in. diameter PVC slotted screen (0.01 in. slot size) was set from 12.7–82.7 ft bgs within the open hole interval and surrounded with filter pack sand from 9–92.7 ft bgs (a total of 83.7 ft of filter pack). Between drilling the original 100 ft deep borehole on September 10, 2014, and the time of this final well completion on November 3, 2014, the lower 7.4 ft of the borehole had collapsed so that the bottom of the casing was placed at 92.7 ft bgs. Centralizers were used in GW-968 (at depths of 27.5, 57.5, and 87.5 ft bgs to maintain the screen and riser in the center of the borehole.

The 10 in. diameter isolation casing for GW-968(I) was grouted in place at 10.0 ft bgs (at auger refusal) on September 8, 2014. The stickup on the 10 in. casing at that time was about 0.41 ft above ground surface. The bedrock interval was subsequently drilled from 10 to 100 ft bgs on September 10, 2014. On September 22, 2014, ground water was observed overflowing the top of the 10 in. diameter isolation casing. Subsequent intermittent water level measurements made at GW-968(I) during October and November 2014 indicated that ground water was either very close to or overflowing the top of the casing.In late November 2014, after the completion of GW-968(I) with screen and riser pipe and a surface stick up, ground water was observed overflowing the top of the 4 in. inner casing (at 2.31 ft above ground surface). DOE was notified of the need to extend the surface casing to capture the static water level (SWL), and on December 23, 2014, an additional 5ft extension of stainless steel riser pipe was added by M&W to the original stick up, extending the overall top of the inner casing to a height of 7.31 ft above ground surface (based on the surveyed ground surface elevation and TOC elevations made by BWSC). Continuous monitoring at the EMDF began officially on December 1, 2014. After the extension of the casing to the 7.31 ft height continuous monitoring data indicated water levels rising to within a few inches of the new TOC elevation at 1,077.52 ft. DOE subsequently directed Alliant to extend the casing even higher to avoid potential future overflows. Alliant added 5.04 ft of additional stainless steel casing on February 9, 2015, extending the new final TOC height to 12.35 ft above ground surface (1,082.56 ft elevation).

4.1.7.3 Well Surface Completions

Each of the shallow and deep wells were completed at the surface with a 4 ft × 4 ft concrete pad sloped to drain and a metal outer protective surface casing with locking cover. The outer protective casing was cemented into the concrete pad with approximately 3 ft of stickup above the ground surface and 2 ft embedded in the ground. A 1/8 in. to 1/4 in. weep hole was drilled into the annulus of the protective casing just above the level of concrete inside the casing. A vented cap was installed on the riser pipe inside the protective casing. Keyed alike locks were placed on each well with keys provided to DOE. The well clusters are all located within the DOE/Y-12 property protected fence (229 fence) with restricted public access. Each well is located within the landfill footprint but would be ultimately plugged and abandoned before landfill construction. Therefore no bollards were installed. Each well was marked with an identification number using a printed metal tag screwed into to the side of the outer metal protective casing, with an equivalent metal tag on top of the well cap/cover.

4.1.7.4 Well Development

Each of the shallow wells and GW-968(I) were developed by surging, bailing, and/or pumping to settle the filter pack and remove fine materials prior to slug testing and installation of continuous monitors. A 4 in. diameter bailer was used to surge the well and a mini-purger Whale® pump was used to remove surged water. Turbidity and other water quality parameters were monitored and documented on well development logs. A minimum of 3–5 well volumes were removed. The development procedures were repeated until sediment-free low turbidity water was produced. In instances where relatively clear water could not be produced conditions were documented with rationale for ceasing development. A summary of development for the Phase I wells is provided in Table 2. Detailed well development logs are provided in Exhibit A.12.

Because the wells are located in historically undisturbed non industrial areas and far upgradient of any subsurface source areas and ground water contaminant plumes, soil and water were assumed to be uncontaminated. In addition, soils were screened in the field for radiological and VOC contamination. Equipment and materials that came in contact with site soils were field screened and smear samples were collected and submitted to ORAU for detection of radiological contamination. No radiological activity in site soils or on equipment and materials used in site activities at the EMDF was detected above background by field screening or laboratory testing. Nevertheless, the water was screened for contamination as done for subsurface soils. Because the screening did not detect any radiological contamination, the well development water was assumed to be uncontaminated (as was water used for cleaning drilling rigs, equipment, etc.). The well development water was contained and solids were allowed to settle out before release to the environment. Clear settled waters were discharged on site.

Table 2. Well Development Summary

Well	Development Dates	Total Volume Removed (gallons)	Max Water Level Drawdown (ft BTOC)	Total Depth of Well BTOC	TOC Elevation (at that time)	Max Water Level Drawdown Elevation
GW-968(I)	11/5/2014	370	84.7	95.2	1072.52	987.82
GW-969(S)	9/30/2014; 10/1/14; 10/7/14	34; from three separate days	Pumped dry each event	13.5	1072.98	1059.48
GW-971(S)	9/22/2014; 9/29/14; 9/30/14	35.5; from three separate days	Pumped dry each event	23.3	1043.11	1019.81
GW-973(S)	9/30/2014; 10/1/14; 10/2/14	63; from three separate days	Pumped dry each event	23	1026.96	1003.96
GW-975(S)	11/5/2014	5.5; from three separate days	Pumped/bailed dry each event	12.32	1005.16	992.84
GW-977(S)	9/30/2014; 10/2/14; 10/6/14	DRY	NA	27.42	1068.17	NA

Notes and abbreviations:

- GW-968(I) is the only deep (intermediate ground water level) boring that was completed with screen/riser pipe within the bedrock interval; all other "deep" wells were completed as open holes and were therefore not developed.
- GW-977(S) is dry; water table is roughly 20 ft or more below the elevation of the bottom of the well at 1,040.75; it is unlikely that this well will ever penetrate the saturated zone.

BTOC below top of casing
TOC top of casing

4.2 SURFACE WATER AND GROUND WATER MONITORING

One of the primary objectives of the limited Phase I characterization was to monitor variations in stream, spring, and seep flow, ground water level fluctuations, and basic water quality parameters at the proposed EMDF site over a period of one year or more. The data would be used to assess seasonal/temporal variations and to correlate those data with meteorological data collected at the adjacent EMWMF and the Y-12 west tower meteorological station. The data would provide baseline environmental data needed for landfill design and satisfy regulatory requirements and guidance.

Instrumentation and data loggers were placed in each of the ten monitoring wells and at three surface water stream gage locations to provide continuous data for evaluating temporal and spatial relationships between stream discharge rates, ground water level fluctuations, precipitation, and key elements of the proposed conceptual design (e.g., the physical relationships between surface and ground water level fluctuations and key elements of the conceptual design such as the base of the geologic buffer and underdrain system). Although the Phase I data currently includes only about three months of data, DOE currently plans to continue the Phase I monitoring program through at least the end of FY 2015. The monitoring period could be extended for a longer timeframe if the TDEC and EPA concur with the selection of the proposed EMDF site for CERCLA waste disposal.

The Phase I surface and ground water monitoring provides initial baseline data for assessing spatial and temporal relationships between surface water runoff, relatively rapid shallow subsurface stormflow zone discharge to streams, and relatively slower ground water discharge to surface streams, springs, and seeps.

Surface water data from previous investigations (USGS 1994a and b, and BJC 1999) and recent field observations along the NT tributaries at and near the EMDF indicate that baseflow along the NT streams varies considerably between the wetter and colder Winter/Spring nongrowing season, and the drier and warmer growing season of late Spring, Summer, and early Fall. During the wetter, cooler, nongrowing season, base flow along the NT streams is typically continuous downstream from headwater springs and flow rates are much higher than during the drier, warmer, growing season when flow is much lower and may be intermittent during the late Summer and early Fall when rainfall is often minimal.

The Phase I monitoring will more accurately define these seasonal changes in stream baseflow and the range of variations for peak flow and baseflow. Depending on seasonal conditions, sections of the NT-2 and NT-3 tributaries may be gaining baseflow from ground water discharge, or losing surface water to the shallow water table. The Phase I monitoring data also provides baseline data for ground water conditions at the EMDF site. Ground water and stream flow conditions are fundamentally important to the design of the proposed underdrain system for the EMDF, and to a design that ensures waste materials remain sufficiently elevated above the water table over the long-term time span of the proposed disposal facility. If the EMDF site is approved, additional characterization would be performed in a Phase II field investigation with data quality objectives to support detailed landfill design.

4.2.1 Surface Water Monitoring

The Phase I surface water monitoring program included two main components: (1) continuous surface water monitoring at three stream gage locations along tributaries of NT-3, and (2) weekly monitoring of six locations upstream from the stream gage locations (see the nine surface water monitoring locations in Figure 1). The weekly monitoring locations included the three headwater spring locations where the NT-2 and NT-3 tributary stream flows originate, and three stream flow monitoring stations at locations between the headwater springs and the stream gage locations. Details of the monitoring program are reviewed in the following subsections.

4.2.1.1 Stream Gage Design, Installation, Instrumentation, and Monitoring

During November 2014, Alliant installed three flume gage monitoring stations to characterize tributary flows draining the uppermost reaches of the NT-3 watershed, including roughly two thirds of the EMDF footprint. The three locations are identified as: EMDNT3-SWG1 (East Branch NT-3), EMDNT3-SWG2 (Middle Branch NT-3), and EMDNT3-SWG3 (West Branch NT-3).

The basic specifications for each stream gage monitoring location included:

- A cutthroat flume with built-in stilling well for continuous water level monitoring (for conversion to flow rate/discharge).
- A staff gage with graduated markings in 0.1 ft increments.
- A separate stilling well for continuous monitoring of temperature, pH, specific conductivity, and oxidation/reduction potential (ORP).

Details of the flume design, installation, instrumentation, and monitoring are addressed in the following subsections.

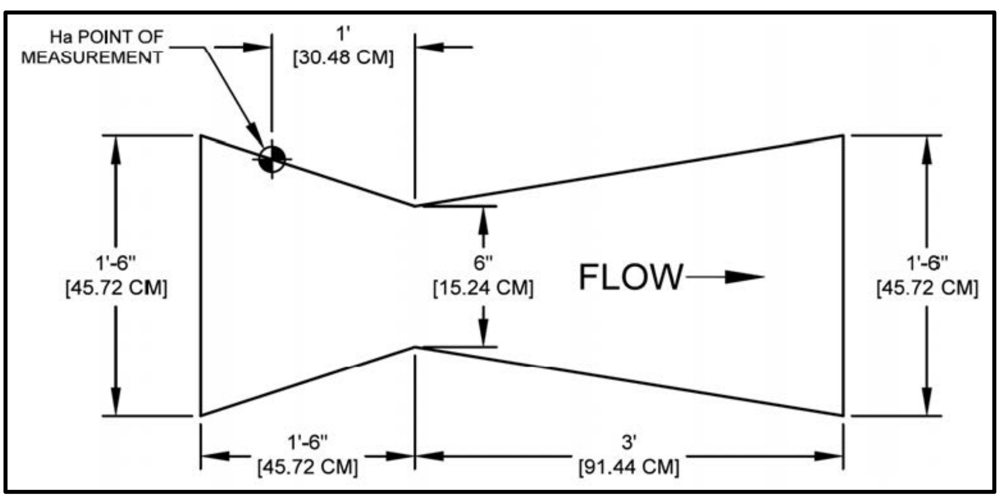
<u>Flume Design and Installation</u>

The intent of surface water flow monitoring is to provide data to support design of the EMDF underdrain and surface water control systems. Measurements of the upper flow ranges (peak flows) were deemed more critical to design, and the flumes were sized accordingly. The cutthroat flumes were designed based in part upon precipitation and streamflow data collected from a number of locations along the middle to upper reaches of NT-4 and one location along NT-3 near the center of the EMDF footprint (BJC 1999,

Appendix G). These data were collected over a one year period prior to the construction of the EMWMF, although instrument failure limited the data at some gaging locations. Alliant purchased the flumes from a commercial vendor (OpenChannelFlow®) from a range of available sizes. Based on the smaller channel width and estimated watershed for the middle NT-3 tributary, a smaller flume was selected for the EMDNT3-SWG2 location (see Figure 3) relative to the other two monitoring stations. The larger channel widths and estimated watershed areas for the NT-3 east and west tributaries warranted the use of a larger flume to capture anticipated peak flow discharge at the EMDNT3-SWG1 and EMDNT3-SWG3 locations (see Figure 4). The flumes are rectangular (not trapezoidal) in cross section with flat bottoms placed perfectly level within the existing stream channels along relatively straight stream segments with relatively low natural gradients.

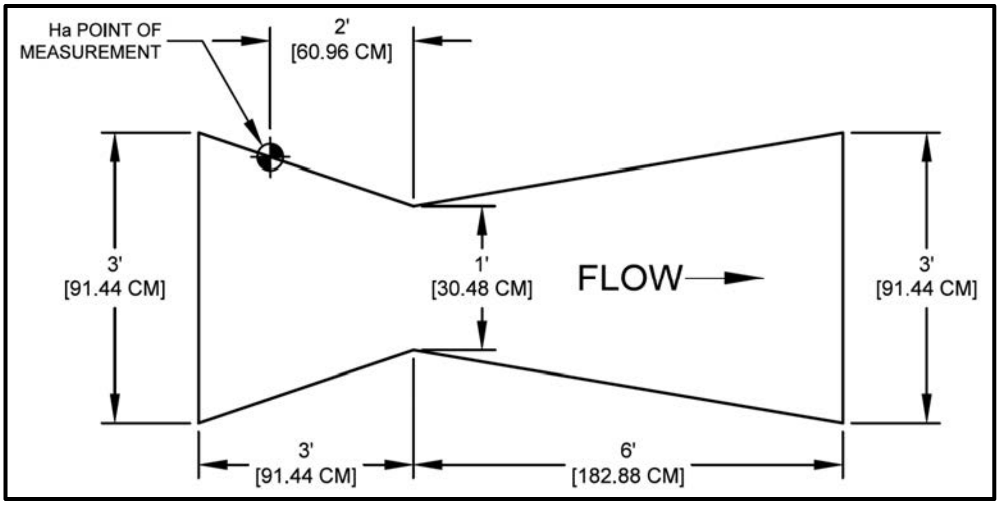
The flumes are constructed of fiberglass with a built-in stilling well that extends about 3 in. below the base of the flume. The stilling well is a cylindrical sump located along the side wall of the flume connected at its base to the water in the flume channel. The stilling well provided the measurement point where a pressure transducer was placed to continuously record water level data. A separate stilling well constructed of 4 in. diameter perforated PVC pipe was placed vertically within the upstream pool at each flume to provide a stable location for continuous recording of water quality data via a separate instrument probe. The photographs in Figure 5 show the typical stream gage monitoring system at the EMDNT3-SWG1 location along the largest main tributary of NT-3 crossing the EMDF site (see location in Figure 1).

A flat staff gage with graduations in tenths of feet was installed on the inner face of the flume wall adjacent to the built-in stilling well for weekly visual monitoring, recordkeeping, and calibration of observed measured water levels to those measured electronically. Measurement point locations were professionally surveyed at each flume to relate water levels/flow rates to topographical elevations. Locations were surveyed to the nearest 0.1 ft horizontally and 0.01 ft vertically. Additional requirements and guidelines for the proper installation of the flumes were defined in the Alliant SOP Flume and Weir Installation Procedure (AC-4301-001-FIP).



(Height is 1.5 ft)

Figure 3. Cutthroat Flume Dimensions for Flume at EMDNT3-SWG2



(Height is 3.0 ft)

Figure 4. Cutthroat Flume Dimensions for Flumes at EMDNT3-SWG1 and EMDNT3-SWG3

The water level data measured continuously by the data loggers are converted to discharge values in cubic ft per second (cfs) or gpm using discharge rating tables and equations provided in Exhibit A.13. The manufacturer recommendations were followed for the proper placement and orientation of the flume within existing channels, and the maintenance and monitoring of the flumes after installation.

(See Figure 1 for location)

Figure 5. One of the Three Continuous Stream Monitoring Systems Installed on the Main Tributary of NT-3 at the EMDNT3-SWG1 Location

Wing walls constructed of several concrete bags anchored with rebar were placed along the upstream sides of the flumes to prevent the bypass of water around the outside of the flumes during high intensity/duration runoff events. It should be noted that the height of the wing walls dictates the maximum flow of water through the flume and therefore the maximum value of peak flow that can be calculated based on discharge rating tables. The lowest approximate levels along or upstream beyond the wing walls where high water could wrap around or overflow low points along the wing walls at each flume were estimated by Pro2Serve using a hand held Leica laser Disto™ D3. The lowest points were leveled back to the staff gage on the flume at the stilling well. The minimum and maximum measurable discharge levels and flow rates at each flume are shown in Table 3.

Instrumentation

Each surface water monitoring station was equipped with two instruments: (1) a multi-parameter data logging instrument for water quality parameters (YSI® 600XLM – 1.7 OD × 18 in.), and (2) a data logger for monitoring of water levels (In-Situ® Level TROLL 700) and temperature. The TROLL device was placed in the stilling well in the flume body, and the YSI® device was placed in a separate stilling well just upstream of the flume. Data were recorded and stored automatically at 20 minute intervals. The stilling wells located upstream of each flume were constructed of 4 in. diameter PVC with pre-drilled holes along an approximately 4 in. vertical spacing. The open bottom of the stilling well was placed about 8–10 in. below the base of the stream channel on top of a thin layer of gravel fill so that stream channel water infiltrates through the base of the stilling well in addition to entering through the vertically spaced holes. The YSI sonde was placed at the base of the stilling well to ensure the water quality probes remained submerged.

Monitoring

The weekly monitoring practices at the gaging stations include: (1) data download to a laptop computer with subsequent conversions of water level data to discharge rates; (2) physical inspections and cleaning of the flume and nearby stream channels to monitor and amend any anomalous conditions that would negatively impact the consistency and completeness of monitoring data; (3) instrument inspections, cleaning, and calibration checks, and (4) field log form/logbook and photo documentation. Monitoring results were documented in field forms completed by field technicians for each weekly visit with notes on general daily activities documented in a bound field logbook. Calibration checks made concurrent with the weekly measurements were documented on a separate calibration log.

Systematic instrument calibrations for the YSI water quality instruments were made every four weeks. These monthly calibration events included the removal of the YSI sonde and immersion of the sonde in calibration fluid standards for each water quality parameter. The calibration process was conducted according to YSI protocols using a hand-held unit and YSI calibration software that determines whether or not sensors are within appropriate calibration ranges. Sensors failing the calibration tests were replaced with new sensors and the sonde was replaced at its former location in the stilling well, or in the case of the monitoring wells, at the previous depth within the well. The field forms include notes on any significant changes or anomalous conditions observed during each weekly visit. Photographs were also taken during the weekly events from a marked surveyed location for consistency. Additional details of monitoring practices were defined in the Alliant SOP *Groundwater and Surface Water Monitoring Procedure* (AC-4301-001-GSM). Practices and procedures for stream discharge measurements for the flumes were defined in the Alliant SOP *Stream Discharge Measurement Methods* (AC-4301-001-SDM), and subsequent updated discharge rating tables for the larger flumes installed at the EMDNT3-SWG1 and EMDNT3-SWG3 locations.

Alliant documentation of weekly data downloads, equipment checks, cleaning, and periodic calibration events for the continuous monitoring is provided in Exhibit A.14. This documentation includes weekly monitoring equipment status/data sheets and checklists, but does not include the raw or processed data files from the continuous monitoring equipment. The processed data are presented in subsequent sections of this report as plots of flow and water quality data over the initial three month Phase I monitoring period. The raw instrument and processed data files are extensive and therefore are not included as attachments to the Phase I report.

Table 3. Measurable Flow Ranges for Phase I Flumes Installed at the EMDF

Flume ID/Location	Cutthroat Flume Size	Lowest Measurable Discharge Rate (Based on Discharge Rating Table)			Highest Measurable Discharge Rate (Based on Lowest Point Along Upstream Wing Wall or Ground Surface at each Flume)			Discharge Formula
		Water Height above Flume Base (ft)	CFS	GPM	Water Height above Flume Base (ft)*	CFS	GPM	
EMDNT3-SWG1	108 in. L × 12 in. W	0.10	0.0964	43.26	1.73	8.230	3694	$CFS = 3.50\ H_{ft}^{\ 1.56}$
EMDNT3-SWG2	54 in. L × 6 in. W	0.10	0.0373	16.76	0.54	0.6792	304.8	$CFS = 1.96\ H_{ft}^{\ 1.72}$
EMDNT3-SWG3	108 in. L × 12 in. W	0.10	0.0964	43.26	1.96	10.00	4488	$CFS = 3.50\ H_{ft}^{\ 1.56}$

Notes and Abbreviations:

* Height of wing walls were not professionally surveyed but estimated based on using a hand held Laser Disto D3 instrument as a level tool; heights are therefore estimated to be ± 0.1-0.3 ft.

- OpenChannelFlow™ discharge rating tables for the installed flumes indicate that water level discharge rates between 0.01 and 0.10 ft above flume base cannot be accurately determined because of "excessive error due to fluid-flow properties and boundary conditions."

CFS cubic feet per second
ft feet
GPM gallons per minute
H height of water in flume above base level in feet
ID identification number

4.2.1.2 Surface Water Observational Monitoring

In addition to the three stream gaging stations, six other surface water locations within and near the EMDF footprint were monitored on a weekly basis without dedicated instrumentation. The weekly observational monitoring locations included:

- EMDNT2-SP1, EMDNT3-SP1, and EMDNT3-SP2: Three springs each located at the head of separate NT-2 and NT-3 tributaries represent the most upstream locations of seasonal stream flow. Each spring is located near the base of ravines that cut into the steep lower south facing slopes of Pine Ridge.
- EMDNT3-ST1, EMDNT3-ST2, and EMDNT3-ST3: These stream channel locations were selected to provide intermediate measurements of flow rates and water quality along the eastern (main) and western branches of NT-3.

The surveyed observational monitoring locations are shown on Figure 1 (Note the SP designation indicates spring locations and the ST designation indicates stream channel locations). The EMDNT3-ST1 location is just below a seepage/wetlands area centered about 150 ft downstream from the EMDNT3-SP1 headwater spring location. The EMDNT3-ST2 location is below a seepage area designated as EMDNT3-SE1 that coalesces into a channel that drains into the west channel of NT-3. The EMDNT3-ST2 location was placed about 10 feet upstream of the junction of the west NT-3 channel with the smaller channel draining from the EMDNT3-SE1 seepage area.

The EMDNT3-ST3 location was selected near the upstream end of a 12 in. diameter (HDPE) culvert below a gravel access road over the west NT-3 channel. The EMDNT3-ST3 location is approximately halfway between the EMDNT3-SWG3 flume location and the headwater spring at EMDNT3-SP2.

One foot tall staff gages attached to wooden stakes were placed at each of the observational monitoring locations and those locations were accurately surveyed by BWSC (see staff gages in photos of Figure 6 at two of the headwater springs for NT-3). The three headwater springs are small ground water discharge areas no more than 1–3 ft^2 in diameter. The absence of distinct stream channels above these spring locations suggest that ground water discharge and surface water flow generally does not occur above these points. The stream channels at the other three observational locations are relatively small with base level flows that are typically just a few inches deep and channels that are less than 1–2 ft wide.

The minimum requirements for the weekly observational monitoring at each of the six locations included:

- Estimate flow rates and measure representative water quality parameters (temperature, pH, conductivity, turbidity, and ORP) from a consistent, marked location.
- Record field observations and data.
- Photograph conditions during each site visit.

Spring EMDNT3-SP1 **Spring EMDNT3-SP2**

Surveyed staff gages mark the locations of each spring – white vertical bars in each photo.

Figure 6. Photos of Two of the Six Observational Monitoring Locations at Springs EMDNT3-SP1 and at EMDNT3-SP2

The water quality parameters noted above were measured weekly using a portable hand-held unit (Horiba U-50 multi-parameter water quality meter) and documented on a field form for consistency and completeness. Calibration checks made concurrent with the weekly measurements were documented on a separate calibration log. The field forms include notes on any significant changes or anomalous conditions observed during each weekly visit. The photographs were taken from a marked surveyed location for consistency. Additional details of monitoring practices were defined in the Alliant SOP *Groundwater and Surface Water Monitoring Procedure* (AC-4301-001-GSM).

Concurrent with the weekly water quality measurements, surface water flow measurements were made at each observational monitoring location. Alliant used two possible methods for measuring stream flow depending on site conditions at the observational monitoring locations. One method involved using a Flo-mate electronic flow meter to determine an average velocity across a measured cross sectional area (where flow rate is calculated as the average velocity times the cross sectional area of the stream channel). A second method involved a simple measurement of the time required to fill a container of known volume. The field measurements and methodology employed were documented on standardized field forms. Additional details of practices and procedures for stream discharge measurements were defined in the Alliant SOP *Stream Discharge Measurement Methods* (AC-4301-001-SDM). Documentation of the weekly observational monitoring is provided in Exhibit A.15.

Near the onset of the Phase I field work, road construction began for the new Uranium Processing Facility (UPF) haul road that extends the existing haul road (located immediately south of the EMDF) further to the east into the Y-12 Plant. Former wetland areas along the southeast side of the EMDF footprint, that included seep, spring, and streamflow channels were destroyed and reworked during the UPF road construction and wetlands mitigation process. Seep, spring, and stream channel flow measurement locations in these areas that were previously identified by the U.S. Geological Survey (USGS) in 1994 were destroyed during the construction and wetland mitigation work (USGS locations 1090, 1095, 1100, 1110, 1125; see USGS 1995/1996). These low elevation areas along the southeast flank of the proposed EMDF footprint are significant in relation to shallow ground water discharge and segments of the proposed underdrain system. The underdrain system proposed for these tributary valleys that intersect the EMDF footprint would dewater the shallow subsurface water table interval and lower the water table in these areas. Phase II field investigations are recommended to further evaluate subsurface conditions associated with these areas of natural ground water discharge and properly design underdrain systems there.

4.2.2 Ground Water Monitoring

Instrumentation and monitoring requirements for ground water levels and water quality parameters in each of the monitoring wells were identical to those for the Phase I surface water gaging stations, with the following exceptions. Turbidity was excluded as a measured water quality parameter in ground water. In the absence of well pumping (which may dramatically increase turbidity levels), the relatively slow fluctuations in water levels and the natural filtration effects of subsurface formations and filter packs typically result in ground water with very low turbidity. The other exception was GW-977(S) which does not intersect the water table. Each of the shallow wells was drilled through shallow soils and weathered bedrock (saprolite) to auger refusal, with screened intervals placed atop the auger refusal depth. GW-977(S) is the only shallow well that experienced dry conditions above the water table; therefore no instrumentation was installed (although weekly monitoring was conducted to evaluate the possible occurrence of any rise of the water table into the well).

The same In-Situ® Level TROLL 700 and YSI 600XLM multi-parameter data logging instruments used at the flumes were placed in each of the monitoring wells to document variations in ground water levels and water quality parameters at one hour increments. The requirements for weekly ground water monitoring and documentation were identical to those described above for the gaging stations, except that inspections and cleaning requirements were limited because of the protected and more stable conditions offered by the inner casing and protective casings. In addition, photo documentation was also not warranted. Additional details of the ground water monitoring practices were defined in the Alliant SOP *Groundwater and Surface Water Monitoring Procedure* (AC-4301-001-GSM). Table 4 provides a summary of instrument depth placements in each well relative to ground surface and the regolith/bedrock interface. Table 4 reflects instrument depths as of March 4, 2015. Previous depth locations are summarized in the notes following the table. Adjustments were made periodically by Alliant to account for adjustments in surface casing stick ups and to ensure data quality.

Records of Alliant weekly downloads, equipment checks, and periodic calibration events for the continuous ground water monitoring are provided in Exhibit A.14. This documentation includes weekly monitoring equipment status/data sheets and checklists, but does not include the raw or processed data files from the continuous monitoring equipment. The processed data are presented in subsequent sections of this report as plots of water level fluctuations and ground water quality data over the initial three month Phase I monitoring period. The raw instrument and processed data files are extensive and therefore are not included as attachments to the Phase I report.

Table 4. Final Monitoring Instrument Placement in Phase I Wells (as of March 9, 2015)

Well ID	Surveyed Elevation TOC	Surveyed Elevation Top of ground surface	Well casing stickup above ground surface	Auger Refusal Depth or Regolith Thickness (ft bgs)	Troll Depth (BTOC)	Troll Elevation	YSI Depth (BTOC)	YSI Elevation	Difference YSI to Troll Depths (ft)	Screen or Open Hole Length (ft)
GW-968(I)	1082.56	1070.21	12.35	10.0	35.0	1047.6	30.0	1052.6	5.0	70.0
GW-969(S)	1082.98	1070.45	12.53	13.5	25.0	1058.0	25.0	1058.0	0.0	5.0
GW-970(I)	1043.17	1040.93	2.24	25.6	55	988.2	40	1003.2	15.0	63.3
GW-971(S)	1043.11	1040.69	2.42	23.8	25.0	1018.1	25.0	1018.1	0.0	10.0
GW-972(I)	1026.20	1023.55	2.65	24.2	32.3	993.9	29.8	996.4	2.5	75.9
GW-973(S)	1026.96	1024.46	2.50	23.0	24.5	1002.5	24.5	1002.5	0.0	10.0
GW-974(I)	1005.38	1002.80	2.58	12.5	20.5	984.9	19.0	986.4	1.5	82.9
GW-975(S)	1005.16	1002.52	2.64	10.0	11.0	994.2	11.0	994.2	0.0	5.0
GW-976(I)	1068.41	1065.84	2.57	24.4	55.0	1013.4	47.0	1021.4	18.0	72.6
GW-977(S)	1068.17	1065.63	2.54	25.1	DRY	DRY	DRY	DRY	DRY	10.0

Notes and Abbreviations:

- GW-968(I) - YSI sonde originally deployed at 20.1 ft BTOC until 12-23-14 when the 5 ft extension was installed. Troll originally deployed at 22.6 ft BTOC until 12-23-14 when the original 5 ft extension was installed.
- Elevations of the Troll and YSI sondes were not changed on 2-9-15 and 2-11-15 when additional casing extensions were added to the TOC at GW-968(I) and GW-969(S).
- GW-970(I) - Troll originally at 45 ft BTOC; lowered to 55 ft BTOC on 12-17-2014.
- GW-974(I) – YSI sonde originally at 18 ft BTOC; lowered to 19 ft BTOC on 1-26-2015.
- GW-976(I) - Troll originally at 45 ft BTOC; lowered to 65 ft BTOC on 12-17-2014.

BTOC below top of casing

4.3 SURVEYING

Professional surveying of all Phase I monitoring locations was completed during the first week of December 2014 by BWSC. The surveying was conducted to accurately define the coordinates and elevations for each well location and the nine Phase I surface water monitoring locations (continuous and observational). For each monitoring well, survey locations included the top of the inside casing (uncapped) as a reference benchmark for water level measurements, and the elevation of the top of concrete (approximate ground surface elevation) at the base of the protective surface casing. Other control points were surveyed such as spot ground surface elevations located adjacent to the concrete well pads, invert locations for some of the culverts installed during road construction, upper corners of the flumes, and intermediate control points.

For the surface water monitoring locations (see Figure 1) benchmarks were surveyed on the following features as shown in Table 5:

- The top and flume floor level at the stilling well location on the three flumes installed at EMDNT3-SWG1, EMDNT3-SWG2, and EMDNT3-SWG3.
- The top and bottom of wooden stakes placed at each of the six observational monitoring locations (the three headwater spring locations at EMDNT2-SP1, EMDNT3-SP1, and EMDNT3-SP2; and the three stream monitoring locations at EMDNT3-ST1, EMDNT3-ST2, and EMDNT3-ST3).

BWSC tied into existing Y-12 system benchmark locations and elevations at monuments 89-Y-116 and 89-Y-117. Surveying data were provided to Pro2Serve for integration into current site topographical survey maps for accurate presentation of key locations on maps and cross sections. The BWSC surveying data (coordinates and elevations) are provided in Exhibit A.16. The elevation data are also included in various report tables where key monitoring well and surface water monitoring data are presented.

Table 5. Elevation Data for Phase I Surface Water Monitoring Locations

<table>
<tr><th></th><th>Surface Water Monitoring Location</th><th colspan="2">Top Staff Gage</th><th>Ground Elevation in Channel Bottom at/near Staff Gage</th><th>Staff Gage Difference</th><th>Top Marking on Staff Gage = Top Staff Gage Elevation</th><th>Elevation at 0.00 ft on bottom of staff gage</th></tr>
<tr><td rowspan="6">Observational Monitoring Locations</td><td>EMDNT2-SP1</td><td colspan="2">1059.33</td><td>1057.81</td><td>1.52</td><td>1.06</td><td>1058.27</td></tr>
<tr><td>EMDNT3-SP1</td><td colspan="2">1042.30</td><td>No Data</td><td>No Data</td><td>1.06</td><td>1041.24</td></tr>
<tr><td>EMDNT3-SP2</td><td colspan="2">1044.39</td><td>1042.83</td><td>1.56</td><td>1.06</td><td>1043.33</td></tr>
<tr><td>EMDNT3-ST1</td><td colspan="2">1011.03</td><td>1009.79</td><td>1.24</td><td>1.06</td><td>1009.97</td></tr>
<tr><td>EMDNT3-ST2</td><td colspan="2">994.00</td><td>992.68</td><td>1.32</td><td>1.06</td><td>992.94</td></tr>
<tr><td>EMDNT3-ST3</td><td colspan="2">1006.96</td><td>1005.74</td><td>1.22</td><td>1.06</td><td>1005.90</td></tr>
<tr><th></th><th>Surface Water Monitoring Location</th><th>Reference Elevation Datum</th><th>Top of Flume at Stilling Well</th><th>Bottom of Flume at Stilling Well</th><th>Flume Height at Stilling Well</th><th colspan="2"></th></tr>
<tr><td rowspan="3">Flume Locations</td><td>EMDNT3-SWG1</td><td>975.06</td><td>978.05</td><td>975.06</td><td>3.0</td><td colspan="2" rowspan="3"></td></tr>
<tr><td>EMDNT3-SWG2</td><td>981.66</td><td>983.17</td><td>981.66</td><td>1.5</td></tr>
<tr><td>EMDNT3-SWG3</td><td>979.68</td><td>982.67</td><td>979.68</td><td>3.0</td></tr>
<tr><td rowspan="5">Other Surface Water Locations</td><td>EMDNT3-SE1</td><td colspan="6">Not surveyed and not part of Phase I monitoring</td></tr>
<tr><td>EMDNT3-SP3</td><td colspan="6">Not surveyed and not part of Phase I monitoring</td></tr>
<tr><td>EMDNT2-SE1</td><td colspan="6">Not surveyed and not part of Phase I monitoring</td></tr>
<tr><td>EMDNT2-SE2</td><td colspan="6">Not surveyed and not part of Phase I monitoring</td></tr>
<tr><td>EMDNT2-SE3</td><td colspan="6">Not surveyed and not part of Phase I monitoring</td></tr>
</table>

Abbreviations:

SE seep
SP spring
ST stream

4.4 WASTE MANAGEMENT

Surface and subsurface media (i.e., soil, rock cuttings, water, etc.) were expected to be uncontaminated because there is no evidence that the EMDF site has been impacted by industrial operations, waste disposal, or other contaminant releases. This was verified throughout the Phase I field work by pre-screening of drilling locations and by visual observation and active use of field instruments (radiation meters, photo-ionization detectors) to screen all media, equipment, and potentially exposed site personnel. Drill cuttings and fluids from soil borings and well drilling were contained on plastic sheeting near each drill site and screened for contamination. After field screening indicated no contamination, subsurface media were spread or discharged in the local areas near the drill sites so as not to negatively impact or influence existing site features or environmental conditions. Disposable personal protective equipment such as latex gloves and other uncontaminated disposable materials such as paper, packaging, plastic sheeting, etc., were bagged and disposed of at the ORR Y-12 Landfill as non-hazardous waste. Water produced during well development was temporarily stored in plastic containers, allowed to settle, and the relatively clear water was discharged to the ground surface near the well site. Documentation for Phase I waste disposal is provided in Exhibit A.17.

5. PREVIOUS INVESTIGATIONS RELEVANT TO PHASE I

Data from previous subsurface investigations along geologic strike with the EMDF in BCV provide a substantial amount of background information applicable to the proposed EMDF. The USGS completed an inventory and limited measurements of flow at spring, seep, and stream locations across the entire length of BCV in the mid 1990’s that included NT-2 and NT-3 tributaries crossing the EMDF (Robinson and Johnson, 1995, and Robinson and Mitchell 1996). More accurate stream flow monitoring was completed in support of the EMWMF along upper portions of the NT-3, NT-4, and NT-5 tributaries during the late 1990’s (BJC 1999). Subsurface investigations were completed by Ogden in 1992/1993 at sites on either side of and along geologic strike with the EMDF (Ogden 1993a and b). The Ogden investigations included 27 borings at Site B, adjacent to the EMDF on the northeast and 52 soil borings at Site C, now occupied by the EMWMF, adjacent to the EMDF to the southwest. The geotechnical and hydrogeological data from these investigations was extensive and relevant to the EMDF site. Pre-construction test pits and monitoring well drilling and installation were conducted at the EMWMF (circa late 1990s/early 2000s) also directly adjacent to and along strike with the EMDF (BJC 1999, CH2M Hill 2000). In addition, subsurface investigation results are available from monitoring well drilling just south of the EMDF and the Haul Road, and for portions of the Bear Creek Burial Grounds further to the southwest and along strike to the EMDF (Bechtel 1984). Results of multiple investigations for waste sites in BCV were synthesized in the multi-volume BCV RI report (DOE 1997). Figure 7 illustrates the locations of borings, monitoring wells, and surface water monitoring stations from previous investigations at and near the proposed EMDF site. A brief summary of the Ogden and EMWMF geotechnical and hydrogeological investigations with excerpts relevant to the EMDF is provided in Exhibit A.19. A careful review of the original reports (Ogden 1993a and b, CH2M Hill 2000) from these investigations and other design related investigations and testing at the EMWMF site is encouraged for planning a Phase II investigation at the EMDF site.

Not shown on Figure 7 but relevant to the EMDF investigation, extensive surface and subsurface investigations were completed in WBCV in the late 1980s and early 1990s within some of the Conasauga Group formations that are along geologic strike with the EMDF. These investigations were completed for the formerly proposed Low Level Waste Disposal, Development, and Demonstration (LLWDDD) Program, also known as the Class L-II Disposal Facility. This facility (never constructed) was located approximately 3.5 miles to the southwest of the EMDF. Field investigations included extensive and detailed hydrogeological site characterization. Multiple reports addressing the LLWDDD site included soils and bedrock characterization, over 8,000 ft of rock coring, numerous monitoring wells and piezometers, surface water and ground water characterization, aquifer testing, tracer testing, and ground water modeling (Lee and Ketelle 1989; Golder Associates 1989; ORNL 1997). The collective results from these investigations and reports provide a valuable and unique source of detailed information that is useful for the interpretation of the Phase I results and for the design and interpretation of data that may be collected from future EMDF investigations.

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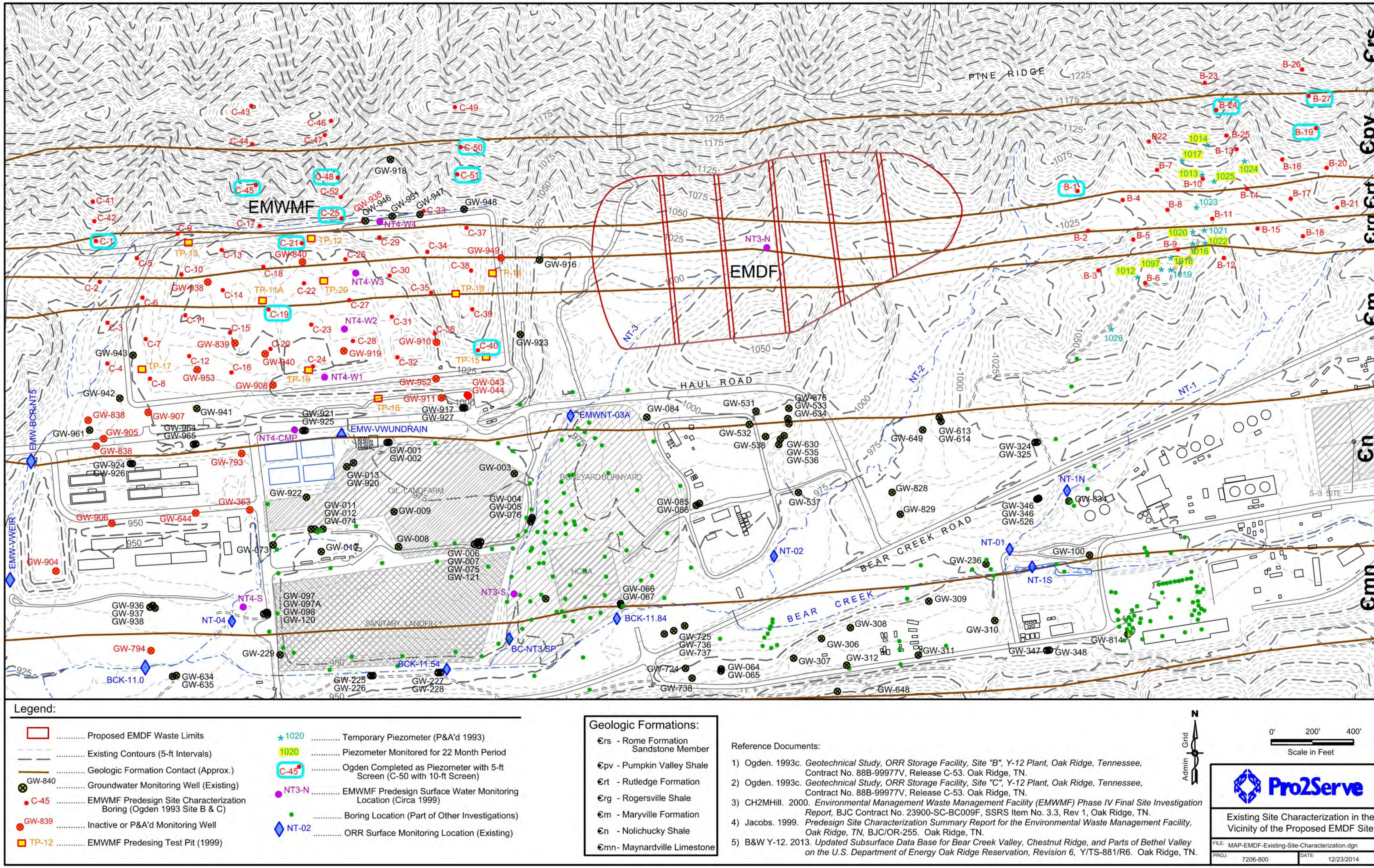

Figure 7. Locations from Previous Investigations in Bear Creek Valley at and Near the Proposed EMDF Site

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6. EMDF HYDROGEOLOGICAL SITE CONCEPTUAL MODEL

A site-specific hydrogeological conceptual model for the EMDF site is presented in Appendix E of the RI/FS Report. This conceptual model is supplemented herein for the Phase I in the attached Plate 1 and in Figures 8–10, and in the summary descriptions that follow. The illustrations and descriptions provided in the cross sectional view of Plate 1 summarizes the site-specific EMDF conceptual model. The cross section is drawn to scale near the center of the EMDF footprint and oriented from northwest to southeast perpendicular to geologic strike. Closeup inserts illustrate details of the hydrogeological model for upland areas and for lowland areas along the valley floor of NT-3 that are characteristic of the site. Intermediate elevation areas of the EMDF site which comprise much of the EMDF footprint are transitional between the upland and lowland areas. The relative positions of the stormflow zone, vadose zone, water table interval, and intermediate and deep ground water intervals are illustrated in cross sectional views. The closeup views also highlight the zone of water table fluctuation that commonly occurs within saprolite of the regolith and the upper portion of bedrock below auger refusal depths. The detailed vertical profile also illustrates the relative change from more porous and permeable regolith materials and shallow fractured bedrock downward into more competent and less fractured and unweathered bedrock at greater depths.

Figures 8–10 present three-dimensional perspective views at and downgradient of the EMDF that provide additional tools for visualizing the conceptual model for ground water flow patterns at the EMDF. The basic elements of the model are derived from the hydrologic framework for the ORR, modifications to that framework (Solomon et al, 1992; Clapp R. B. 1997 and 1998), and similar conceptual models presented for other sites within BCV (ORNL 1997), particularly that presented in the BCV Remedial Investigation Report (see Volume 4 of Appendix E of DOE, 1997). Those reports should be referenced for additional detailed descriptions reflected in the EMDF hydrogeological conceptual model illustrated in these figures. The EMDF conceptual site model refines earlier models by including a mechanism for transferring ground water across the structural-stratigraphic grain of BCV. This refined concept postulates strike-parallel flow towards tributary streams and underlying vertically-oriented fracture systems that have been enhanced by deep weathering. Ground water flow is then captured by the streams and underlying fractures and conveyed towards Bear Creek and Maynardville Limestone conduit systems.

The hydrogeological cross sections shown in Plates 1–4 show the relationships between the Phase I results and surface topography, surface water features (springs, seeps, and NT drainage paths), and key conceptual design elements. Hydrogeological features, including water level data from the Phase I monitoring wells, are accurately shown in relation to existing surface topography, and the positions of underdrain trench/blanket system, the geobuffer, liner system, and final landfill surface grades proposed in the engineering conceptual design for the EMDF. Research on the ORR has demonstrated that the majority of ground water flux occurs via two subsurface pathways: 1) within the stormflow zone associated with the surficial topsoil layer and 2) within the water table interval which commonly occurs within regolith saprolite and weathered bedrock near the zone of water table fluctuations. Solomon et al (1992) reported that >90% of the estimated water flux occurs through the stormflow zone, but subsequent studies reported by Clapp (1997/1998) have shown that the proportion of stormflow zone flux may be much less. The studies suggest that the proportions of shallow stormflow zone versus shallow ground water zone contributing to stream flow were 53% and 47%, respectively. However, there simulations were based on a seven year study period where mean annual precipitation was 25% below the average. The stormflow zone contribution was therefore thought to be closer to 70% during an average year. The overall conclusions of the study suggest that annual ground water recharge and contributions of the ground water zone to streamflow may be much higher than originally proposed by Solomon et al (1999) and closer to 30% on average rather than the 10% originally reported. The relative proportions of the water table, intermediate, and deep intervals of the ground water zone would remain similar to those presented by Solomon et al (1992), as illustrated on Plate 1, with most of the ground water flux still occurring from the water table interval.

As illustrated conceptually in Figures 8 and 10, ground water flow in the water table and intermediate intervals migrates from recharge zones in upland areas and converges toward and slowly discharges along valley floors supporting baseflow along the NT streams. Upwelling may occur from the lower water table and intermediate ground water intervals via fracture zones that intersect with valley floors. Flow along fracture paths is preferential along geologic strike toward the cross cutting NT tributary valleys as illustrated conceptually in Figure 9. Actual fracture flow paths are three dimensionally complex and cannot be accurately defined beyond the locations of individual monitoring wells. Ground water discharge through macropores of regolith materials and fractures within saprolite and bedrock is commonly expressed at seeps and springs along lower slopes of the NT tributaries and along upper reaches of the NT tributaries where abrupt slope transitions occur (see springs/seeps and wetland areas shown on Figures 1 and 9).

It is important to note that the natural conditions just described will be significantly altered during the construction and post-closure period of the proposed EMDF. As the landfill is constructed the area available for ground water recharge will be progressively reduced and restricted to a relatively narrow strip along the uppermost south facing slopes of Pine Ridge north of the EMDF footprint (roughly 10 acres in size). The waste footprint area is estimated to cover about 30 acres while the final cover system will occupy about 35 acres. The former natural recharge area contributing to current surface and ground water flow at the EMDF site would be reduced by roughly 75% after landfill construction. Topsoil materials will be removed and replaced with engineered fill and geobuffer clays. Alluvial and colluvial materials along the valley floors will be removed and replaced with the underdrain system and topped with fill, geobuffer, and liner system materials. The natural surface water and ground water flow regime will thus be dramatically altered and reduced. Ground water within undisturbed natural materials would continue to migrate slowly downgradient but the elimination of significant portions of the former natural recharge area will greatly reduce the overall ground water flux below the footprint. These changes are addressed in modeling simulations that include changes to recharge, surface and ground water flux, and contaminant transport (see Appendix H to the current RI/FS report). These changes are also reflected in the post construction water table configuration shown elsewhere in this Phase I report.

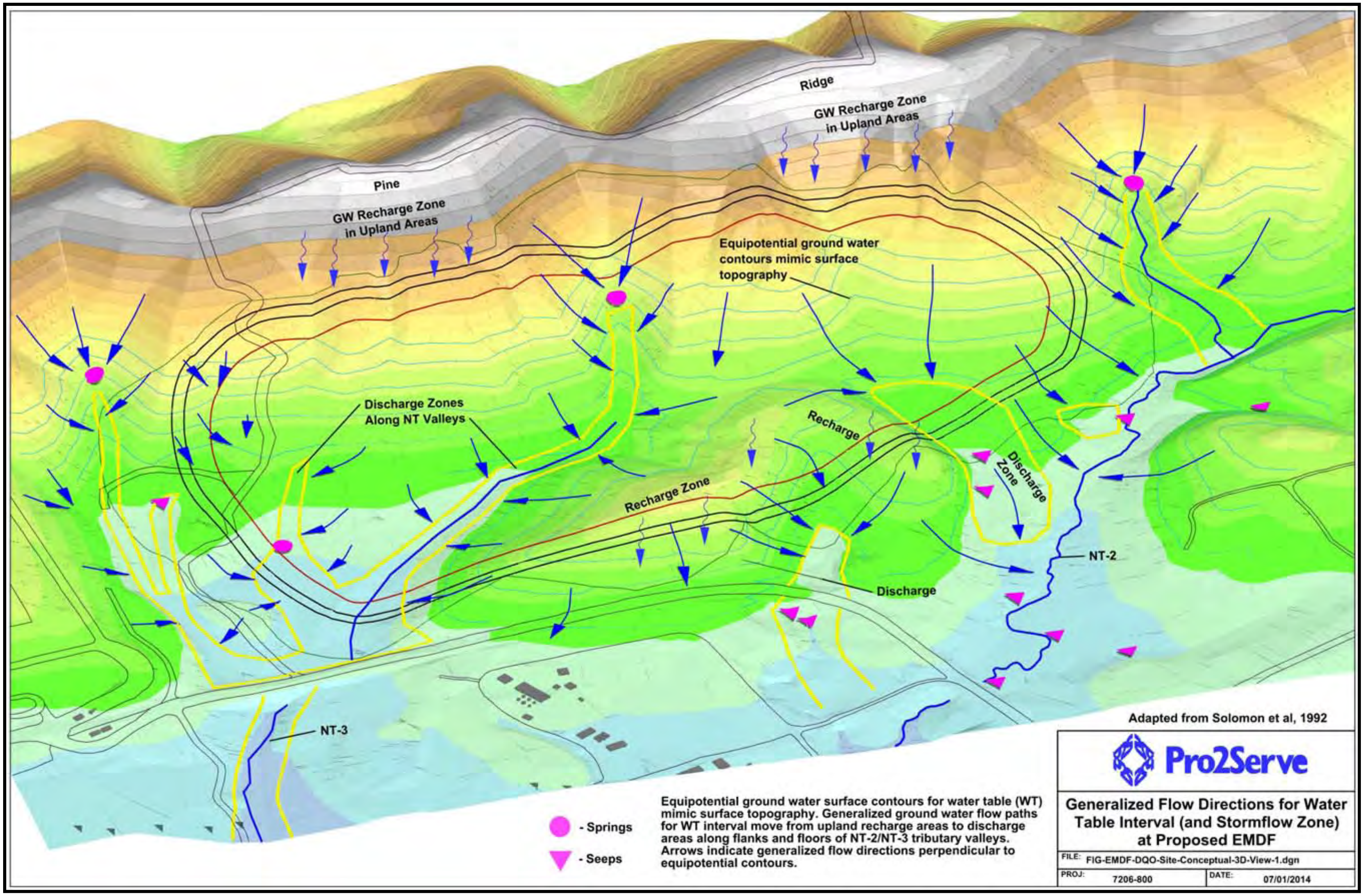


Figure 8. Hydrogeological Site Conceptual Model for the Shallow Water Table Interval at the EMDF Site

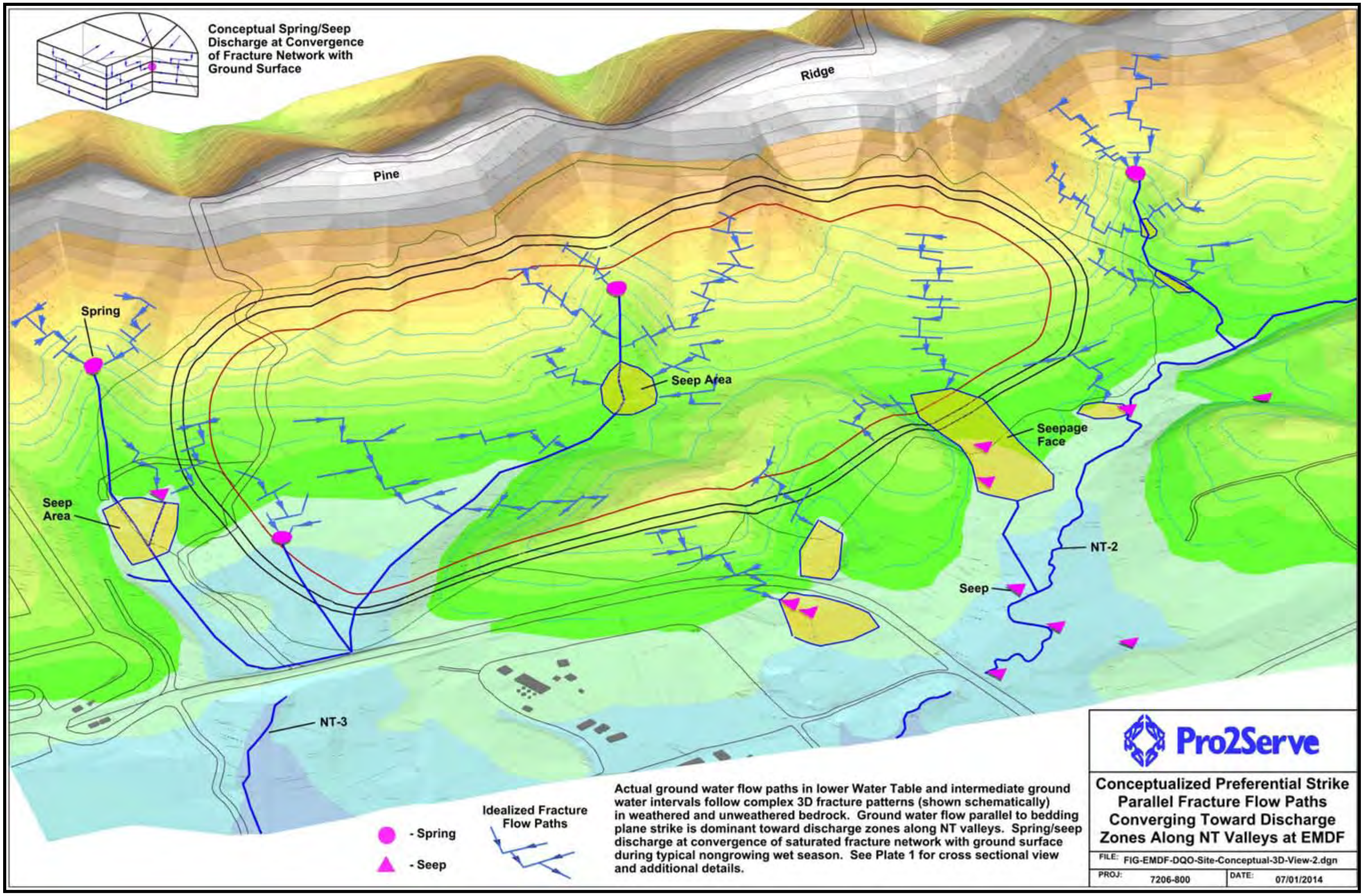


Figure 9. Hydrogeological Site Conceptual Model Illustrating Conceptualized Fracture Flow Paths in the Lower Water Table and Intermediate Ground Water Zones

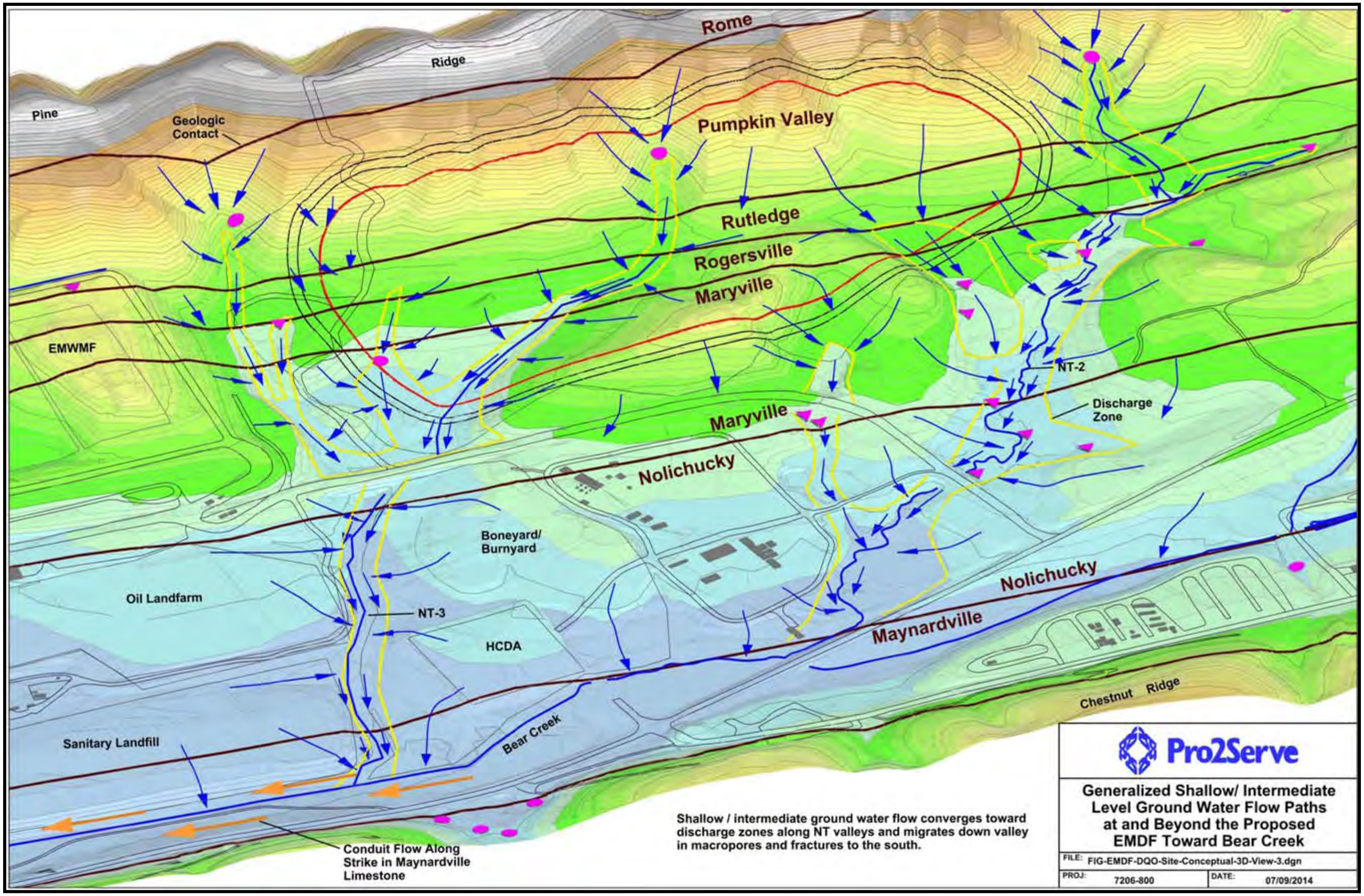


Figure 10. Hydrogeological Site Conceptual Model for Generalized Flow Paths in Shallow and Intermediate Ground Flow at and Downgradient of the EMDF Site

7. PHASE I RESULTS

The limited Phase I investigation results focus primarily on the hydrogeology of the shallow and intermediate ground water intervals, surface water features (springs, seeps, and stream flow), and the general relationships between ground water and surface water. The results are representative of the wet non-growing season when runoff and ground water levels are normally at their highest levels. Results from monitoring surface water flow and water quality parameters are reviewed in Section 7.1. The various subsections of Section 7.2 review Phase I water level monitoring, flow directions and gradients, ground water quality parameters, and results of Phase I hydraulic conductivity tests and heat pulse flow (HPF) meter tests. Additional Phase I findings from geotechnical laboratory tests of soil/saprolite and bedrock hydrogeological conditions based on collective interpretations of rock cores, geophysical logs, and hydraulic data are presented in Section 7.2.5. Where Phase I data are lacking, relevant results from previous investigations at sites similar and/or in close proximity to, and along geologic strike with the EMDF, are compared with the EMDF site. Longer term precipitation and runoff records from locations near the EMDF were also used for comparison with the short term Phase I data (Late November 2014 through late February 2015).

It is important to note that the Phase I investigation was not intended to provide a comprehensive characterization of the EMDF site. The Phase I results were intended to provide initial baseline data to demonstrate the suitability of site conditions in relation to the conceptual design for the disposal facility, and set the stage for further investigations. With EPA and TDEC approval of the EMDF site, a follow on Phase II investigation would be performed to provide much more extensive and detailed data in support of a detailed engineering design for the disposal facility. A Phase II investigation would also provide data to improve the accuracy of fate and transport modeling used for development of final waste acceptance criteria. For now, the Phase I investigation provides baseline site-specific data limited to that obtained from the five well pair locations, three surface water gaging stations, and six surface water weekly monitoring locations.

7.1 SURFACE WATER HYDROLOGY

The surface water and ground water hydrology at the EMDF site are addressed below in separate sections but interactions between surface and ground water are clearly significant at the EMDF site and throughout BCV, as shallow ground water supports seasonal baseflow to the uppermost tributaries of NT-2 and NT-3 and discharge to springs and seeps within and adjacent to the EMDF footprint. If the proposed EMDF site is approved, interactions between surface and ground water would presumably be further characterized during a Phase II investigation, particularly in support of a detailed engineering design for the proposed underdrain system.

7.1.1 Local Climate and Recent Precipitation

Current climate normal values (1981–2010) from the National Weather Service (NWS) for the Oak Ridge area are 50.91 in. for annual precipitation and 58.8° F for mean annual temperature. Precipitation is distributed uniformly through most of the year, with normal monthly precipitation for August through October averaging about 1 in. lower than during other months (see Figure 11). These three months of lower precipitation and high temperatures tend to comprise a seasonal dry period in which evapotranspiration losses are large relative to inputs of rainfall.

Cumulative monthly precipitation data since 1999 (NWS station KOQT in Oak Ridge) and corresponding recent records from the Y-12 West Tower meteorological station (Y-12W) located near the EMDF site (see Figure 12) suggest that precipitation amounts for the 2014-2015 winter wet season are close to averages observed over the last decade (see Figure 13). Hourly precipitation data for Y-12W are utilized in this report to represent rainfall at the EMDF site.

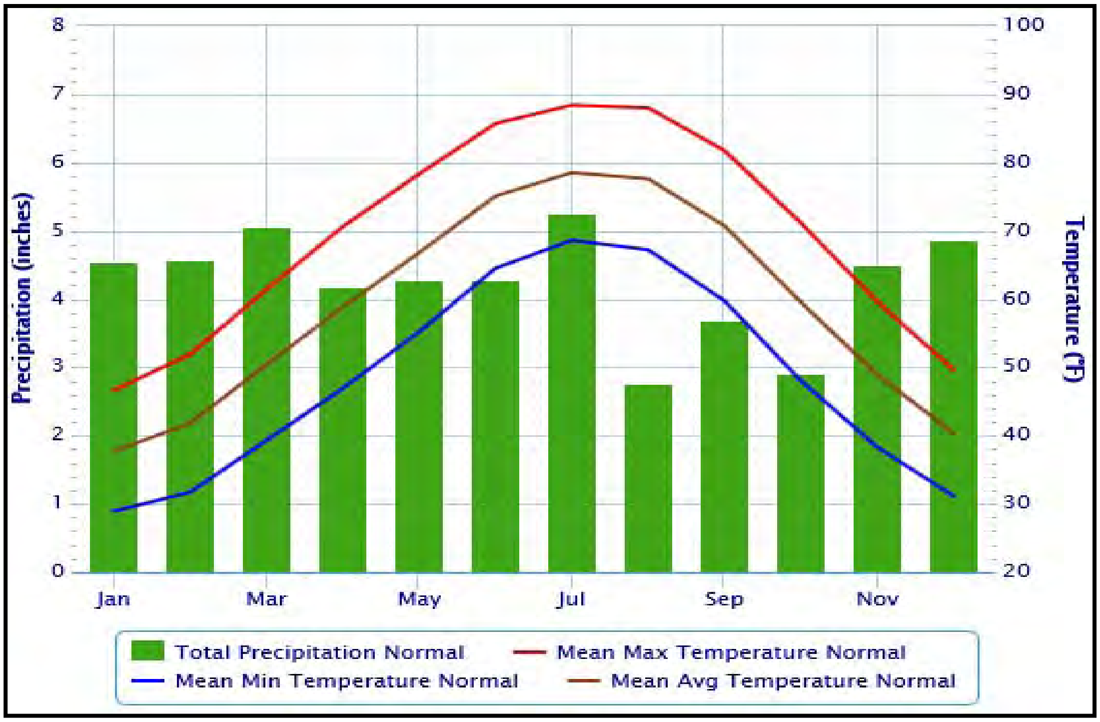
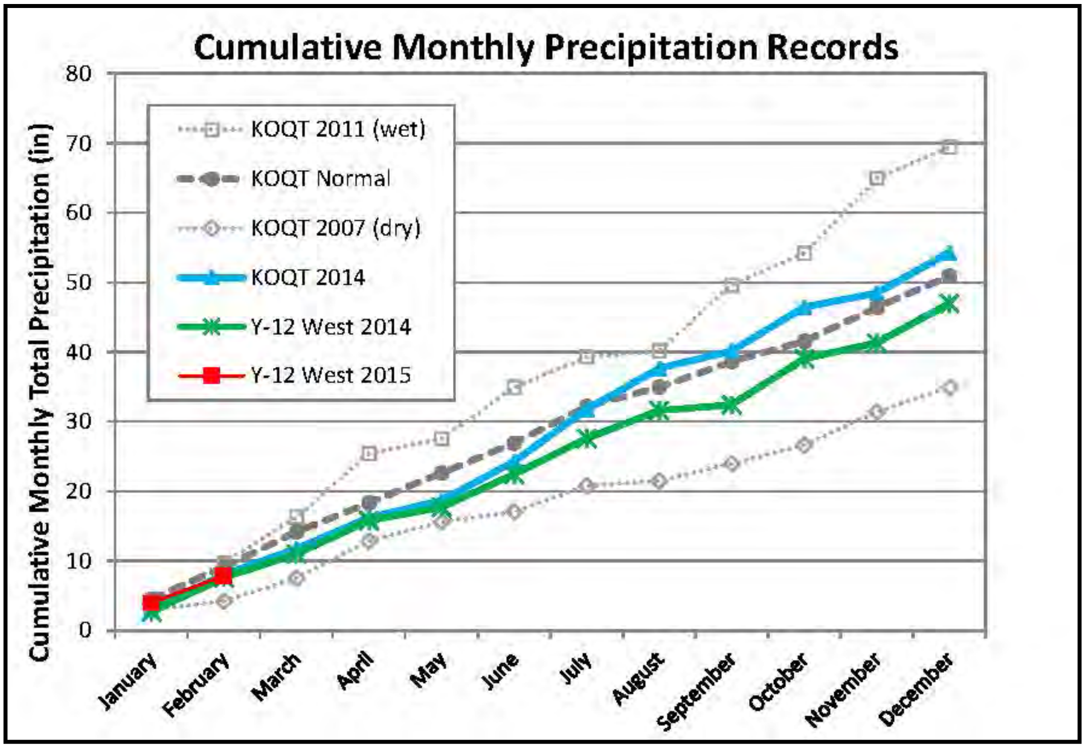


Figure 11. Monthly Climate Normals (1981–2010) – Oak Ridge Area, Tennessee

Figure 12 Location Map for Meterological Stations



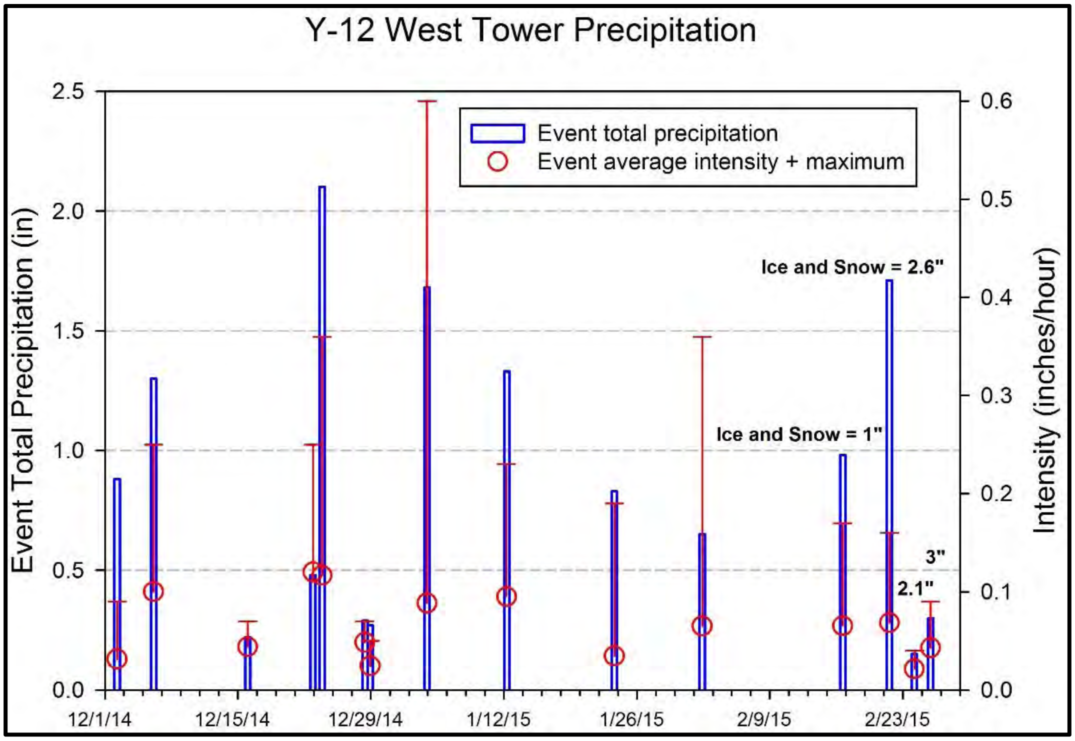
KOQT records for the year of highest (2011) and lowest (2007) total annual precipitation illustrate the observed range of variability since 1999. Refer to Figure 12 for locations of KOQT and Y-12W.

Figure 13. Cumulative Monthly Precipitation Records for NWS Station KOQT and the West Tower Meteorological Station at Y-12 (Y12 West)

For the period from December 1, 2014 through February 28, 2015, there were 15 precipitation events exceeding 0.1 in. at the Y12W tower (see Figure 14). Five of these events exceeded 1 in. total storm precipitation and one event exceeded 2 in. For the February 2 and earlier events, the type of precipitation was primarily rain, whereas the last four events (February 1626) included significant amounts of snow and ice as noted on Figure 14.

Average rainfall intensity for the four earlier events exceeding a 1 in. storm total was approximately 0.1 in. per hour, and maximum hourly intensities during these storms ranged from 0.23 to 0.6 in. per hour. To put the magnitude of these storm events in hydroclimatic context, the NWS point precipitation frequency estimate for hourly rainfall intensity at the National Oceanic and Atmospheric Administration Atmospheric Turbulence and Diffusion Division station (within 4 miles of the EMDF site, see Figure 12) given a one year average recurrence interval is 1.14 in. per hour, almost twice the maximum observed hourly intensity for Y-12W precipitation during the three month reporting period. Hourly precipitation exceeding 0.6 in. was recorded at Y-12W 48 times during the five years from 2009 to 2014, over nine times per year, on average.

Similarly, for the three month reporting period, the Y-12W storm event with the highest average intensity (0.12 in. per hour over 4 hours on December 22, total rainfall = 0.48 in.), is small compared to the 1.58 in. over four hours (0.395 in./hour) NWS estimate for a one year average recurrence interval. Storms of equal or greater magnitude than the 15 observed events are likely to occur several times per year in the vicinity of Oak Ridge.



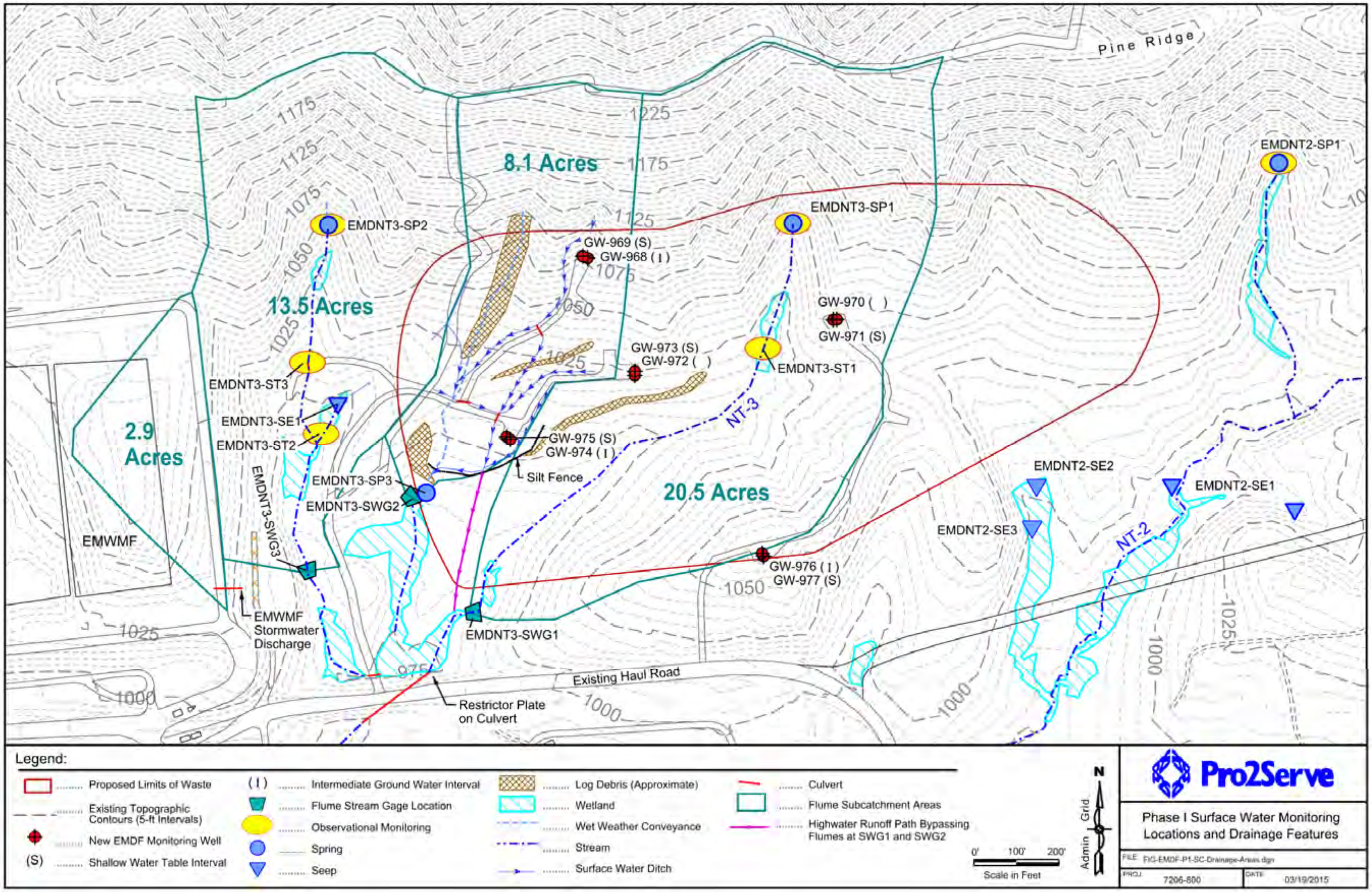
As Recorded at the Y-12W Station during December 2014 and January–February 2015

Figure 14. Summary of Observed Total Precipitation, Average Precipitation Intensity, and Maximum Hourly Intensity for each of 15 Rainfall Events Exceeding 0.1 in. Total

7.1.2 Rainfall Runoff Relationships

The portion of the NT-3 watershed upslope of the existing haul road along the base of Pine Ridge at the EMDF site has experienced several significant physical disturbances over the last two years. Following severe storm-damage to the forest cover that occurred in May 2013 (refer to Section 1.6 and Figure 2), salvage logging operations began in November 2014 and continued through July 2014. Heavy equipment used during this effort produced widespread disturbance of existing vegetation cover and soils on portions of of Pine Ridge within the proposed EMDF footprint (see Figure 2). Subsequent development of the site for well drilling operations including grading and road construction has altered the original drainage patterns and further disturbed the watershed. These physical and biological impacts will have altered the hydrologic response of the upper portion of the NT-3 catchment, likely resulting in increased runoff and higher peak flows compared to pre-disturbance conditions. The surface flow and water quality monitoring data collected during the three month period covered by this report document the current disturbed condition of the watershed, and may or may not be representative of future conditions, depending on the recovery of natural vegetation and drainage patterns and ongoing development of the site for EMDF construction.

Figure 15 illustrates the current approximate catchment areas for the three subwatersheds draining to each of the three Phase I surface water gaging (SWG) stations. The Phase I road construction has altered the natural runoff patterns primarily within the central catchment area associated with SWG-2. Eastern portions of the current catchment area for SWG-2 that previously flowed into the catchment for SWG-1 are now diverted toward runoff feeding into the SWG-2 flume. However, during periods of higher precipitation and runoff a high water overflow pathway breaches the existing silt fence (shown in Figure15) and flows southward bypassing both the SWG-1 and SWG-2 flumes. DOE plans to have this



New runoff patterns associated with Phase I road construction/culverts and the high flow bypass route are shown with blue and magenta arrow lines.

Figure 15. Phase I Monitoring Locations and Approximate NT-3 Subcatchment Areas and Runoff Pathways for Flumes SWG-1, SWG-2, and SWG-3

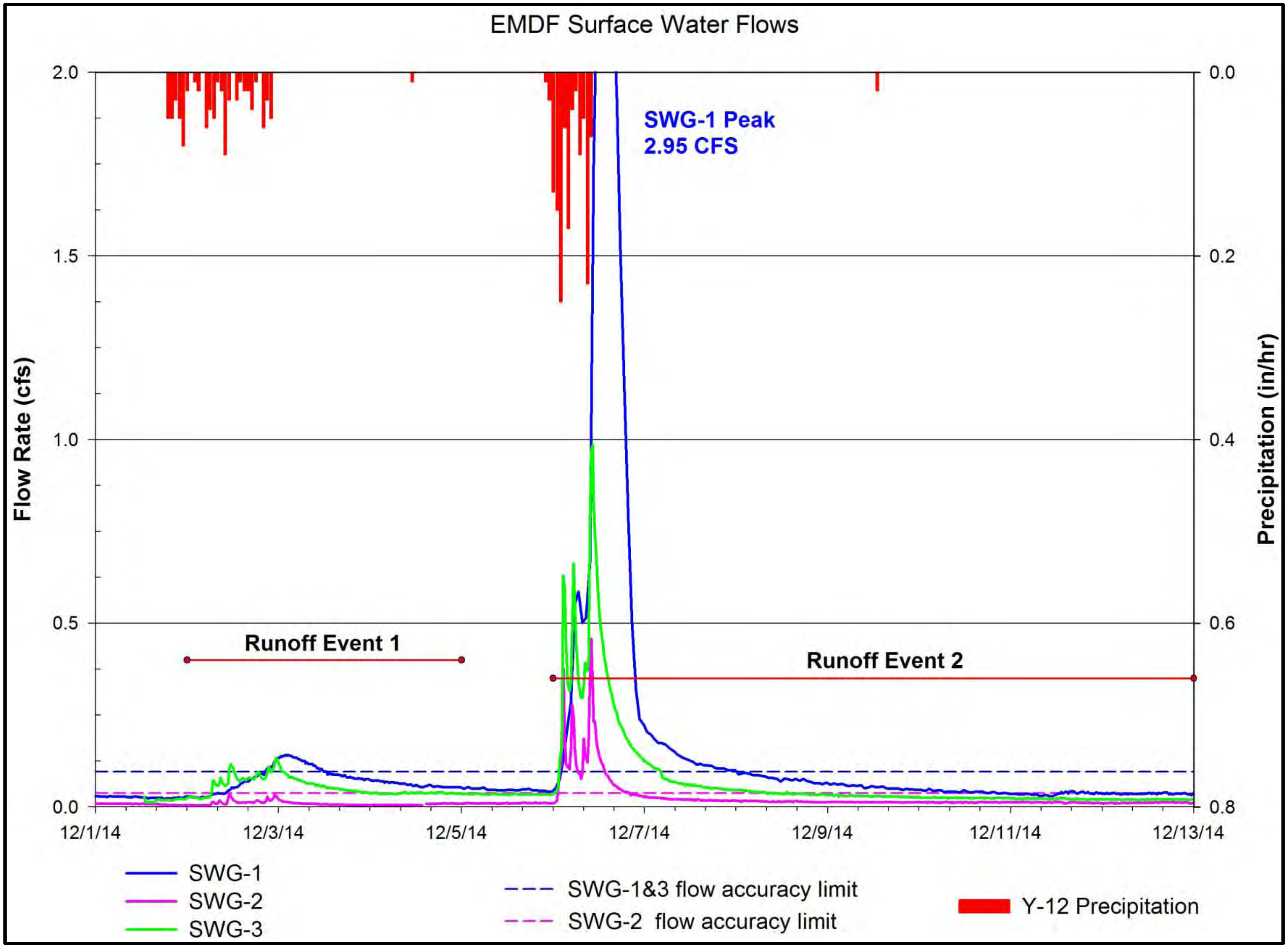
drainage pattern modified to direct runoff toward the west into the SWG-2 catchment area but runoff data for the current reporting period does not include this ungaged fraction of overland bypass flow.

Stream hydrographs recorded at the three SWG stations illustrate relatively rapid hydrologic response to rainfall, as expected for a small, fairly steep, recently disturbed watershed. An example of this response is illustrated in Figure 16). The streamflow data are consistent with precipitation inputs and appear to be generally reliable (see Figure17), although for flow depths less than 0.1 ft, the manufacturer's rating for the flumes is subject to uncertainty resulting from the site-specific geometry of the flume installation and flume entrance hydraulics. Flow rates corresponding to this lower flow accuracy limit for the larger (SWG-1 and SWG-3) and smaller (SWG-2) flumes are indicated by dashed horizontal lines on the hydrographs in Figures 16 and 17. Much of the runoff record lies below these lower flow accuracy limits, but the data are coherent in terms of responses to precipitation and the similarity of hydrographs for events of varying magnitude, suggesting that reliable flow ratings for depths less than 0.1 ft could be developed on a site-specific basis. For the analysis in this report all flows including those below the lower accuracy limit (less than 0.1 ft depth), have been estimated using the manufacturer's flume ratings. Given that the flume sizes were selected to ensure that peak flow rates are reliably estimated, the errors in estimating low flows are considered acceptable for the purposes of this Phase 1 site characterization.

An additional source of error in estimated flow rates is related to the accuracy and precision of flow depth measurements. The factory-calibrated pressure transducers are accurate to +/- 0.01 ft and uncertainty in precisely positioning transducers (datum control) is at maximum +/- 0.05 ft. Changes in estimated flows corresponding to datum shifts of this magnitude are evident in the SWG-2 flow record on some occasions when instruments were serviced and data downloaded. For the smaller flume at SWG-2, this flow depth uncertainty corresponds to relatively large proportional errors in flow estimates near the lower accuracy limit. As flow depth increases, the proportional error decreases rapidly in proportion to 1/depth. For the two larger flumes (SWG-1 and SWG-3), the proportional error due to depth uncertainty at the flow accuracy limit would be lower than for the smaller flume, and becomes negligible at higher flows. The uncertainties in low-flow estimates related to flow depth accuracy and precision are probably larger than the errors associated with utilizing the manufacturer's flume ratings to estimate flow at depths less than 0.1 ft.

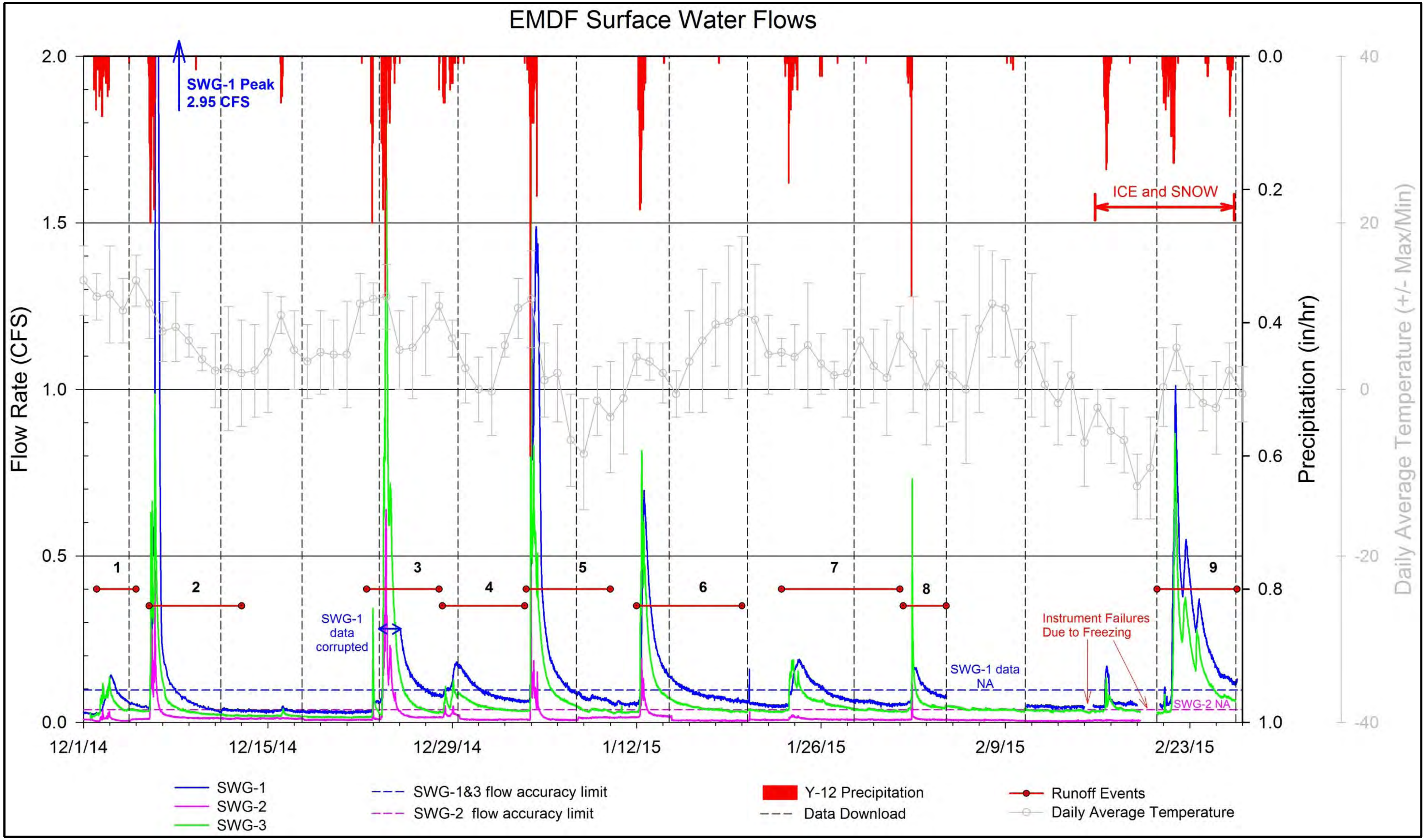
For purposes of comparing runoff to precipitation inputs, nine runoff events (discrete portions of the runoff record) were identified (see Figure 17) and event-total streamflow volume was calculated by integrating flow rates over time. These estimated volumes were scaled by the estimated area contributing runoff to each SWG (see Figure 15) to obtain a measure of total runoff per area (inches) suitable for direct comparison with precipitation (see Figure 18), and to facilitate direct comparisons among the three subcatchments. Figures 18 and 19 also include estimated runoff at the BC-NT3 gaging station on NT-3 downstream of the EMDF site and located about 100 ft above the confluence with Bear Creek (See location on Figure 7). The rainfall-runoff (mass-balance) analysis was performed as a rough data quality assessment only, and was not intended to quantify rainfall-runoff dynamics or the factors affecting these dynamics. Using this approach, the flow data for SWG-1 during event #3 (December 22–27) was found to correspond to 8 in. of runoff versus an estimated precipitation input of 2.6 in. This discrepancy was determined to be caused by a wooden pallet obstructing the flume entrance, leading to larger flow depths and overestimated flow rates.

In comparing estimated runoff to precipitation inputs, the selection of the time period over which streamflow is integrated will affect the results. For example during events #1 and #8, an increase of water storage in the SWG-1 and SWG-3 subcatchments is suggested by the difference in flow rates between the beginning and end of the integration period (see Figures 16, 17). This gain in storage is reflected in the low runoff as a proportion of precipitation input for events #1 and #8 relative to the other seven events (see Figure 19). In these two cases the selection of a longer flow integration period to more closely



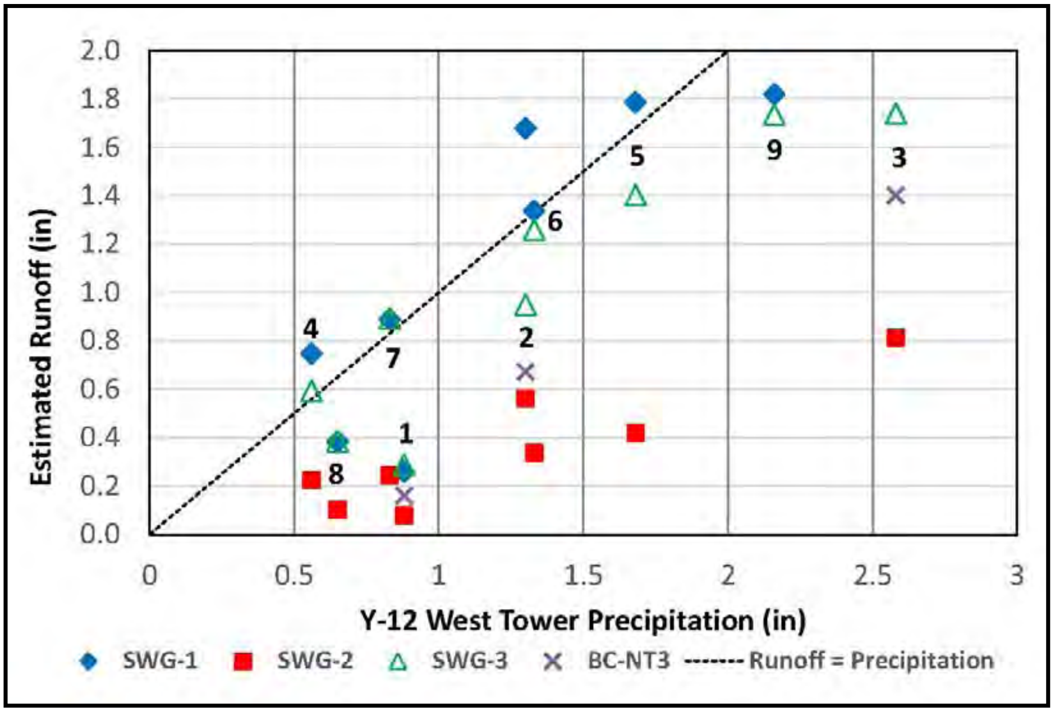
Hourly Y-12W precipitation is also shown for reference.

Figure 16. Streamflow Hydrographs for the Three SWG Stations in the NT-3 Watershed



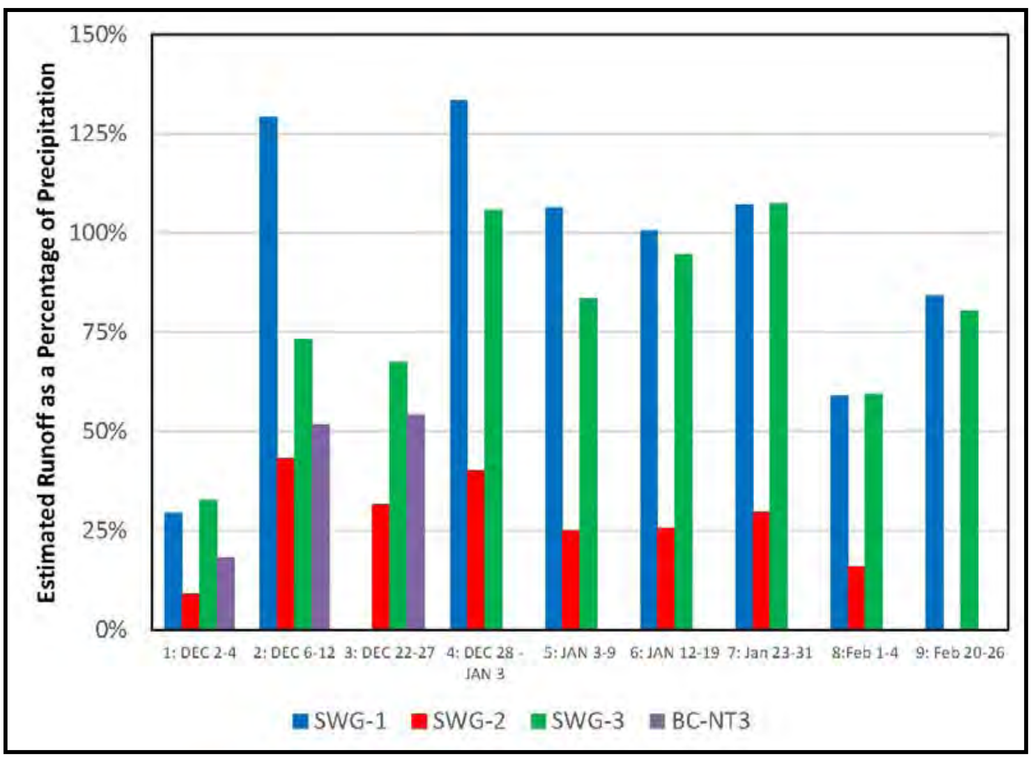
Daily average, minimum, and maximum air temperatures for the Oak Ridge area are NWS data. Numbered horizontal lines delimit the runoff events identified for analysis.

Figure 17. December 2014–February 2015 Streamflow Hydrographs for the Three Phase I SWG Locations and Precipitation Data from the Y-12W Meteorological Station



Numbers on plot correspond to the nine runoff events identified in Figure 17.

Figure 18. Estimated Event-total Runoff Plotted Against Storm Total Precipitation



Data from Y-12 gaging station BC-NT3 downstream of the EMDF near the junction with Bear Creek shown for comparison.

Figure 19. Event-total Runoff as a Percentage of Precipitation for Nine Runoff Events

approximate zero change in storage is precluded by the occurrence of flow event #2 and the loss of SWG-1 water level data for February 4–10 due to equipment failure.

Runoff in relation to precipitation varied considerably among the three flumes and among flow events, reflecting differences among subcatchments and among precipitation events, as well as a number of data uncertainties. Estimated event-total runoff increased with observed storm-period precipitation, with SWG-2 having much lower runoff values than SWG-1 and SWG-3 (see Figure 18). Event-total runoff measured at SWG-2 was less than 44% of precipitation input for the first eight events (no SWG-2 data was collected during event #9 due to equipment failure). In contrast, runoff at SWG-1 and SWG-3 was greater than 50% of precipitation for all but the first event (December 2–4), and exceeded 100% on several occasions (see Figure 19). For the first event, relatively low runoff relative to precipitation for all three stations is consistent with the transition from drier conditions into the wet season, and reflects increasing ground water storage during the event (see Figure 16) and possibly higher interception and evapotranspiration losses than occurred during subsequent events. For event #8, well into the wet season, precipitation is less than for event #1, but event-total runoff is higher than for event #1 at all three stations (see Figure18), despite a net increase in water storage during the relatively short flow integration period (see Figure 17).

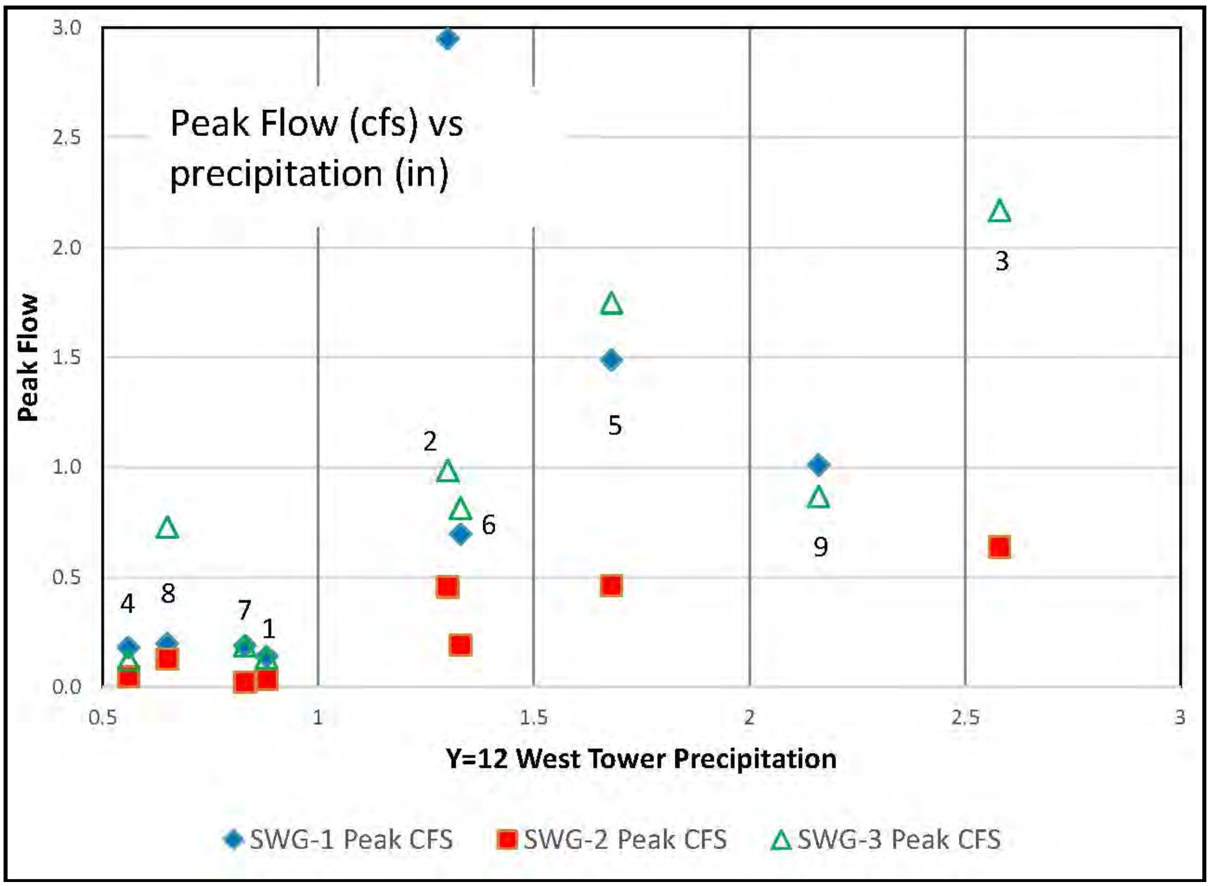
For events one through seven, for which SWG-1 and SWG-3 have consistently more runoff volume per catchment area than does SWG-2 (see Figure 17), there are several possible factors that may explain this difference. Because the SWG runoff estimates utilize the subcatchment contributing areas for scaling the storm-total flow volume, uncertainty in surface water drainage pathways and the location of subcatchment divides affects the magnitude of estimated runoff and differences among gaging sites. Owing to the physical disturbance of salvage logging and access road construction, drainage patterns in the lower portion of the SWG-2 subcatchment are complex and variable. The subcatchment areas identified in Figure 15 are based upon digital topographic data and field mapping of drainage pathways during the monitoring period, but do not reflect the potential for surface runoff originating upslope of the gaging sites to cross the assumed subcatchment boundaries or to bypass the flumes. Field observations indicate that during larger flow events (e.g., events #2, #3, #5, #6, and #9) a portion of surface runoff flowing toward the SWG-2 flume along a silt fence can overtop the fence and flow into NT-3 below the SWG-1 flume, leaving a portion of the runoff from the SWG-2 catchment ungaged (see Figure 15). This ungaged flow may account for the persistently low SWG-2 runoff (see Figures 18, 19).

Other environmental factors that can cause inter-site and inter-event differences in runoff include variations in total precipitation and the intensity and type of precipitation, which may account for some of the disparity between SWG-1 and SWG-3 for events #2, #4, and #5, where SWG-1 runoff is significantly greater than SWG-3 and exceeds 100% of assumed precipitation input (see Figure 19). Runoff totals exceeding 80% of precipitation inputs are not unreasonable for the wet season in a humid-temperate climate, while estimates exceeding 100% are not unexpected given spatial variations in precipitation and errors in precipitation measurements, uncertainty in flow rate estimates and contributing areas, and the potential for ungaged flows.

7.1.3 Stream Flow Response to Precipitation

Subcatchments SWG-2 and SWG-3 respond more quickly to precipitation than does SWG-1. SWG-2 and SWG-3 flows tend to peak earlier than SWG-1 (see Figure 16), and for runoff events #5 and #8 SWG-3 peak flow is higher than SWG-1 (see Figure 17). SWG-2 and SWG-3 also tend to exhibit several successive peaks in response to brief periods of high rainfall intensity, whereas SWG-1 exhibits a less flashy response. These differences reflect variation in drainage area and topography among the three subcatchments, with SWG-1 having longer hydrologic travel distances and travel times than SWG-2 and SWG-3.

Peak flows tend to scale with storm-total precipitation and subcatchment area (see Figure 20), and also depend on precipitation intensity and watershed characteristics. Runoff event #8, produced by a precipitation event (0.65 in. over 9 hours) with over half (0.36 in.) of the total rain falling in a single hour, exhibits very rapid flow increase at all three SWG locations and a much higher SWG-3 peak flow (0.73 cfs) than occurred at the other two gages (< 0.2 cfs). Event #2 is another unusual case in which the SWG-1 peak flow rate is much higher than at SWG-2 and SWG-3 (see Figure 16). The higher SWG-3 flow peak during runoff event #8 is probably related to catchment size and shape effects on hydrologic response time coupled with precipitation intensity, whereas the extremely high SWG-1 peak during runoff event #2 may reflect higher total precipitation input and higher rainfall intensity in the SWG-1 subcatchment than the rest of the NT-3 watershed.



See Figure 17 for duration and magnitude of nine events.

Figure 20. Peak Flow Rates Plotted Against Storm-total Precipitation for the Nine Runoff Events

During the late February 2015 period of ice and snow accumulation, event (#9) peak flows are small relative to total precipitation because snowmelt patterns controlled runoff (see Figure 20) and produced three distinct peaks following precipitation on February 21 (see Figure 17).

Longer-term stream flow data are available from a flume gaging station, BC-NT3, located on NT-3 at a location about 100 ft upstream of the junction with Bear Creek (see location on Figure 7). The BC-NT3 station is located approximately 1200 ft downstream of the NT-3 culvert at the Haul Road along the southwest corner of the EMDF site. A restrictor plate with a vertical slit was placed across the upstream side of this culvert at the end of remedial actions completed at the Bone Yard/Burn Yard site in September 2002 (the culvert was plugged during construction activities between May and September 2002 while NT-3 stream flow was diverted to NT-2). Since September 2002, this restrictor plate has constrained the runoff rates from the upper NT-3 watersheds at the EMDF site and created artificial wetland areas immediately above and behind the Haul Road. Exhibit A.13 contains streamflow hydrographs illustrating the daily average flow rates from 2000 through 2014 at the BC-NT3 gaging station, along with more recent hourly BC-NT3 flows from October 1 through December 31, 2014. The recent hourly BC-NT3 flow data are shown along with the Phase I continuous streamflow monitoring records for the three EMDF surface water gaging stations to permit comparison during the first month of the Phase I reporting period (December 2014). For the relatively small flow events #1 and 4, peak BC-NT3 flow rates were much higher than peak flows at SWG-1 and 3, whereas during the larger event #2, peak flows at BC-NT3 and SWG-1 were of similar magnitude (1462 and 1324 gpm, respectively). Further analysis of the relationships between hydrologic response at the EMDF site and the downstream BC-NT3 gaging station are recommended as additional BC-NT3 records are issued on a quarterly basis and as additional Phase I stream flow data are produced [at least through the end of September 30, 2015 (FY 2015)]. Comparisons of future stream flow hydrographs between the three Phase I SWG stations and the BC-NT3 gaging station would allow for comparisons of flow rates and precipitation records over about a fifteen year historical period (bearing in mind the effects of the restrictor plate). Correlations between extreme rainfall events could be assessed for a decade or more of records from BC-NT3.

Given that the precipitation events recorded during the three month reporting period are relatively small magnitude, high frequency occurrences (refer to Section 7.1.1), peak flow rates higher than those reported here are almost certain to occur in an average year. The USGS Tennessee Water Science Center has developed a web-based application (http://water.usgs.gov/osw/streamstats/tennessee.html) for estimating peak flows for unregulated Tennessee streams (Law and Tasker, 2003, Ladd and Law, 2007). This statistical tool utilizes multivariate regression to predict peak flows of varying return period as a function of catchment size, stream channel slopes, and local climate factors. The empirical model was developed from data for catchments ranging in size from 2.5–2,560 square miles, and may not be accurate for catchment areas outside of this range. Peak flows for the SWG-1 subcatchment (0.3 square miles) predicted with this tool are likely to be underestimates because very small catchments are more likely to experience uniformly large and intense rainfall inputs. These SWG-1 estimates for 2-year, 5-year, and 10-year return period peak flows are presented here as a rough indication of possible high flow rates in the future, and should not be considered to be statistically robust predictions (see Table 6).

Table 6. Peak Flow Rates Estimated for the SWG-1 Subcatchment

Return Period (years):	2	5	10
Annual Maximum Peak Flow Rate (cfs)	9.77	16.8	22.5

Rates estimated using data obtained from Tennessee StreamStats using the regression model of Law and Tasker, 2003.

Peak runoff for the nine major precipitation events for the Phase I monitoring period to date are shown in Table 7. The peak flow ranges include:

- SWG-1: 0.14-9.63 cfs (62.84 – 4322 gpm)
- SWG-2: 0.02-0.64 cfs (8.98 – 287.3 gpm)
- SWG-3: 0.13-2.17 cfs (58.35 – 974 gpm)

Table 7. Peak flow Rates at Stream Gages for Current Phase I Monitoring Period

Runoff Event	Dates	Peak Flow (cfs)			Peak Flow (gpm)		
		SWG-1	SWG-2	SWG-3	SWG-1	SWG-2	SWG-3
1	12/4/2014 - 12/2/2014	0.14	0.04	0.13	63.6	16.2	60.5
2	12/6/2014 - 12/12/2014	2.95	0.46	0.99	1323.6	205.2	442.7
3	12/22/2014 - 12/27/2014	*	0.64	2.17	*	286.6	973.8
4	12/28/2014 - 1/3/2015	0.18	0.05	0.13	81.4	22.3	56.8
5	1/3/2015- 1/9/2015	1.49	0.46	1.75	668.0	207.7	785.0
6	1/12/2015- 1/19/2015	0.70	0.19	0.82	312.3	86.1	365.9
7	1/23/2015- 1/31/2015	0.19	0.02	0.19	84.9	10.0	84.0
8	2/1/2015- 2/4/2015	0.20	0.13	0.73	89.2	57.6	327.5
9	2/20/2015- 2/26/2015	1.01	NA	0.87	453.6	NA	389.4

* A peak flow value of 9.63 cfs (4321.4 gpm) was calculated for Event #3 at SWG-1 based on the hourly water level readings. Subsequent analysis indicated that this peak flow value was far too high relative to the total precipitation for this event. A check of Alliant field notes indicated that a wooden pallet had been swept into the upstream end of the flume during this runoff event. This was presumed to have distorted and erroneosuly magnified the water level readings, resulting in invalid peak flowsfor Event #3 at SWG-1.

The baseflow rates at the three Phase I stream gages are below the minimum quantifiable flows rated by the vendor (OpenChannelFlow™) for the two types of flumes installed:

- For SWG-1 and SWG-3 – 0.0964 cfs (43.26 gpm)
- For SWG-2 - 0.0373 cfs (16.76 gpm)

These limits are set by the vendor rating tables (see Exhibit A.13) where the water level in the flume is at 0.1 ft (for both flume sizes). The rating tables note “excessive error due to fluid-flow properties and boundary conditions” for flow rates where water levels fall below 0.1 ft.

7.1.4 Surface Water Observational Monitoring Results

The six Phase I quasi-weekly observational monitoring stations are highlighted on Figure 15 with yellow ovals. The locations include the three headwater springs originally identified by USGS surveys of BCV circa 1992, and three locations along the east and west upper tributaries of NT-3 at locations intermediate between the headwater springs and the SWG locations. Details of the monitoring activities are described above in Section 4.2.1.2. The results of weekly water quality parameter readings, photographs, and estimates of flow rates are provided in Exhibit A.15 along with spreadsheet compilations of data for the initial 12 weeks of monitoring (from December 10, 2014 through February 27, 2015).

Part of the rationale for weekly monitoring was to determine the nature of spring and stream flow along the upper most reaches of the NT tributaries at the EMDF site over the course of a full year. The weekly observational data would document whether or not the headwater springs and upper sections of the stream channels become dry or flow is intermittent during the late summer and fall growing season when evapotranspiration is highest and flow is typically at its lowest. Field traverses before the Phase I investigation indicated that each of the three springs mark the beginning of the stream channels with surface water runoff along the uppermost sections of the NT-2 and NT-3 tributaries. The three springs are relatively small features no more than 1–2 ft wide and only a few inches deep. The natural stream channels below the springs follow the primary NT tributary valley floors as shown by the dashed lines on Figure 15. The spring at EMDNT3-SP3 (not monitored during Phase I) located just above the middle flume location at EMDNT3-SWG2 marks the start of a relatively smaller and shorter stream channel between the two primary NT-3 tributaries crossing the middle and western parts of the EMDF site. No other springs or seeps have been identified along the other narrow ravines that drain the steep south facing slopes of Pine Ridge. The locations of other individual seeps and broad flat seepage areas indicated as wetlands are shown on Figure 15 within and adjacent to the proposed EMDF footprint. Each of these areas should be assessed during a Phase II investigation to ensure data are available for proper design of the underdrain system. Road construction for the new UPF haul road included reworking of the seepage/wetland areas along the southeast part of the EMDF footprint (see EMDNT2-SE1, -SE2, and SE3 locations on Figure 15). Outlets for the proposed underdrain systems would be located along these valleys as they represent discharge zones for shallow/intermediate ground water. Water within the newly constructed wetland mitigation pond near EMDNT2-SE2 is almost certainly maintained by shallow ground water discharge.

The results of the weekly surface water observational monitoring flow data are presented below. The results from the weekly observational water quality data are reviewed separately in Section 7.1.5 in conjunction with the water quality results from continuous monitoring at SWG-1, SWG-2, and SWG-3.

7.1.4.1 Weekly Observational Monitoring Flow Data

The weekly Phase I data indicate that flows during the wetter winter/early spring season are continuous at and below the springs (see photographs and estimates of flow rates in Exhibit A.15 for details). Table 8 presents stream flow statistics for the three locations EMDNT3-ST1, -ST2, and -ST3, located between the SWG locations 1 and 3, and the two headwater springs EMDNT3-SP1 and –SP2, and the seep at EMDNT3-SE1. It should be noted that these flow measurement calculations are relatively inaccurate and based on simple measurements of flow rates and cross sectional areas of the stream channels (the flume data above the minimum 0.1 ft level are much more accurate and reliable than the observational data). Flows at EMDNT3-ST3 may be considered slightly more accurate in that measurements were made there using the culvert outfall to contain and time water flow. Baseflow averages in Table 8 were calculated based on the weekly measurements made during the flat sections of the flow recession curves shown in Figure 17. Flows were averaged for the four baseflow measurements made on December 17, 2014, and on January 21 and 29, and February 11, 2015. The data in Table 8 indicate baseflow rates ranging from 0.007 cfs (3.1 gpm) at EMDNT3-ST3 to 0.056 cfs (25 gpm) at EMDNT3-ST1 located on the primary branch of NT-3. EMDNT3-ST2 is located just downstream of a relatively broad wet season seepage area at EMDTN3-SE1 where ground water discharges near the base of a swale draining from Pine Ridge. The baseflow average at EMDNT3-ST2 is apparently slightly more than that at EMDNT3-ST3 which is located further upstream along the primary channel of the west tributary adjacent to the EMWMF. These data provide an indication of the very low baseflow rates that occur at the site during the wet winter months. Site reconnaissance during the warm growing summer/fall seasons indicate that these stream paths hold water in puddles along the channel but that the movement of base flow water is barely perceptible.

Table 8. Flow Statistics for NT-3 Tributary Locations between Headwater Springs/seeps and SWG Locations

Weekly Surface Water Monitoring Location	Statistics	Flow (cfs)	Flow (gpm)
EMDNT3-ST1	Average	0.073	32.7
	Maximum	0.134	60.1
	Minimum	0.020	8.98
	Baseflow Average	0.056	25.0
EMDNT3-ST2	Average	0.033	14.9
	Maximum	0.054	24.2
	Minimum	0.017	7.6
	Baseflow Average	0.034	15.1
EMDNT3-ST3	Average	0.01	6.22
	Maximum	0.027	11.9
	Minimum	0.001	0.40
	Baseflow Average	0.007	3.1

Note:

Baseflow averages are based on observational monitoring data from December 17, 2014, January 21 and 29, 2015, and February 11, 2015. These four dates were selected based on the stream flow recession curves in Figure 17 as the lowest four runoff periods representative of baseflow conditions. See locations on Figure 15. At the NT3-ST2 location lower flows were measured at other times, skewing the overall average below the baseflow average – see detailed tables in Exhibit A.15 for details.

7.1.5 Surface Water Quality

Continuous monitoring of water temperature, pH, specific conductivity (SpC), and ORP at the three surface water gaging stations, along with weekly observational monitoring of these parameters at the locations described in Section 7.1.4 provide a general characterization of surface water quality at the EMDF site during the reporting period. The continuous collection (generally at a 20 min interval) of these data is potentially valuable for understanding water quality over the full range of flow conditions that may occur. During the three month reporting period, a variety of challenges including sensor malfunctions, calibration errors, cold weather impacts, and development of unrepresentative microenvironments in stagnant water surrounding sensors has limited the amount of data that is useful for site characterization purposes. Fortunately, the quasi-weekly field measurements at stream sites upstream of SWG-1 and SWG-3 are more consistent and can be used as a basis for assessing the reliability of the continuous monitoring data as accurate measures of water quality variations at the EMDF site.

In the following description, general observations on water quality variations are limited to the most reliable portions of the continuous monitoring records. Assessment of data reliability is based upon the similarity of parameter values to weekly independent field measurements and on the magnitude of unusual or unexplained variations in parameter values in relation to calibration uncertainties and the magnitude of responses to runoff events, and upon comparison among records for different parameters or sites over the same time period. Using these data quality criteria, very little of the continuous records of

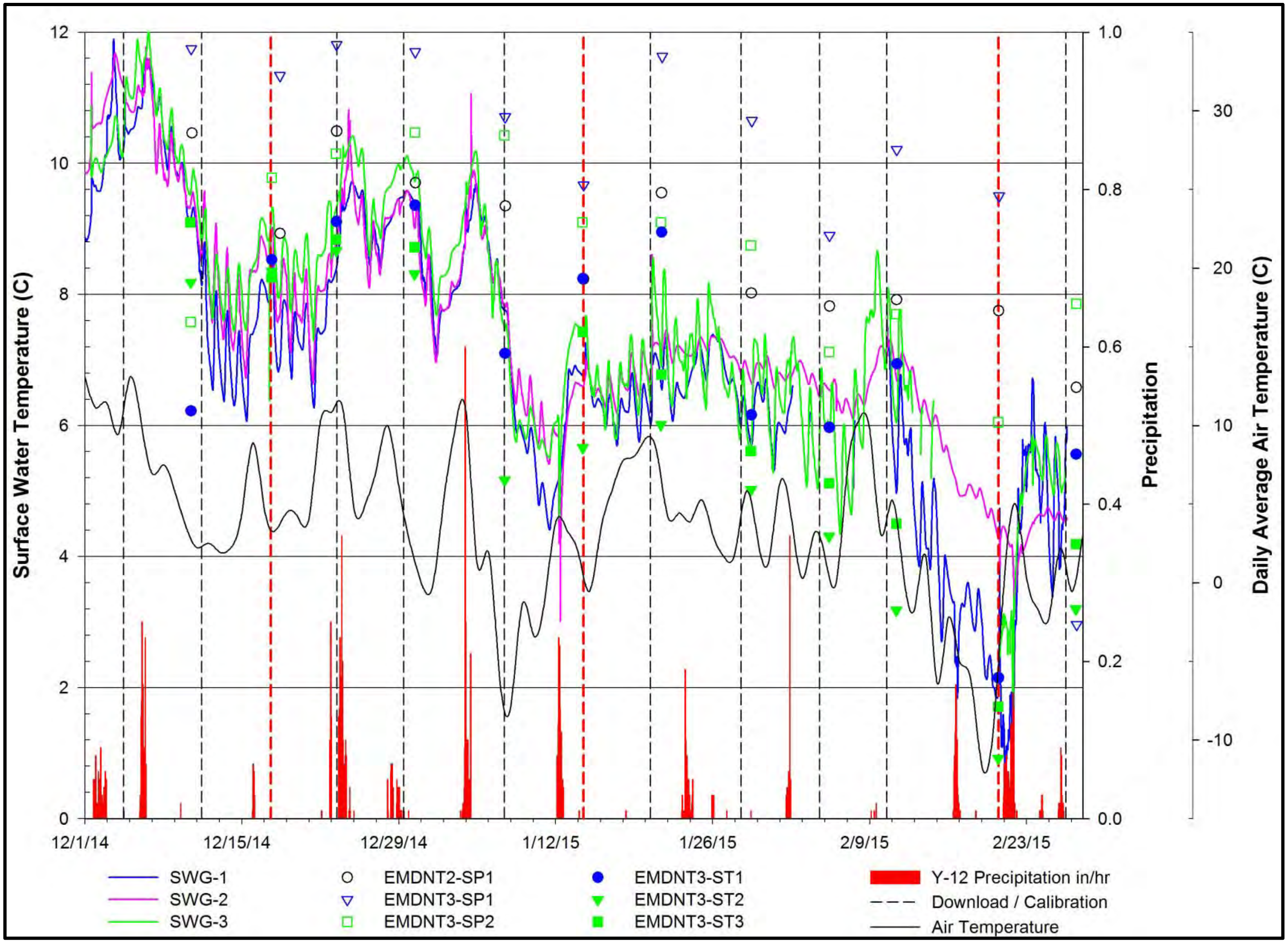
ORP were found to be acceptable, and so characterization of surface water in the following subsections is based solely upon records of water temperature, SpC, and pH. In addition, the records for the latter two parameters were not judged as sufficient for making credible estimates of mean values or observed ranges of values for comparison among surface water stations or among discrete time periods. Consequently, only some general observations about the observed ranges of SpC and pH over the reporting period are presented, along with an illustration of water quality responses to precipitation and runoff during a time period with reliable data.

7.1.5.1 Surface Water Temperatures

Over the three month reporting period, surface water temperatures closely tracked both daily and longer term variations in air temperature measured nearby (see Figure 21). The continuous temperature data appear to be reliable throughout the reporting period, and in general are close to the temperatures measured manually at the observational monitoring stream sites in the SWG-1 subcatchment (EMDNT3-ST1) and SWG -3 subcatchment (EMDNT3 -ST2, and –ST3) . Temperatures measured at the three springs (EMDNT2-SP1, EMDNT3-SP1 and -SP2) were generally higher than temperatures at the surface water stations (SWG-1, -2, and -3) by one to three degrees C (Figure 21), consistent with the difference between ground water temperatures and surface air temperatures (see Section 7.2.3.4, Figure 31, and Figure 32). Temperatures measured at the observational monitoring stream sites were occasionally lower (most commonly at EMDNT3-ST2 and –ST3) or higher (or both, e.g., Jan 14) than temperatures at the surface water stations, depending on the date and time of day of the field measurements (see Figure 21). Note that the colors for the gaging station temperature records and observational monitoring sites in Figures 21 and 22 differentiate data for the SWG-1 subcatchment (blue) and the SWG-3 subcatchment (green). These differences arise in part from daily temperature cycles (field observations were obtained over a period of a few hours during which air temperatures changed), and may also reflect differences in the accuracy of individual instruments.

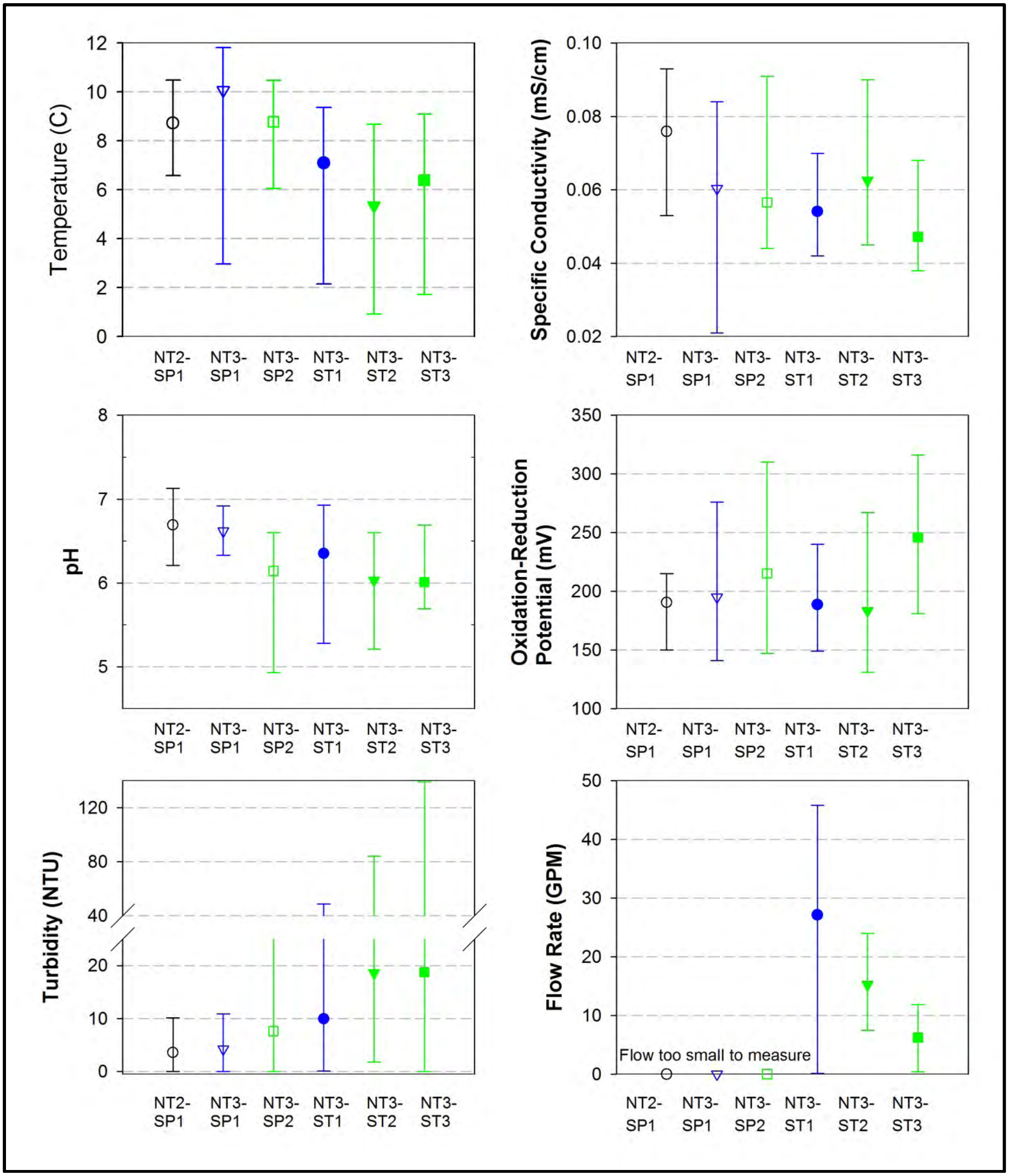
7.1.5.2 Specific Conductivity and pH

SpC recorded at the surface water gaging stations ranged from approximately 0.05–0.35 mS/cm over the reporting period. Observations at SWG-1 and SWG-3 SpC were typically in the range from 0.15–0.35 mS/cm, with SpC rapidly decreasing to lower values during runoff events. In contrast, SpC values at SWG-2 were typically less than 0.13 mS/cm, with rapid, smaller magnitude decreases during storm runoff similar to the other two surface monitoring stations. SpC values measured at the six observational monitoring sites were never greater than 0.1 mS/cm during the three month reporting period (see Figure 22). These field observations of low SpC values at all of the spring and stream sites (in contrast to consistently higher values at SWG-1 and SWG-3) could indicate significant discharge of ion-rich ground water between those locations and the surface water stations. However, given that all of the ground water monitoring wells except for GW-971(S) exhibited SpC values consistently greater than 0.1 mS/cm (see Figure 33), it is also possible that the relatively low SpC values at the observational monitoring sites reflect a persistent difference in calibration between the portable instrument used for the weekly field measurements and the SpC sensors on the multiparameter sondes at the surface water sites and ground water monitoring wells.



Weekly observational data are shown as symbols, continuous data as solid lines.

Figure 21. Phase I Surface Water Temperature Data



Symbols represent average values over the the reporting period; error bars indicate minimum and maximum observed values for each parameter.

Figure 22. Summary of Weekly Surface Water Quality Measurements Collected at the Six Observational Monitoring Sites

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Continuous records of pH logged at the three surface water gaging stations ranged between 6 and 7 for all but the early weeks of the record for SWG-1 and SWG-3, when pH values higher than 7 were recorded. Differences between pH recorded at those two stations and at the observational monitoring sites in the SWG-1 and SWG -3 subcatchments (blue and green symbols in Figure 22) were larger during these early weeks than for the remainder of the record, suggesting that some of the earlier high pH readings could be caused by calibration errors or sensor malfunctions. The pH measurements at EMDNT3-ST2 and -ST3 were nearly always lower (typically 0.5–1.5 units lower) than concurrent downstream readings at SWG-3, whereas measurements at EMDNT3-ST1 tended to be within 0.5 units of concurrent downstream pH readings at SWG-1. These apparent increases in pH along surface flow pathways correspond to similar patterns in the SpC data.

SWG-2 pH values were generally lower than for SWG-1 and SWG-3 prior to January 20. Beyond that date SWG-2 pH data are less reliable and relatively large portions of the SWG-1 and SWG-3 data are missing or bad due to instrument failure during cold weather. Variations of surface water pH during runoff events were complex and variable among the three surface water stations and among events, but do show some consistency over time and similarities to SpC variations. Figure 23 illustrates the variation in water quality parameters in response to runoff during a period of the record with reliable data for all three surface water gaging stations and includes data for three stream observational monitoring sites upstream of SWG-1 and SWG-3. Both pH and SpC at the surface water stations decrease rapidly as flow increases in response to precipitation, with the exception of SWG-2 which exhibits more complex responses that include increasing pH during some flow events prior to January 20. Decreasing SpC and pH is consistent with the arrival of relatively dilute, slightly acidic runoff at the surface water gaging stations.

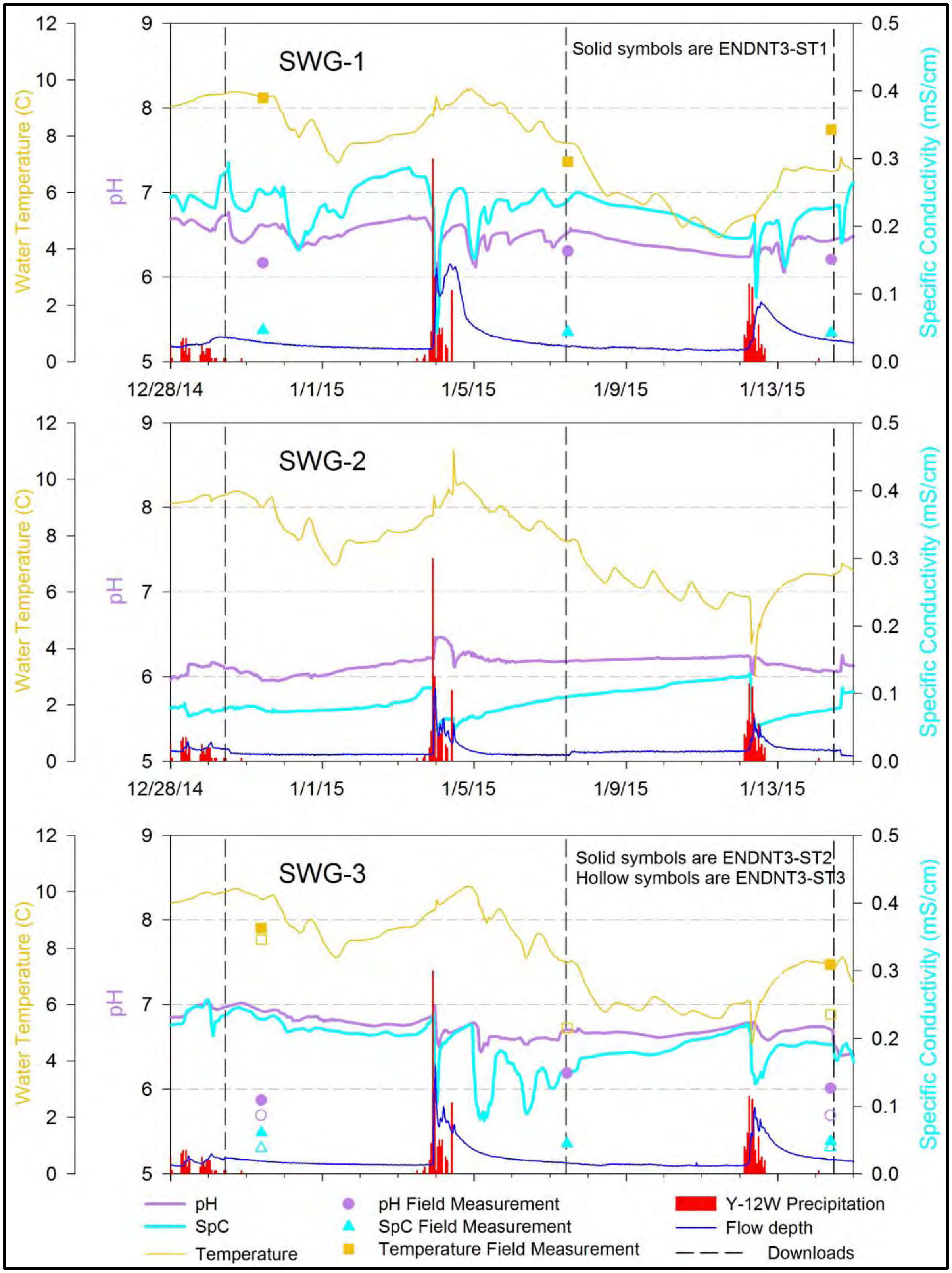
7.2 HYDROGEOLOGY

The hydrogeology of the regolith and bedrock at the EMDF are reviewed below based on the limited Phase I results. Geological characteristics (lithologic, stratigraphic, and structural features) combined with subsurface hydrology are fundamental to understanding and estimating subsurface ground water flow paths and flow rates in soils, saprolite, and bedrock. These characteristics are in turn important to risk assessment modeling used to simulate the hypothetical fate and transport of contaminants via ground water and surface water pathways and to back calculate preliminary waste acceptance criteria for the EMDF. The Phase I hydrogeological data support the conceptual engineering design for the three dimensional configuration of the proposed landfill. The Phase I results also provide a foundation for planning a more thorough Phase II investigation to fully characterize the site hydrogeology and to support a detailed engineering design.

The hydrogeology section is introduced with a review of the sequence of geologic formations and the typical vertical subsurface profiles at the EMDF and along strike elsewhere in BCV. Subsequent sections review ground water conditions for the shallow water table and intermediate ground water intervals based on Phase I data. The final sections present and interpret the hydrogeology of the regolith, followed with a review of the hydrogeology of the underlying bedrock materials.

7.2.1 Stratigraphic Section

The geologic formations underlying the EMDF site include the Lower Cambrian Rome Formation (Sandstone Member) and the lower four formations of the Middle Cambrian Conasauga Group – in ascending order, the Pumpkin Valley` Shale, the Rutledge Limestone (Friendship Formation), the Rogersville Shale, and the Maryville Limestone (Dismal Gap Formation). The outcrop belts of these sedimentary rock formations are shown on Figure 1 and their general subsurface dip toward the southeast is illustrated in cross sectional views on Plate 3. All but the Rome Formation outcrop directly below the



Symbols are water quality measurements at upstream observational monitoring locations.

Figure 23. Example of Reliable Water Quality Data at three SWG Stations

proposed EMDF footprint. The formations typically dip on the order of 45° to the southeast and trend along a strike direction that is parallel with the trend of Pine Ridge and BCV at the EMDF site (N52°E).

The five Phase I well pair locations were originally placed with one pair in each of the five outcrop belts at and near the EMDF site. However as previously noted, the upgradient well pair (GW-968[I]/GW-969[S]) originally intended to penetrate the Rome Formation atop Pine Ridge was moved downhill to a new location within the outcrop belt of the Pumpkin Valley Shale.

The Phase I investigation was not intended to gather data across the entire geologic section below the EMDF site. Missing geological sections are apparent on the cross sections shown in Plates 3 and 4. With site approval, Phase II investigations will provide additional data to close these current data gaps.

7.2.2 Typical Subsurface Hydrogeological Profile

The results from the Phase I investigation and from subsurface investigations adjacent to the EMDF site along geologic strike indicate a typical downward subsurface profile in undisturbed upland areas of the EMDF. This profile is illustrated in Figure 24 and includes: (1) a thin topsoil layer, (2) a clayey residuum interval, (3) variably weathered bedrock (saprolite), and (4) unweathered bedrock.

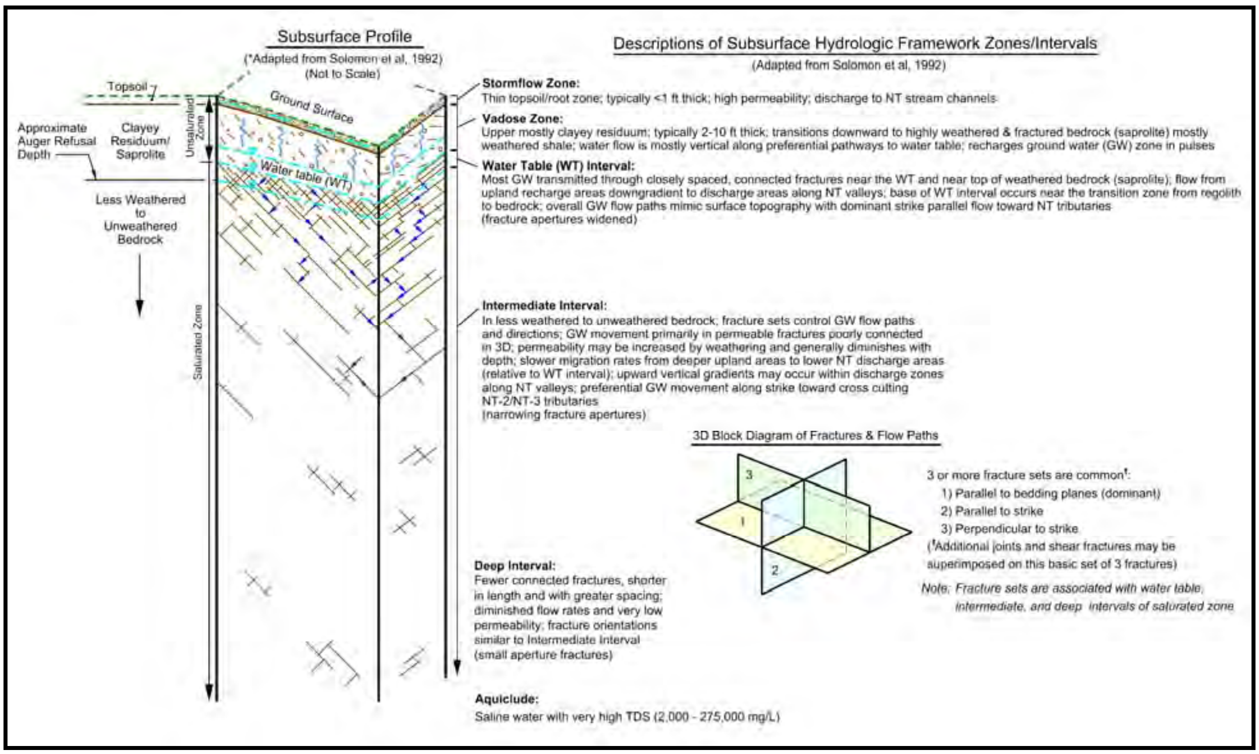


Figure 24. Typical Subsurface Profile in Relation to the Conceptual Hydrogeological Model for Upland Areas at the EMDF Site

The natural subsurface profile at the EMDF site typically consists of a thin topsoil layer or root zone of organic rich clayey soils from a few inches to <1 ft thick below the ground surface. Below this relatively more porous and permeable topsoil layer is a zone of clayey/silty residuum that typically varies from less than two to ten feet in thickness. Below this is an interval of weathered fractured sedimentary rocks (saprolite) that can generally be drilled using a HSA rig to refusal atop less weathered or unweathered fractured competent bedrock. The thickness of these intervals and downward transition from one to the next may be fairly sharp or gradual depending in part on the degree of chemical weathering and topography. The degree of weathering and fracturing generally decreases with depth with a typical equivalent decrease in effective porosity, permeability, and ground water flux.

Along the present valley floors of the NT tributaries cross cutting the EMDF footprint, the upper portion of the zone of clayey residuum may be replaced with stream channel and floodplain sediments (alluvium) that vary in width and thickness (see Figure 25). Colluvium also may occur surficially along the lower marginal slopes of these valleys. The nature and extent of alluvium and colluvium is currently undefined at the EMDF but would warrant investigation during a Phase II investigation as these deposits would be removed for placement of the proposed underdrain system and overlying geobuffer. Ancient paleo-colluvial/alluvial deposits may also occur at the site outside of the current NT stream valleys, as demonstrated by detailed soil surveys conducted for the LLWDDD in WBCV (see Figure 26; adapted from Lietzke et al, 1988). However, these loose deposits are anticipated to be relatively minor in extent and would be removed prior to landfill construction.

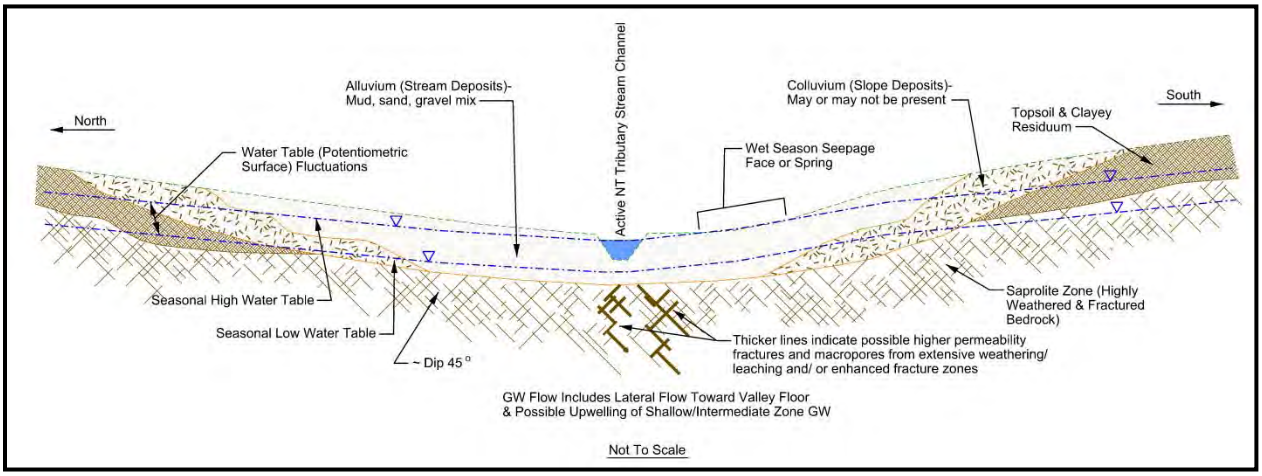


Figure 25. Typical Subsurface Profile Anticipated Across the Valley of NT-3 near the Center of the EMDF Site

The depth to ground water or vadose zone thickness within this typical vertical profile varies from upland to lowland areas. Vadose zone thickness is greatest in upland areas such as those along Pine Ridge and the spur ridge along the south side of the EMDF footprint and thins into the NT valley floors where shallow ground water is assumed to converge and seep into surface water stream channels supporting base flow along the valley floors during the wet non-growing season. Shallow ground water also discharges to springs at point locations at the base of tight headwater ravines of the NT-3 tributaries and across seepage faces along portions of the NT valleys (See Figure 15 for the locations of springs, seeps, and wetlands where shallow ground water intersects the surface at and near the EMDF site). Phase I water level data for the wet non-growing season thus far indicate that shallow ground water occurs within regolith materials above auger refusal bedrock depths at all Phase I well locations, except at GW-976(I)/GW-9777(S) where the water table is found roughly 20 ft below the bedrock/regolith interface. The Phase I data are consistent with the migration of shallow water table and intermediate level ground water migration from upland areas downgradient toward discharge zones along the NT valley floors.

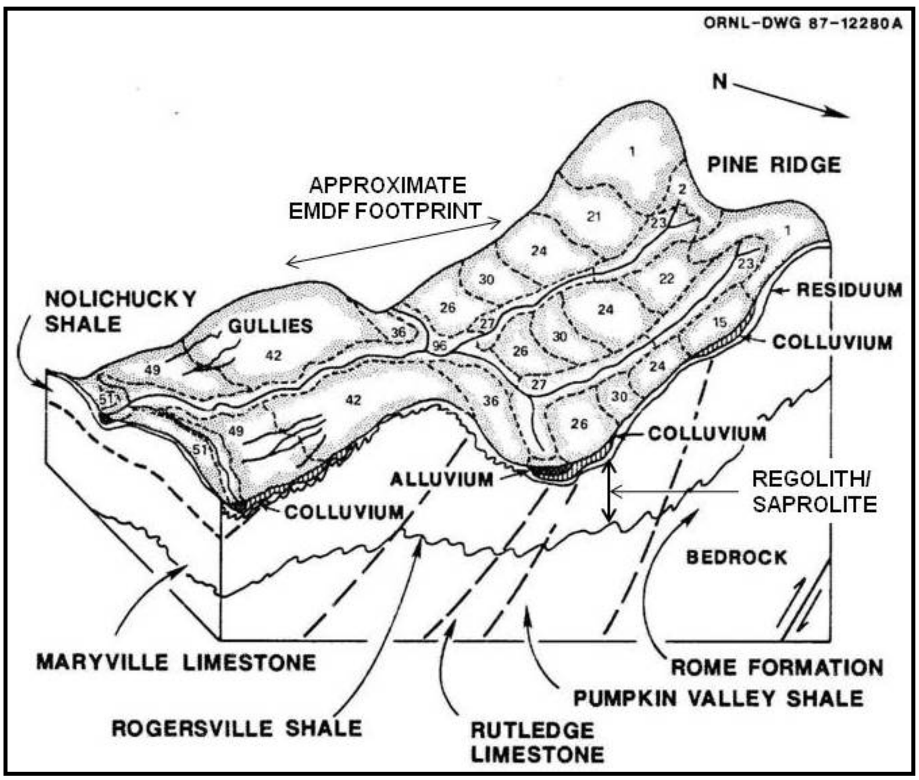


Figure 8a from Lietzke et al 1988, LLWDDD Site.

Figure 26. Diagram Illustrating Relationships between Alluvium/Colluvium, Residuum, Saprolite, Bedrock, and Topography Anticipated at the EMDF Site

7.2.3 Ground Water

Results from the drilling, testing, and monitoring of the five Phase I well pairs provide preliminary data on ground water conditions for the shallow water table and intermediate intervals at the EMDF. Results associated with ground water are reviewed in the following subsections. Water level hydrographs for the well pairs define water level depths and fluctuations in response to precipitation events. The highest water levels in the shallow wells provide benchmarks for assessing relationships between basal landfill conceptual design features and high ground water levels that occur during each wet non-growing season. Potentiometric surface contour maps for the water table interval define general flow directions and gradients across the EMDF and demonstrate convergence of shallow ground water flow from topographically high recharge areas toward discharge zones along the NT-2/NT-3 tributaries. The water table across much of the EMDF footprint during the wet winter non-growing season monitored thus far occurs within the regolith, except for the area along the south edge of the footprint where the water table occurs at lower elevations down within bedrock. The contour maps and water levels among well pairs provide data for estimating variations in horizontal and vertical gradients. Hydraulic conductivity values were determined for regolith materials based on slug tests in shallow wells and laboratory analysis of Shelby tube samples. Packer tests provide a range of hydraulic conductivity values for selected bedrock intervals. All of these results provide baseline data for further project planning and EMDF design.

7.2.3.1 Phase I Ground Water Level Data

Hydrographs illustrating fluctuations in water level elevations among the five Phase I well pairs are provided in Figures 27 and 28. The figures illustrate the initial period of continuous water level monitoring available for the Phase I report from November 21, 2014, through February 26, 2015. DOE plans to continue with continuous monitoring at least through the end of FY 2015 as long as the proposed EMDF continues to remain a viable disposal site. The hydrographs show the surveyed elevations of the ground surface at each well so that the vadose zone interval is illustrated on the hydrographs. The hydrographs include hourly precipitation data from the Y-12 west tower meteorological station. The hydrographs also show the overall range in water level fluctuations (maximum/minimum elevations) along the left margin for the period of record shown and weekly manual measurements made using an electronic water level indicator. The manual measurements allow for accurate calibration of the downhole In-situ® Troll instruments used for recording continuous water level data at hourly intervals. Where the continuous monitoring data are at odds with the manual measurements, the manual measurements (shown by black triangles in the hydrographs) should be regarded as valid, as there is virtually no potential for instrument error or instrument drift using electronic water level indicators. The high and low water level elevations, depths relative to ground surface, and range of fluctuations in each of the Phase I wells are also presented in Table 9 and illustrated on the cross sections in Plates 2 through 4.

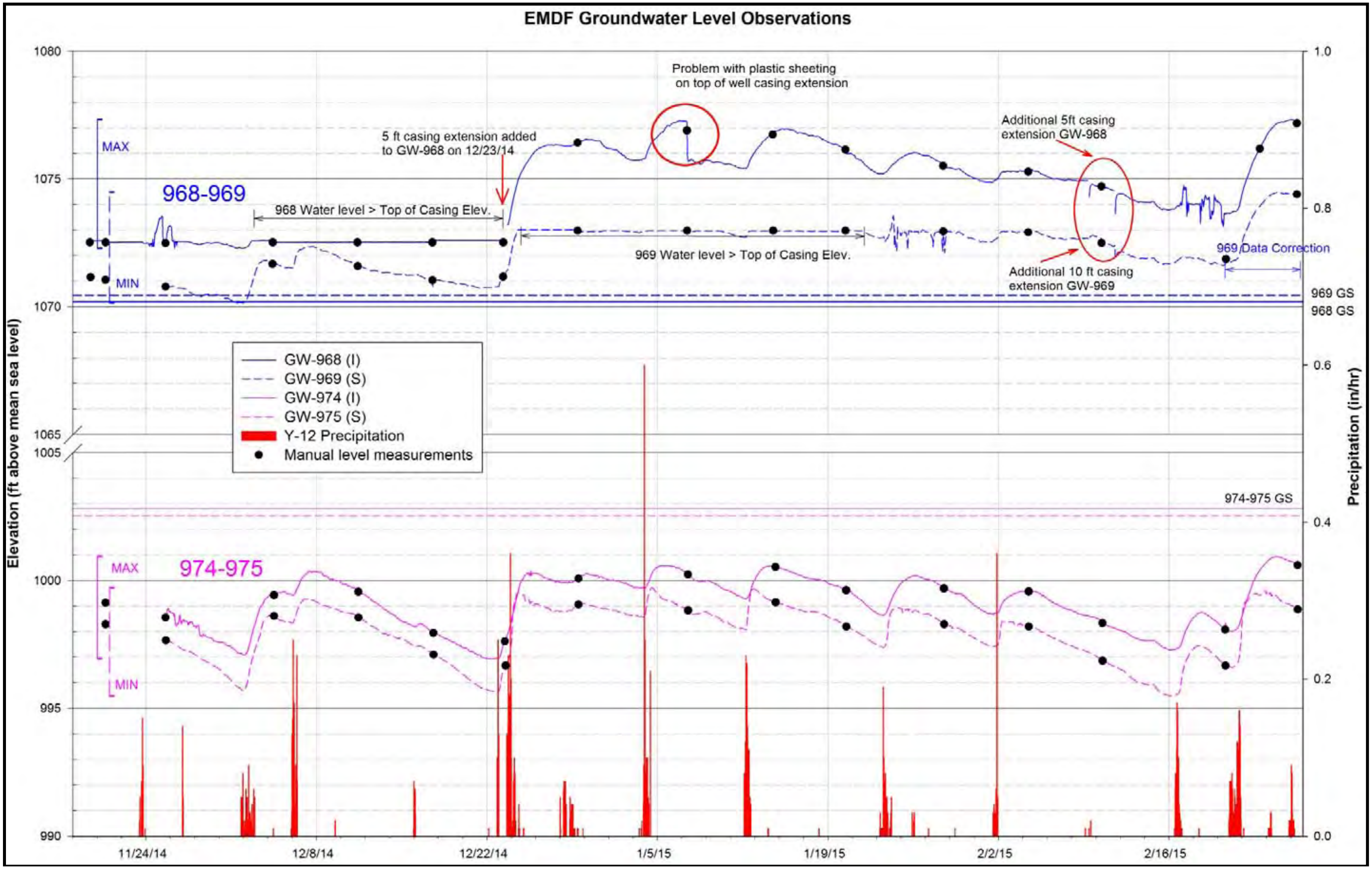


Figure 27. Water Level Hydrographs and Precipitation Data for Phase I Well Pairs

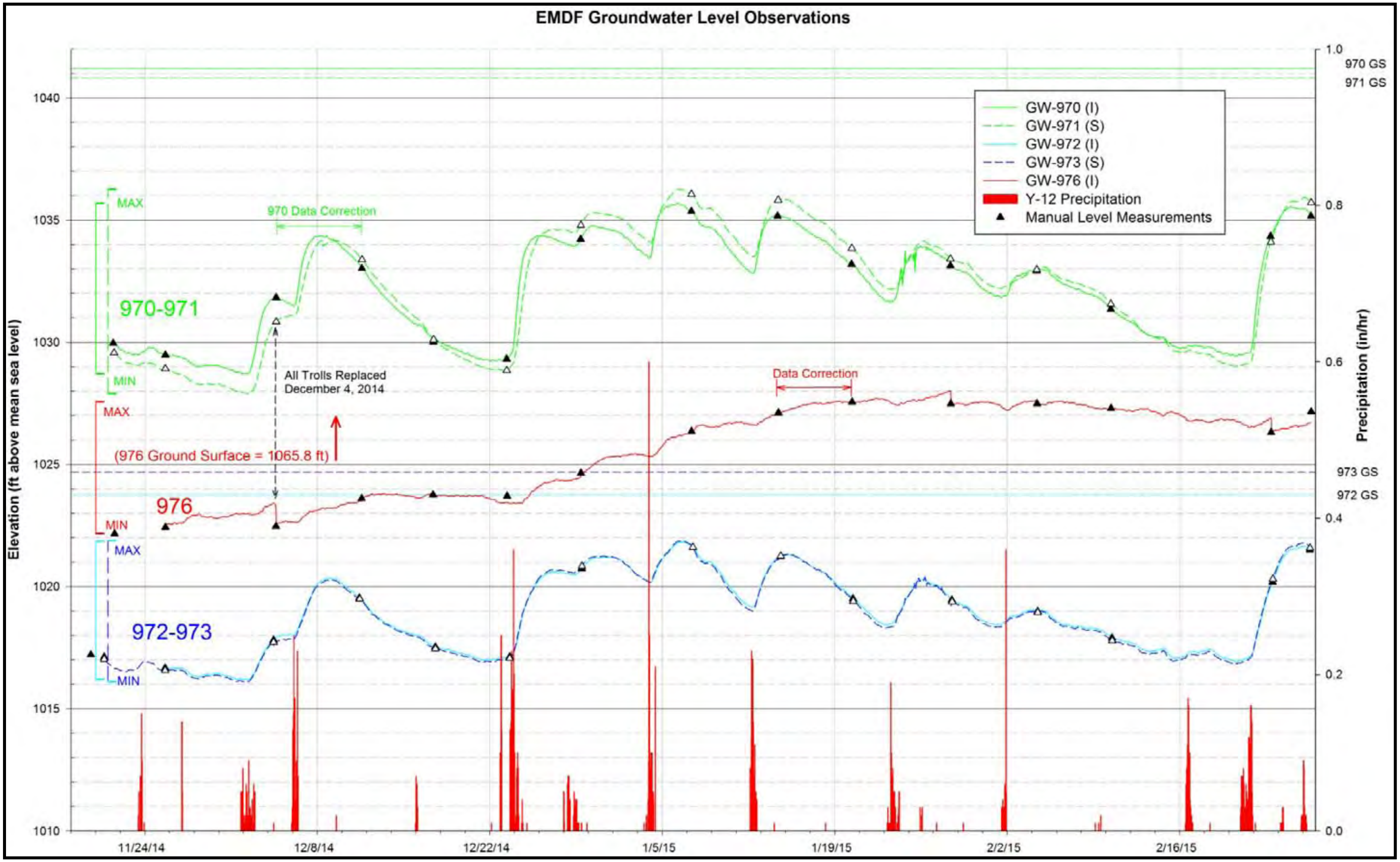


Figure 28. Water Level Hydrographs and Precipitation Data for Phase I Well Pairs

Table 9. Highest and Lowest Water Level (Potentiometric Surface) Elevations in Phase I Wells

Well	Lowest Potentiometric Surface			Highest Potentiometric Surface			
	Elevation (ft AMSL)	Date	Depth (ft bgs)	Elevation (ft AMSL)	Date	Depth (ft bgs)	High/Low Difference (ft)
GW-968(I)	1072.29	12/1/2014	-2.1	1077.33	2/26/2015	-7.1	5.0
GW-969(S)	1070.15	12/1/2014	0.3	1074.48	2/24/2015	-4.0	4.3
GW-970(I)	1028.72	12/1/2014	12.2	1035.70	1/6/2015	5.2	7.0
GW-971(S)	1027.90	12/2/2014	12.8	1036.26	1/6/2015	4.4	8.4
GW-972(I)	1016.19	12/2/2014	7.4	1021.85	1/6/2015	1.7	5.7
GW-973(S)	1016.11	12/1/2014	8.4	1021.89	1/6/2015	2.6	5.8
GW-974(I)	996.93	12/22/2014	5.9	1000.95	2/24/2015	1.9	4.0
GW-975(S)	995.49	2/16/2015	7.0	999.72	1/4/2015	2.8	4.2
GW-976(I)	1022.17	11/21/2014	43.7	1027.56	1/20/2015	38.3	5.4

Notes and Abbreviations:

- For the current three months of continuous monitoring from November 21, 2014, to February 26, 2015.
- Note that GW-976(I) high and low elevations come from manual measurements; all others were obtained from continuous monitoring data
- Data for the approximately three-month period of record available for the Phase I report comes from continuous monitoring using In-situ® Troll instruments with weekly manual calibration measurements made using an electronic water level indicator.

Ft AMSL feet above mean sea level

The close correlation between precipitation events and changes in water levels are obvious for all well pairs except for GW-976(I) where the water level response to precipitation events is much more subdued and gradual. Upward gradients are indicated in Figure 27 for the well pairs GW-968(I)/GW-969(S) and GW-974(I)/GW-975(S), both of which show consistently higher total heads (i.e., water levels) for the deeper versus shallow wells. For the GW-968(I)/GW-969(S) well pair, the water levels in GW-968(I) in early December are about 2.0 ft higher than those in GW-969(S) and about 1.7 ft higher on December 24, 2014, before the water levels in GW-969(S) exceeded the TOC elevation. In the GW-974(I)/GW-975(S) well pair, water levels in GW-974(I) generally average from around 0.5 to 1.3 ft higher than those in GW-975(S). Exceptions occur when water levels rise in both wells in response to precipitation events. During those shorter periods of rising water levels the head differences are reduced and may even be coincident or overlap for short periods where the water levels rise much faster in the shallow wells with respect to the deeper well. This appears reasonable as the shallow well screen/filter pack intervals intersect with the water table surface and would be expected to respond more directly with pulses of recharge water added to the top of the water table with rainfall/recharge events.

Water level conditions in GW-970(I)/GW-971(S) are similar to those in GW-974(I)/GW-975(S) except for a number of shifts between upward and downward gradients during December 2014 and February 2015. For the first 16 days of continuous monitoring upward gradients persist but then transition to downward gradients for about six days (between December 11 and 17, 2014) and then return again to upward gradients for about nine days (between December 17 and 26, 2014). Approximately four weeks into the monitoring period the upward gradients finally change relatively quickly again to downward gradients on December 26, 2014. Thereafter the downward gradients persist through the monitoring period, except for a period between February 14 and 24 when upward gradients resume. This period occurs toward the end of a relatively longer 16 day period of slow steady water level declines in water levels in both the shallow and deep wells. Once water levels rise sharply again around February 25, the downward gradients resume. The cause(s) for these gradient fluctuations is unclear, but the hydrographs do indicate a consistent pattern of upward gradients when the water levels are in their lowest cycles when the effects of precipitation and recharge taper off. Manual measurements using an electronic water level indicator made weekly by Alliant indicate that the continuous monitoring data are accurate and that the changes do not appear to be associated with instrument or weekly field calibration errors.

Water level elevations in GW-972(I)/GW-973(S) track very closely over time with elevation differences that typically vary less than 0.15 ft. Relative to the other Phase I well pairs these elevations appear close to identical and do not vary greatly during precipitation/recharge events or declining baseline periods as seen in the other three well pairs. Water levels across much of the monitoring period are very slightly higher in the deeper well GW-972(I) suggesting very slight upward gradients. In addition, the vertical separation between the isolation casing in GW-972(I) and the screen/filter pack interval in GW-973(S) is not extensive. The close tracking of water levels in the wells suggests that the water table interval intersected by the shallow well may be well connected to the uppermost part of GW-972(I) at and near the base of the 10 in. diameter isolation casing. In addition, the water level data suggest that the bedrock well has not intercepted fractures with high transmissivity under confined or semi-confined conditions that would exert substantial upward flow gradients (as indicated for other well pairs). The results of packer tests, borehole geophysical logs, and heat pulse flowmeter tests are also consistent with relatively low ground water flux and minimal upward gradients in GW-972(I).

The water level changes in GW-976(I) differ greatly from those at any of the other four Phase I locations. The shallow well, GW-977(S), adjacent to GW-976(I) was completed at auger refusal depth and is dry. No data are therefore available for evaluating vertical gradients by paired well water level elevation differences. However, the water table at the GW-976(I)/GW-977(S) cluster occurs within the open hole interval of GW-976(I) well below the bottom of the isolation casing placed near auger refusal. The top of the saturated zone (water table) or vadose zone thickness along the crest of the spur ridge at GW-976(I) has varied from 38.1 to 43.6 ft bgs between November 22, 2014 through January 23, 2015. This depth range is approximately 14-19 ft below the top of competent bedrock and well below the surficial regolith layers. Water levels in GW-976(I) do not show the dramatic fluctuations in water levels seen in response to precipitation events. With the exception of GW-976(I), the hydrographs in all the Phase I wells show prompt increases and steady declines in their potentiometric surfaces after precipitation events. In contrast, the hydrograph for GW-976(I) shows only very slight adjustments in water levels relative to precipitation events and a gradual increase in water level elevation over time that is not seen in other well pairs. This overall upward increase in water level is about 5.2 ft from November 22, 2014 through January 23, 2015. The relatively rapid decline in water levels following precipitation events seen in all the other Phase I wells suggests a greater rate of ground water flux, drainage, and discharge to the main NT-3 tributary valley than from the ground water mound below the boot-shaped area of the spur ridge encompassing GW-976(I). This apparent higher rate of flux may be influenced by the higher hydraulic heads below and more directly adjacent to Pine Ridge. In addition, the thicker vadose zone below the spur ridge crest may result in a slower rate of recharge to the water table in that area. Ground water fracture flow paths toward the northwest of GW-976(I) may also be more restricted in a direction opposite to the northeast-southwest geologic strike and bedding plane dip direction toward the southeast.

The Phase I data summarized in Table 10 suggest that the wet season water table surface consistently occurs several feet above the regolith/bedrock interface (i.e., above auger refusal depths) across most of the EMDF footprint. The exception occurs below the boot-shaped areas of the spur ridge that occur along the south side of the EMDF footprint, where the water table occurs well below the top of bedrock and where the vadose zone is much thicker. Except for the spur ridge areas, the overall range of these data between ground surface and 12.8 ft bgs may be typical for the wet season across most of the EMDF site when higher water levels occur.

Table 10. Relationships between Water Level Depths and Depths to the Regolith/bedrock Interface

Well	Depth to Water Table [vadose zone thickness] (ft bgs)*	Auger Refusal Depths [regolith thickness] (ft bgs)
GW-969(S)	0.3 to -4.0	13.5
GW-971(S)	4.4 to 12.8	23.8
GW-973(S)	2.6 to 8.4	23.0
GW-975(S)	2.8 to 7.0	10.0
GW-976(I)	38.1 to 43.6	24.4

Notes and Abbreviations:

- Data in this table are based on Phase I continuous water level monitoring data for the period from late November 2014 through February 26, 2015, that are probably typical for the seasonal wet period when relatively higher ground water levels occur.
- Negative value for ft bgs indicates water levels above ground surface as a result of lowering the original ground surface during site grading for access roads and drilling pads.

Ft bgs feet below ground surface

For the current three months of Phase I monitoring, differences between high and low water levels shown in Table 9 (and on Figures 27 and 28) range from 4.0 ft in GW-974(I) to 8.4 ft in GW-971(S). The lowest range of water level fluctuations occurs in the GW-974(I)/GW-975(S) cluster and the greatest range of water level fluctuations occurs in the GW-970(I)/GW-971(S) cluster. The fluctuation data from GW-968(I) and GW-969(S) were limited over certain time periods before the tops of the casings were extended upward to capture and accurately monitor continuous changes in water levels (see notations on Figure 27).

Water level hydrographs that illustrate seasonal cycles from 2000 to 2014 are available for many of the EMWMF monitoring wells and well clusters (see representative hydrographs in attached Exhibit A.18). These hydrographs show seasonal high water levels that occur consistently in the winter and early spring when recharge and runoff tend to be higher, and evapotranspiration is lowest. The Phase I hydrographs shown in Figures 27 and 28 reflect the winter quarter of these annual seasonal cycles.

7.2.3.2 Potentiometric Surface Contour Maps

Figure 29 illustrates the potentiometric surface for the water table interval at the EMDF site on December 25, 2014. This map is representative of flow directions and gradients for the uppermost water bearing zone below the EMDF site during the wet non-growing season. Control points for the contours shown on Figure 29 are based on synoptic water levels in the *shallow* Phase I wells, except for GW-976(I) where the shallow well (GW-977[S]) is dry. Control points also include nine Phase I surveyed channel bottom elevations at monitoring locations along the NT-3 stream paths. In addition to those control points, the potentiometric surface (water table) is assumed to intersect with ground surface elevations along the NT-2 and NT-3 stream paths. Figure 30 illustrates the model predicted potentiometric surface for the water table interval at the EMDF site based on post-construction steady state conditions. In comparison with Figure 29, this surface represents predicted declines in the water table surface assuming the low permeability landfill cap is in place significantly limiting recharge, the underdrain is functional, and natural recharge only occurs across a narrow swath of land along the upper south facing slopes of Pine Ridge. The most striking difference is the elimination of the existing ground water mound below the spur ridge along the south side of the EMDF footprint. But elsewhere the water table is lowered and maintained through the combined effects of limited recharge and the underdrain system.

The water level hydrographs (Figures 27 and 28) indicate that the highest water levels reached for the period of record so far occur around January 6, 2015, in most wells except for GW-976(I) where the maximum water level occurs around January 22, 2015. The water level elevations on January 6, 2015, are about 1.5–2 ft higher than those on December 25, 2014, in most wells, except at GW-976(I) where the water level difference is about 2.4 ft higher. The water level in GW-976(I) continues to climb beyond January 6 and reaches a maximum elevation on January 22 that is about 4.0 ft higher than that on December 25, 2014. These highest (and lowest) water level elevations for the Phase I period of record so far are plotted on the site cross sections of Plates 2 through 4. These north/south and east/west cross sections through the EMDF site are cut through the Phase I wells and also illustrate the potentiometric surface for December 25, 2014, which is representative of the relatively high wet season water table.

The vadose zone is believed to thin progressively toward the NT valley floors where the water table during the wet non-growing season seeps into the stream channels providing baseflow for the NT streams. The water table contour map is a subdued version of surface topography with a flattening of the water table and thickening of the vadose zone below topographically high areas such as along the crest of Pine Ridge and the spur ridge where GW-976(I) is located. However, the actual water table surface may be more uneven on a local scale than shown, as shallow ground water occurs and migrates unevenly within macropores and fractures of saprolite and weathered bedrock that are not necessarily of a uniform or even configuration. The configuration of the potentiometric surface at greater depths within the intermediate and deep intervals of the saturated zone would be increasingly less uniform and uneven, according to the complexity of deeper interconnected fractures and depending upon which fractures are penetrated in any given monitoring well.

Relatively flat wetland areas with seeps and springs have been identified along the drainage paths of the NT-2 and NT-3 tributaries crossing and adjacent to the EMDF site (see hatchured areas on Figure 29). These areas have been delineated using GPS field mapping as part of ecological/wetland surveys, and commonly occur at transitions between steeper and flatter slopes where the shallow water table intersects and discharges to the ground surface. These areas would be targeted for Phase II subsurface investigations to provide data for the proper design of the proposed underdrain system. The topographically low areas near seep locations EMDNT2-SE1, EMDNT2-SE2, and EMDNT2-SE3 along the southeast margins of the EMDF site (see locations on Figure 29) were partially excavated and reworked during the Fall of 2014 as part of the UPF haul road construction. But these areas remain as significant discharge areas for shallow/intermediate level ground water emanating from the southeast quarter of the EMDF site. These areas would also be included in future Phase II investigations to support the underdrain system design.

It is noteworthy that the three headwater springs, EMDNT2-SP1, EMDNT3-SP1, and EMDNT3-SP2, all occur consistently at elevations near the 1,050 ft surface elevation contour. These springs do not occur at or near the projected surface contact between the Rome Formation and Pumpkin Valley Shale (see locations and outcrop belts on Figure 1 and Plate 3). This suggests that the location of these springs is influenced primarily by the intersection of the water table with the ground surface within regolith soils/saprolite, and not in relation to springs or seeps that have been conjectured to occur along contacts between geologic formations.

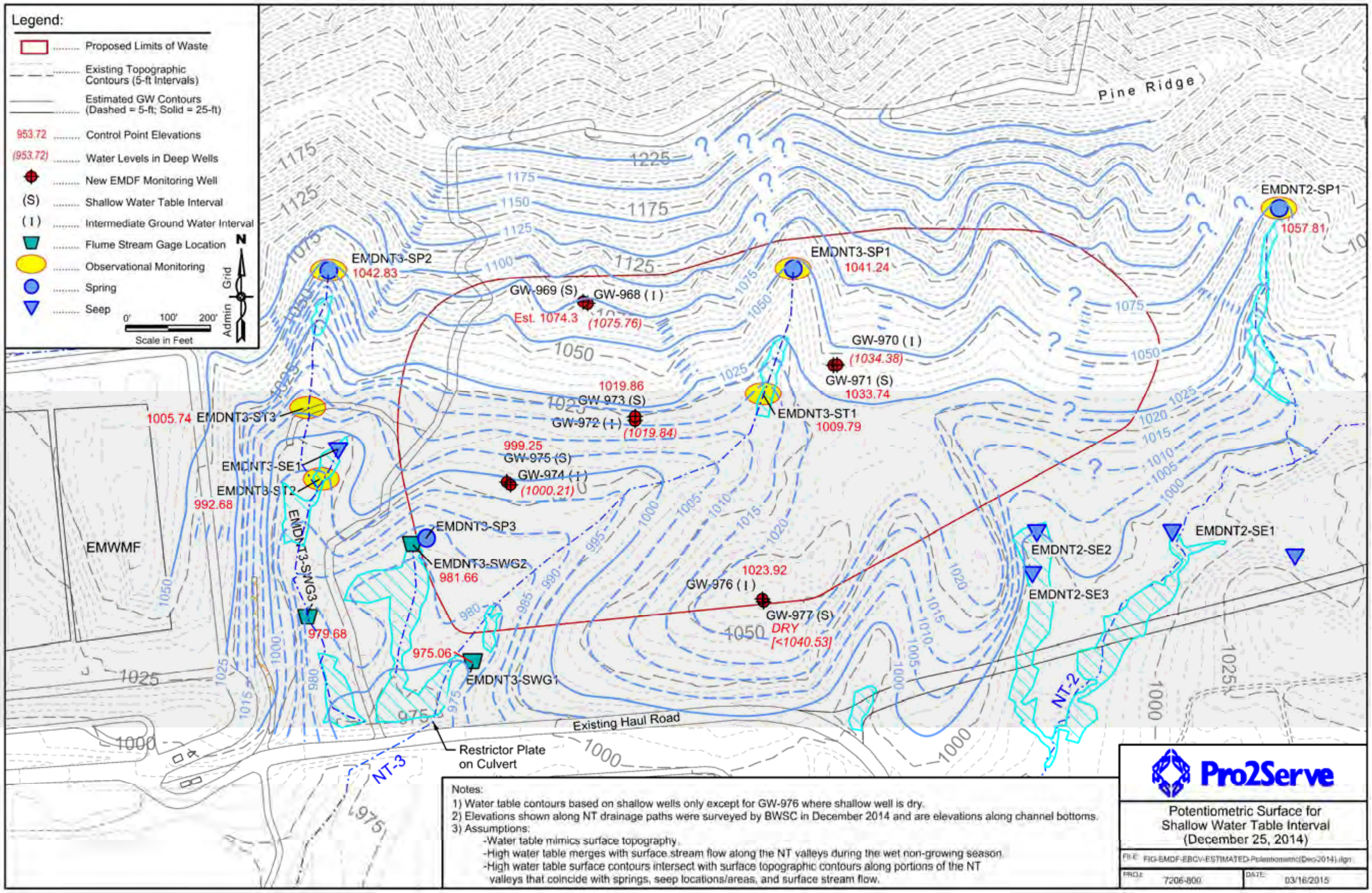


Figure 29. Contour Map of the Potentiometric Surface for the Shallow Water Table Interval – December 25, 2014

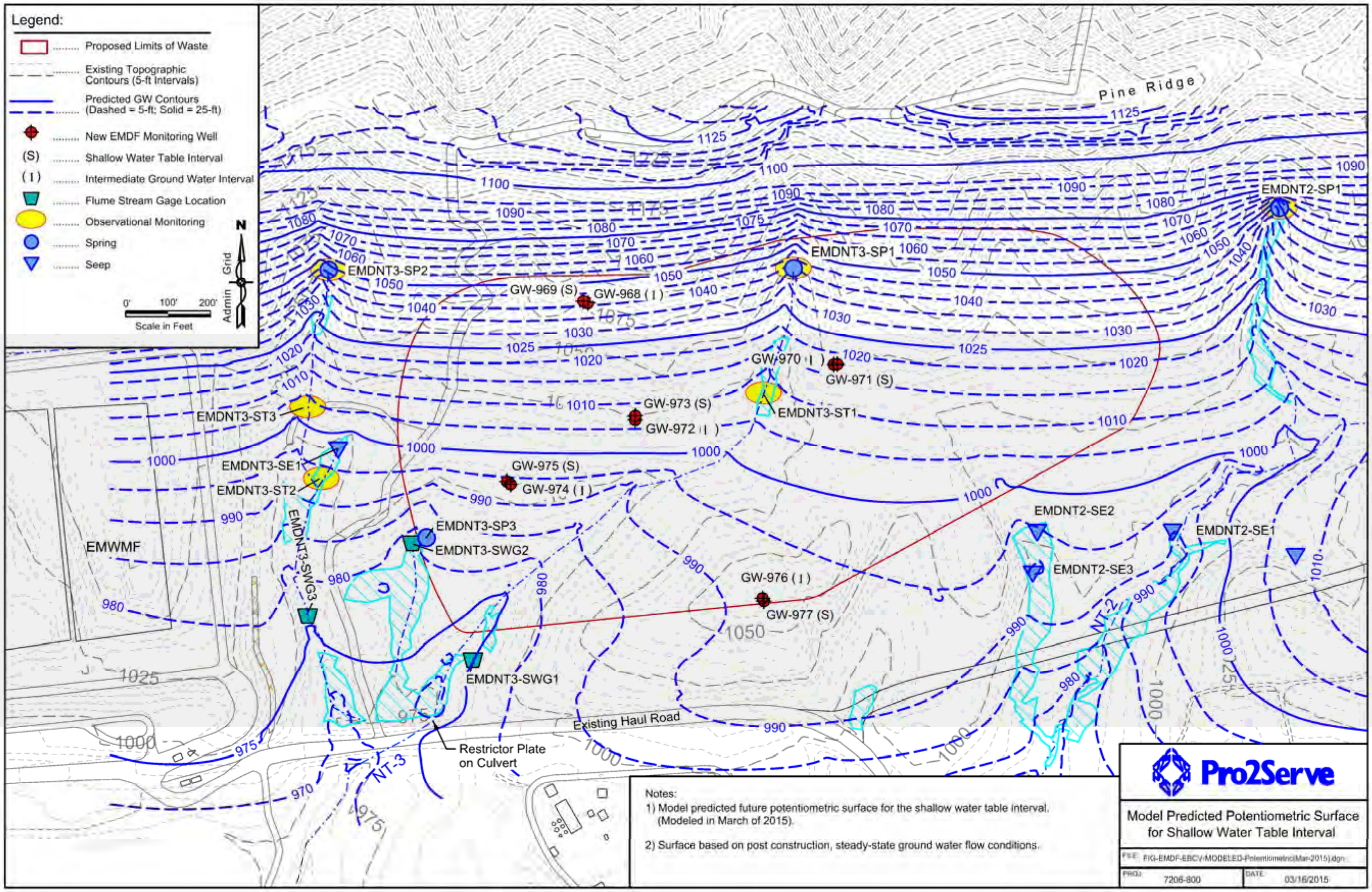


Figure 30. Contour Map of the Potentiometric Surface for the Shallow Water Table Interval – Model-predicted Post Construction Steady State Ground Water Flow Conditions

7.2.3.3 Horizontal and Vertical Ground Water Gradients

Horizontal gradients for the water table interval are illustrated in Figure 29 and easily determined by measuring the change in the equipotential contours over a given distance in a direction perpendicular to the potentiometric surface contours. Horizontal gradients for the water table interval at and near the EMDF footprint range from 0.33 to <0.05 flattening out to even lower gradients along the lowest areas of the NT valley floors just downslope of the EMDF waste limit boundary. Near the EMDF footprint, horizontal gradients are steepest in areas along the mid to lower south facing steeper slopes of Pine Ridge. The gradients lessen as the surface topography and underlying water table surface flatten out and merge with the NT valley floors. Horizontal gradients estimated in areas upgradient of GW-969(S) are on the order of 0.33. Horizontal gradients measured between GW-969(S) and GW-973(S) decrease to about 0.24; gradients between GW-973(S) and GW-975(S) are about 0.11; and gradients within an area about 200 ft south of GW-975(S) decrease to around 0.07. Gradients along the main branch of NT-3 near the center of the EMDF footprint are about 0.045. The Phase I data indicate a ground water mound below GW-976(I) along the top of the spur ridge located along the south edge of the EMDF footprint (see Figure 29). Horizontal gradients for the water table interval toward the northwest of GW-976(I) toward NT-3 are about 0.09. This mound below the spur ridge would be dewatered during landfill construction as the northern portion of the ridge would be excavated to allow for placement of the underdrain system, engineered fill, geobuffer clay, and the overlying liner/leachate system (see cross sectional view of EMDF site and conceptual design features on Plate 3).

Vertical ground water gradients shown in Table 11 were calculated based on representative synoptic water levels in the Phase I well pairs. Vertical hydraulic gradients for the four Phase I shallow/intermediate well pairs were calculated to determine the vertical direction (upward or downward) of ground water flow between the water table interval and the deeper intermediate interval. The unitless vertical gradient calculated from a shallow well to a deeper well represents the difference in hydraulic head (in ft) divided by the distance between the midpoints of the screened/filter pack intervals or open borehole for the wells (in ft). For the Phase I calculations, a positive vertical gradient value represents upward gradients and a negative value indicates downward gradients.

The water level hydrographs based on continuous water level monitoring (see Figures 27 and 28) were used to determine a representative synoptic event for calculating vertical hydraulic gradients. January 12, 2015, (at 0 hrs) was selected as a representative date for the four well pairs. This date was selected as it represents one of the few periods in the first two months of monitoring where data were simultaneously available for the GW-968(I)/GW-969(S) well pair, before the original top of casing for GW-969(S) was extended 10 ft higher on February 11, 2015, to prevent overflow of ground water and capture and continuously record water level fluctuations. This date was also selected as representative of typical periods during which water levels are in a natural period of decline between precipitation/recharge events. As shown in Figures 27 and 28, water levels and vertical gradients may change dramatically in response to rainfall/recharge events. In some cases, vertical gradients decrease significantly during periods of rapid water level rise and water level elevation differences between the well pairs may decrease or become zero for relatively short periods (see hydrographs for GW-974[I]/GW-975[S], GW-970[I]/GW-971[S], and GW-972[I]/GW-973[S]).

Table 11. Vertical Gradients and Related Data

Well ID	Surveyed Elevation Top of Ground Surface	Screened or Open Hole Interval (ft bgs)		Screen or Open Hole Length (ft)	Filter Pack Interval (ft bgs)		Filter Pack Length (ft)	Midpoint Elevation of Filter Pack or Open Hole	Difference in Midpoint Elevations	Vertical Gradient Data for 1/12/15		
		Top	Bottom		Top	Bottom				Water Level Elevation 1/12/15	Well Pair WL Difference (+ sign = upward grads)	Vertical Gradient (WL Diff/MP Elev Diff)
GW-968(I)	1070.21	12.7	82.7	70.0	9.0	92.7	83.7	1019.36		1075.42		
									41.59		2.69	0.065
GW-969(S)	1070.45	8.4	13.4	5.0	5.5	13.5	8.0	1060.95		1072.73		
GW-970(I)	1040.93	34.1	97.4	63.3	NA	NA	NA	975.18		1032.92		
									47.68		-0.71	-0.015*
GW-971(S)	1040.69	13.2	23.2	10.0	11.9	23.8	11.9	1022.865		1033.63		
GW-972(I)	1023.55	23.8	99.6	75.9	NA	NA	NA	961.88		1019.23		
									45.94		0.15	0.003
GW-973(S)	1024.46	12.9	22.9	10.0	10.3	23.0	12.7	1007.81		1019.07		
GW-974(I)	1002.80	15.0	97.9	82.9	NA	NA	NA	946.35		999.32		
									49.22		1.20	0.024
GW-975(S)	1002.52	4.9	9.9	5.0	3.9	10	6.1	995.57		998.12		

Notes and Abbreviations:

- A negative sign for the vertical gradient indicates a downward gradient, whereas positive signs indicate upward gradients between the well pairs.
- A positive upward vertical gradient of 0.76 was calculated for the GW-970(I)/GW-971(S) well pair based on representative water level elevations of 1028.86 and 1028.10, respectively, for December 1, 2014, during the first two weeks of continuous monitoring when gradients were consistently upward.

Elev elevation
Ft bgs feet below ground surface
Diff difference
MP midpoint
NA not applicable
WL water level

Upward vertical gradients have remained the most consistent for the GW-968(I)/GW-969(S) and GW-974(I)/GW-975(S) well pairs. Among the well pairs, water level differences between GW-968(I)/GW-969(S) have been the highest, with differences on the order of 2 ft or more. These differences are attributed primarily to the location of this well pair near the base of a steep ravine incised into Pine Ridge (see Figure 29). Water level differences between GW-974(I)/GW-975(S) have also been relatively high, as much as 1.3 ft during periods of baseline decline, but with sharp decreases during some precipitation/recharge events. The water level differences for the GW-970(I)/GW-971(S) well pair are unusual and difficult to interpret. Water level differences during periods of baseline decline are typically on the order of 0.5-0.7 ft, but shifts between upward and downward gradients have been recorded at various times that appear to be unrelated to precipitation/recharge events. Water levels initially recorded from late November 2014 up through December 11, 2014, were consistently higher in the deep well (GW-970[I]), but changed to downward gradients from December 11 through December 17, 2014. The water levels then transitioned back to upward gradients until a reversal of gradients again on December 26, 2014 that has remained with water level elevations in the shallow well remaining about 0.5-0.7 ft above those in the deep well (indicating downward vertical gradients). The only exceptions during the latter period have occurred during relatively short periods (roughly 24 hours or less) following rainfall events when water level elevations between the well pairs have equalized. The depth of the isolation casing within the upper part of the bedrock surface below auger refusal may have some influence on water level differences between the well pairs. The greater the depth of the isolation casing placed into bedrock, the more likely the intermediate interval is to be isolated from the shallow water table interval above bedrock auger refusal depths. The range of depths for the isolation casing are presented in Table 1. The separation between the isolation casing and auger refusal is greatest at the GW-970(I)/GW-971(S) well pair and least at the GW-972(I)/GW-973(S) well pair, where the water level elevation differences between the shallow and deep wells are also the least (typically <0.15 ft).

It should be noted that the relatively large open hole intervals in the deep wells (and large screened interval in GW-968[I]) result in a composite hydraulic head distributed across the entire interval in each of the deep wells. Individual or nested wells/piezometers with smaller screen lengths would allow for a more precise determination of the vertical distribution of hydraulic heads at these locations. The broad intervals in the deep wells add uncertainty as to whether the hydraulic heads are attributable to shallow, intermediate, or deeper fracture zones (or some combination) in the deep Phase I wells. Nested wells or piezometers could be installed in the deep open hole Phase I wells to provide more certainty on the vertical distribution of hydraulic heads at the EMDF site. These are recommended for the Phase II investigation. As noted in Section 4.1.7.2, artesian ground water conditions were encountered at GW-968(I) overflowing the top of casing early in the Phase I field program. These were followed later with casing overflow conditions in the adjacent shallow well, GW-969(S). Table 1 includes the pre-Phase I ground surface elevations estimated for these well locations. No springs, seeps, or evidence of continuous or intermittent surface water flow had been identified within the ravine area of this well cluster during previous field reconnaissance work at the EMDF site (including detailed wetland surveys involving GPS delineation of wetland areas). However, the water level monitoring data from GW-968(I)/GW-969(S) well pair suggests that shallow ground water at this location prior to the Phase I effort may have been near the ground surface during the annual wet season. While the Phase I results suggest that the seasonally high water table surface may be relatively shallow near the base of similar ravines at the EMDF site, it is important to note that the current landfill design places the base of the geologic buffer at elevations on the order of 20–30 ft or more above these areas. Each of these ravines would be backfilled with engineered fill prior to placement of the more elevated geologic buffer and overlying liner system. The distance between the waste and the original ground surface at these ravine locations would therefore be on the order of 50 ft or more at locations such as GW-968(I)/GW-969(S).

7.2.3.4 Ground Water Quality Parameter Data

Hourly monitoring of temperature, pH, SpC, and ORP collected from the nine ground water monitoring wells during the December 2014 through February 2015 period suggest some persistent differences between the shallow wells (water table interval) and the deeper wells (intermediate bedrock interval). These spatial patterns may reflect hydrogeologic conditions described below and in Sections 7.2.4 and 7.2.5.

Variations in water quality associated with changes in ground water levels in response to precipitation are also evident in the monitoring data, but patterns over time and differences among wells are more difficult to generalize because of data quality problems affecting much of the record. These problems include sensor malfunctions and calibration errors due to a variety of operational and environmental factors, and make it difficult to identify reliable portions of the record with confidence. The remainder of Section 7.2.3.4 includes additional detail on observed ground water quality variations over time and also addresses data quality concerns. The downhole depths and elevations of the sondes used for continuous water quality (YSI™) and water level (In-situ® TROLL) instruments are shown on the well logs of Plate 2 and in Table 4. The sonde depth locations within the saturated zone have some influence on the measured water quality parameters as noted in some cases below.

Differences between Shallow and Intermediate Interval Ground Water Quality:

In general, for temperature, pH, and SpC, inter-well differences are large enough relative to variations over time due to environmental changes, instrument calibration, or other causes to differentiate among wells. In contrast, for ORP inter-well differences are small relative to parameter variation over time, reflecting larger data errors and uncertainty in characterizing mean values and the range of variation for that parameter.

Ground Water Temperatures

Temperature records from the ground water monitoring wells are perhaps the most reliable data available, and reflect differences among wells as well as seasonal trends and the impact of precipitation events (see Figure 31). For each of the four well pairs for which data are available[1], the deep wells exhibit less water temperature variation than the paired shallow wells (Figure 32). The deep well ground water temperatures are generally warm relative to the paired shallow well in each case except for GW-972(I)/973(S) and, prior to December 23rd, GW-974(I)/975(S). This difference in mean temperature between deep and shallow wells is consistent with the expectation of relatively cold winter air and colder recharging ground water temperatures near the surface, and might be expected to reverse during the warm season. A similar reversal in shallow vs deep ground water temperature is apparent in the GW-974(I)/975(S) record (see Figure 31).

[1] Monitoring well GW-977(S) was dry throughout the reporting period.

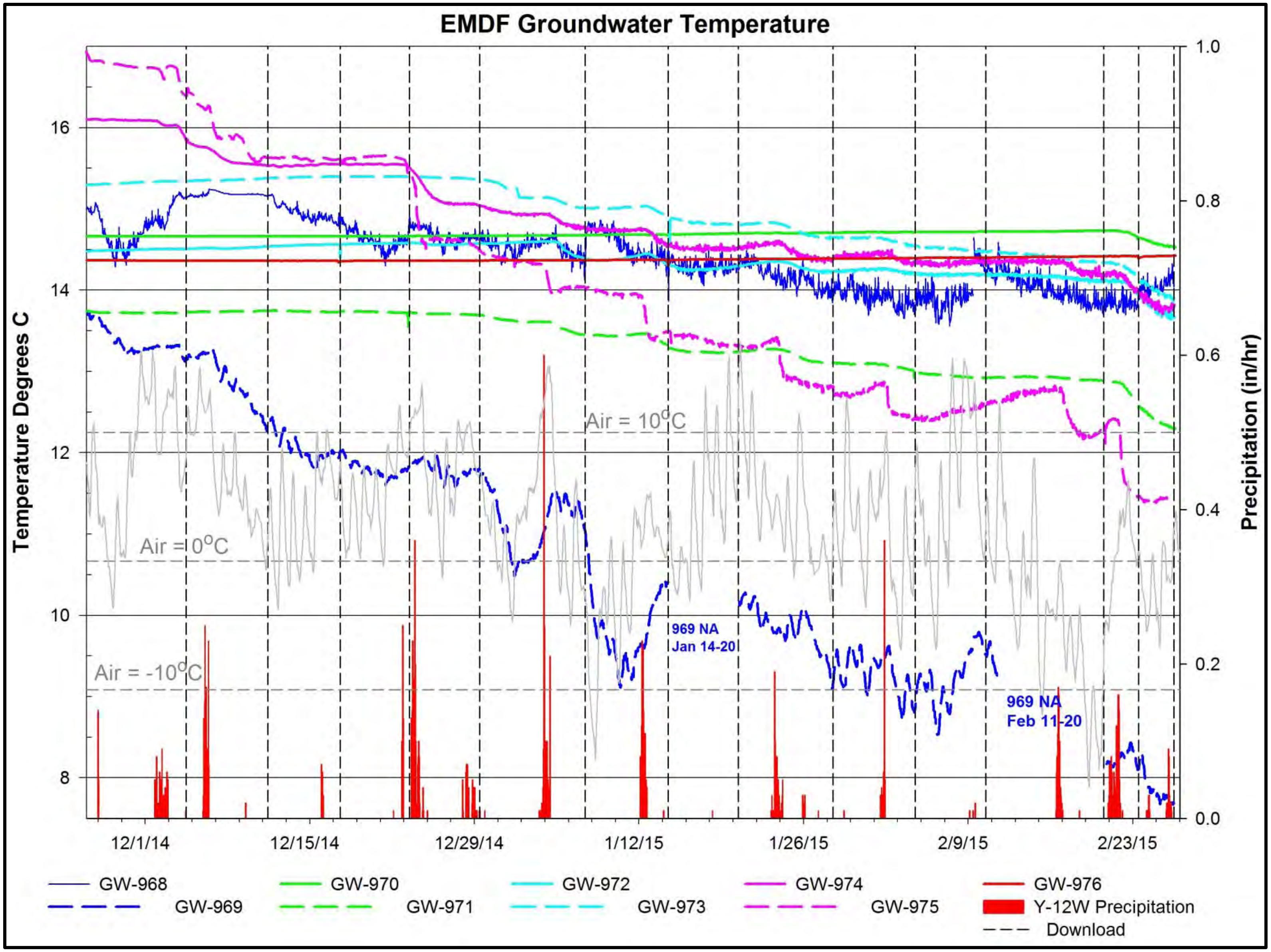


Figure 31. Ground Water Temperatures Observations during the December 2014 through February 2015 Reporting Period

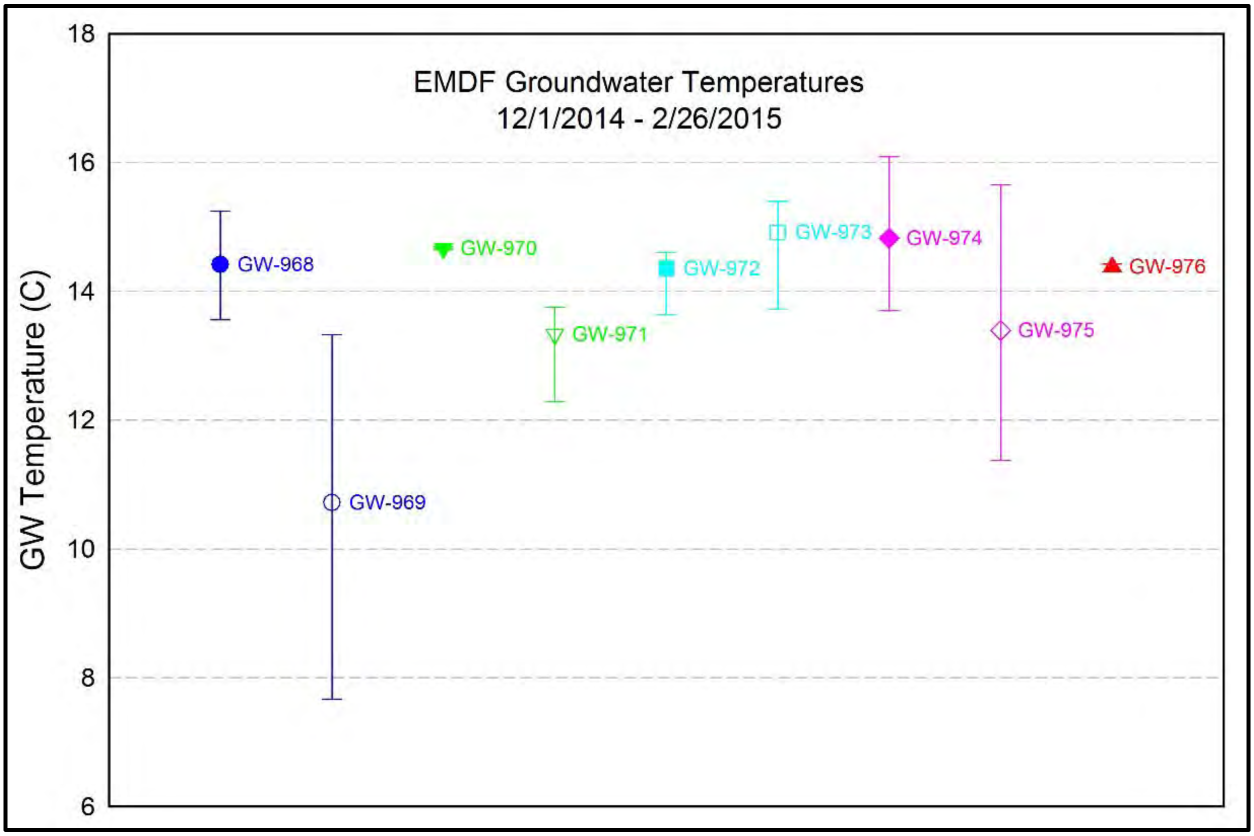


Figure 32. Average, Minimum, and Maximum Ground Water Temperatures Observed during the December 2014 through February 2015 Reporting Period

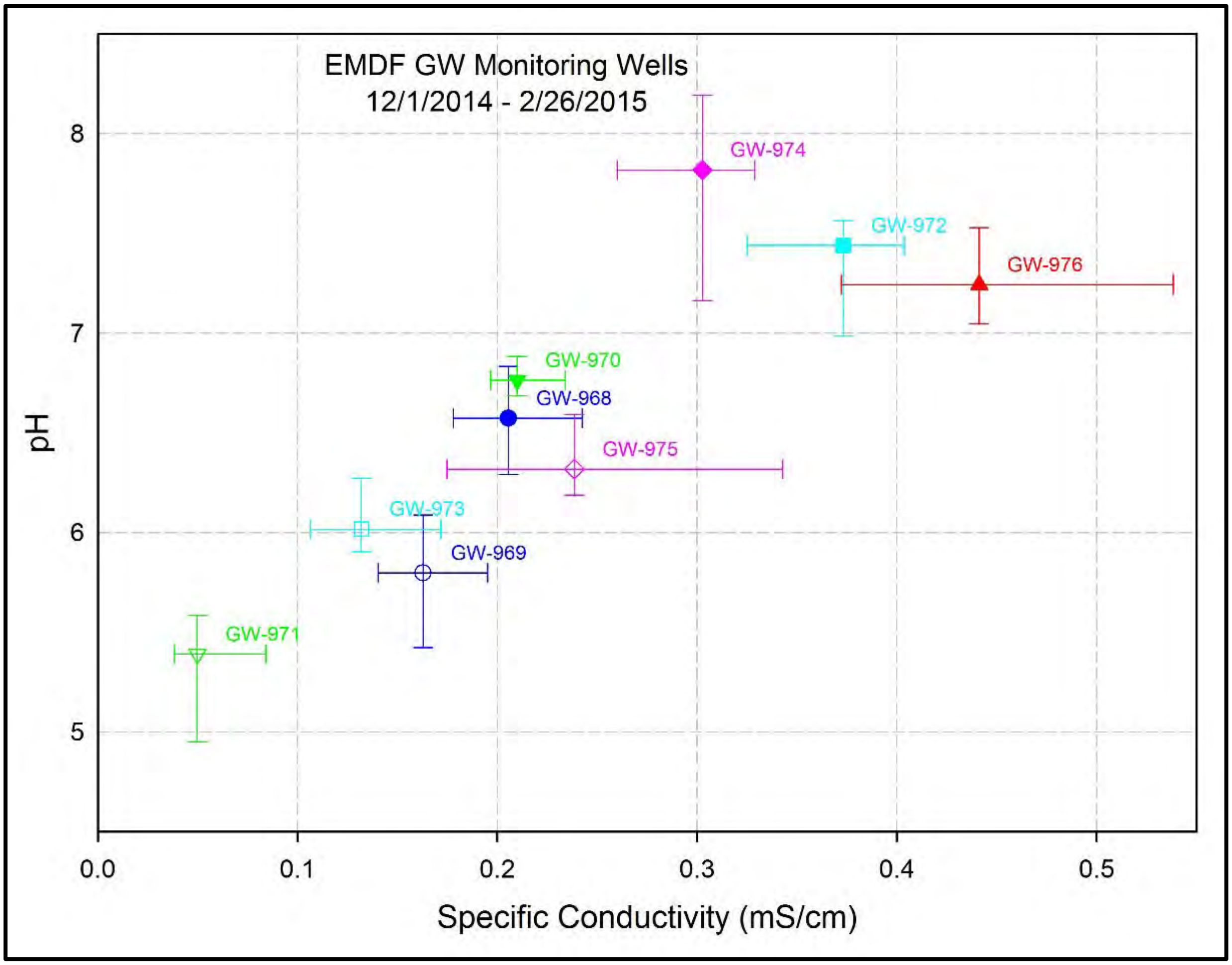
Ground water temperature declined progressively over the reporting period at all wells except for intermediate bedrock interval wells GW-970(I) and GW-976(I), which had almost no variation in temperature prior to February 20th, when the temperature in GW-970(I) began to decrease. The rate of decrease in ground water temperatures observed is not constant and clearly reflects periodic inputs of cold meteoric water. With the exceptions of GW-969(S), -970(I) and -976(I), rapid decreases in ground water temperature occur after precipitation events and these decreases account for essentiallyall of the variation in ground water temperature over the reporting period. The nearly constant temperatures at GW-976(I) and GW-970(I) suggests isolation from the effects of surface temperatures and recharge of cooler water, and for GW-970(I) could be related to upward flux of deep ground water in the well. This interpretation for GW-970(I) is supported by three heat pulse flow meter tests indicating upward vertical flow in the borehole that would keep the YSI sonde at a temperature more representative of intermediate level ground water rather than of the shallow water table interval. In addition, water temperatures recorded simultaneously by the deeper Troll sonde positioned 15 ft below the water quality sonde, are slightly higher than temperatures recorded by the YSI sonde above (see Plate 2 for the locations of the sondes and flow meter test depths and results). The relatively constant ground water temperature in GW-976(I) appears to be related to the much greater depths to ground water (vadose zone thickness) below the crest of the spur ridge, and the more gradual rates of recharge occurring there, which apparently combine to insulate and buffer colder recharge water from the deeper level of the saturated zone.

Ground water temperature decreased more quickly over the reporting period in the shallow wells than in the paired deep wells, and decreased the most from observed maximum to minimum at shallow wells GW-969(S) and -975(S) (see Figure 31). These two wells, as well as the deep well GW-968(I) show a less consistent decrease in temperature over the reporting period, including short term temperature fluctuations that appear to reflect surface air temperature changes, particularly in the shallow wells. GW-969(S) in particular may be uniquely affected by a shallow well (TD – 10 ft bgs) and high water levels (from artesian conditions) that expose the well water in the casing above ground surface to very cold winter outside air temperatures. The cause of the high frequency temperature fluctuations observed at GW-968(I) is unknown, but the pattern is present both of the independent temperature records logged by the water level (In-Situ) and water quality (YSI) instruments.

Specific Conductivity and pH

Despite some relatively large calibration uncertainties, and some SpC data that were clearly erroneous and thus eliminated from further analysis, inter-well differences in mean values of pH and SpC clearly illustrate general water quality differences between the deep and shallow wells and reflect the influence of hydrology and lithology on ground water geochemistry.

Over the three month reporting period, the four shallow (water table interval) wells exhibited lower mean SpC and pH than the five deep wells, and minimum-maximum ranges of these two parameters were similarly separated, with some degree of overlap among groups of deep and shallow monitoring wells (see Figure 33). Three deep wells GW-972(I), GW-974(I) and GW-976(I) had consistently higher ground water pH (>7.0) and SpC (>0.25 mS/cm) than the other six wells. The two remaining deep wells (GW-968[I], GW-970[I]) had somewhat lower pH and SpC values that were closer to the upper end of the range of pH and SpC observed at the four shallow wells. Shallow wells GW-969(S), GW-971(S), and GW-973(S) had consistently low pH (< 6.25) and SpC (<0.20 mS/cm), whereas observations at GW-975(S) were similar to those for deep wells GW-968(I) and-970(I). For each of the four monitoring well pairs, mean pH and SpC measured in the shallow well were lower than in the paired deep well (e.g., GW-974[I]/975[S]), with little or no overlap in the observed range of values. These distinctions in the range of observed pH and SpC among monitoring wells are fairly pronounced, even though for the deep wells much of the observed range is due to large changes in values upon instrument calibration. If these calibration uncertainties could be removed from data, the differences among groups of wells would be even more pronounced.



Horizontal (SpC) and vertical (pH) error bars indicate observed minimum and maximum values.

Figure 33. Average Ground Water pH vs SpC Values observed during the December 2014 through February 2015 Reporting Period

One basic hydrogeologic explanation for these water quality patterns is that pH and SpC in shallow ground water are strongly influenced by surface infiltration of relatively dilute, slightly acidic rainwater, whereas recharge to deeper ground water involves a longer period of geochemical evolution that is reflected in higher pH and SpC readings in the deep monitoring wells. Bedrock lithology is another factor that may affect differences among wells, in particular the observation that the two deep monitoring wells completed in the Pumpkin Valley Shale (GW-968[I] and -970[I]) have pH and SpC ranges closer to three of the four shallow wells than to the higher ranges observed at the three deep wells completed in the Rutledge Limestone (GW-972[I]), Rogersville Shale (GW-974[I]), and Maryville Limestone (GW-976[I]).

Changes in pH and SpC in response to precipitation varied among wells and among rainfall events. With the exception of GW-968(I), the deeper (intermediate bedrock interval) wells exhibited few changes in pH or SpC that were clearly linked to precipitation events, whereas monitoring wells GW-968(I), GW-969(S), and especially GW-975(S) often exhibited pronounced decreases in pH and/or SpC associated with rising ground water elevations following precipitation. Decreasing pH and SpC in response to infiltration and ground water recharge reflects the input of meteoric water that is dilute and weakly acidic relative to ground water.

Oxidation-Reduction Potential

The frequency of sensor malfunctions, extreme calibration shifts, and unexplained, rapid changes in measured values of ground water ORP precluded an effective analysis of these data similar to the observations of inter-well differences in ground water temperature, pH, and SpC and variations in those three parameters over time. In many cases it appears that continuous deployment of ORP sensors in a quasi-static ground water monitoring well environment without provision of fluid circulation via pumps or similar devices does not permit consistent collection of reliable data. If ORP data are required for future ground water characterization, alternative technical approaches for monitoring these parameters should be considered.

7.2.3.5 Phase I Hydraulic Conductivity Tests

Phase I K tests included:

- Laboratory analysis of five Shelby tube samples collected from regolith materials.
- Slug tests conducted in four shallow monitoring wells (GW-977[S] was dry).
- Nine packer tests conducted over selected 10 ft intervals of bedrock in the open deep boreholes

Results are presented in the following subsections.

Slug Test Hydraulic Conductivity Results

Table 12 summarizes the values for K based on the slug tests conducted in each of the Phase I shallow monitoring wells. The tests use pressure transducer data loggers connected to a laptop computer to continuously record the rate of recovery of water levels after a solid cylinder or "slug" is quickly introduced into or out of the water column inside the well casing. Alliant used the AQTESOLV for Windows program to plot, interpret, and solve for K. The program uses the Bouwer and Rice (1976) method for determining K. The method can be applied to unconfined, semi-confined, or confined/stratified aquifers in partially or fully penetrating wells or piezometers (Bouwer 1989). Details of the tests including plots and tables of head data versus time, and other key data are provided in Exhibit A.10. Additional information on the testing methods are reviewed above in Section 4.1.6.3.

The slug tests provide K values for the shallow water table interval based on the average permeability of the unconsolidated regolith materials over which the shallow wells are screened. The screen lengths were five or ten feet in the shallow wells depending on the depths to auger refusal and the depths to the water table (see data in Table 12). At the time of the tests, the pre-test water table at GW-969(S) and GW-973(S) was located well above the top of the screen interval. At GW-975(S), the pre-test water table was located about one foot below the top of the screen. At GW-971(S), the pre-test water table was located above the top of the screen. However, during the earliest part of the rising head test at GW-971(S), the water level fell below the top of the screen.

Falling head (slug-in) tests were conducted first in each well followed by rising head (slug-out) tests. An exception was made for GW-975(S) where only a rising head test was conducted because the pre-test SWL occurred below the top of the well screen. Errors are possible in wells where the water table falls below the top of the screened interval where "slug-in" tests force water upward and outward into the capillary fringe above the water table, or in "slug-out" tests if the water level falls below the top of the screen causing the filter pack material to drain rapidly into the well casing.

The falling head test results are presented in Table 12 for GW-969(S), GW-971(S), and GW-973(S), as these K values are assumed to be the most representative for these wells. The potential negative effects associated with more rapid drainage of the higher K filter pack material and insufficient time for the well to return to equilibrium conditions were both avoided during the initial slug-in/falling head phase of these tests. During the slug-in phase, water flow is directed into the formation which has a much lower K value than the filter pack K, which may be two or more orders of magnitude greater than the formation K. The lower K of the regolith materials therefore places a limit on the flow of water into the formation during the initial falling head (slug-in) portion of a test. During the rising head (slug-out) portion of a test faster drainage of water may initially occur from the filter pack material. In particular the rising head results in GW-971(S) were discounted because the water level fell below the top of the screen during the first half hour of the test. This would have allowed for a more rapid water level change during this early period of the test than might have occurred under totally saturated flow conditions. The data also indicate that the recovery period may have been insufficient as the water level was 1.23 ft higher at the onset of the rising head test relative to the initial depth to water.

In GW-975(S), the solid slug was placed in the well on October 28, 2014 at 4:30pm and was allowed to sit overnight until the slug-out/rising head test was conducted at 1pm on the following day. This allowed about 20 hours for the water level to equilibrate in GW-975(S) before conducting the test and provided more confidence in the test results. The plot of water level recovery for GW-975(S) shows an unusual increase in the rate of water level recovery at approximately 1.4 hours into the test (see plot in Exhibit A.10). Precipitation data from the Y-12 west tower indicate 0.67 in. of rainfall from 2–7 A.M. on October 29. The data suggest that this rainfall event may have led to an increase in the recharge rate to the water table interval during the latter 2.5 hours of the test.

The slug tests provide a general order of magnitude range for K from a low of 1.2×10^{-7} cm/sec in GW-971(S) to a high of 1.5×10^{-6} cm/sec in GW-973(S). Hydraulic conductivity is a fundamental parameter used, along with hydraulic gradient and effective porosity (equivalent to specific yield in unconfined aquifers), for estimating ground water flow rates. Given constant gradients and effective porosities, then higher k values result in higher ground water flow rates.

Slug tests conducted in EMWMF site monitoring wells during the pre-design site characterization for the EMWMF were evaluated for comparison with the EMDF results. Six of the tests were conducted in wells screened in the Maryville; the remainders were conducted in wells screened in the Nolichucky Shale. However, examination of the data plots and input parameters for the tests in the Maryville wells suggest that the results are based only on the very earliest water level recovery data within time intervals less than 4 minutes after the start of the tests. Those very early recovery data are typically excluded for determining K values. The results are therefore questionable. The only exception occurred in GW-905 were the test results were based over a period of about 7.3 hours. The K value for GW-905 was reported as 2.67×10^{-5} cm/sec. This well was presented as a “deep” well, with a total depth of 51 ft and a 10 ft screen length, and was located near the southern edge of the Maryville outcrop belt at a location along strike that would fall approximately 400 ft south of the EMDF waste limit footprint (see location on Figure 7). The Pre-Design Site Characterization Report should be reviewed for additional details (BJC, 1999).

Another source of K data along strike with the EMDF comes from investigations at the former LLWWDD site in WBCV. Hydraulic conductivity data from shallow open hole bedrock monitoring wells located at this site are presented in Exhibit A.10. The data were reported in the Performance Assessment for the Class L-II Disposal Facility (ORNL 1997 – Table E.1), based on data from Golder Associates (1988) from rising head slug tests. The K values from 14 wells tested in the Rutledge/Pumpkin Valley (1), Rogersville (3), and Maryville (10) formations span three orders of magnitude, from a low K of 4.24×10^{-6} cm/sec to a high of 3.35×10^{-4} cm/sec. The 14 wells were completed across open hole intervals from the upper portion of the bedrock. The open hole intervals are mostly on the order of 10–13 ft, except for two wells with intervals about 5 and 8 ft.

Table 12. Slug Test Hydraulic Conductivity Results and Relevant Test Data for Shallow Wells - EMDF Phase I

Monitoring Well	Geologic Formation	Hydraulic Conductivity -K (cm/sec)	Date of Slug Test	Initial Water Level Displacement (ft)	Pre-test water column in well (ft)	TOC Elevation (at time of test)	Top GS Elevation	Casing stickup (ft above GS)	Pre-test DTW (ft BTOC)	Pre-test DTW (ft bgs)	Total Depth of Well at Auger Refusal (ft bgs)	Screen Length (ft)
GW-969(S)	Cpv	7.65E-07	10/29/14	2.52 up	13.18	1072.98	1070.45	2.53	2.75	0.22	13.5	5.0
GW-971(S)	Cpv	1.22E-07	10/30/14	2.31 up	10.44	1043.11	1040.69	2.42	15.18	12.76	23.8	10.0
GW-973(S)	Crt	1.46E-06	10/28/14	2.89 up	15.35	1026.96	1024.46	2.5	10.05	7.55	23.0	10.0
GW-975(S)	Crg	3.43E-07	10/29/14	2.13 down	3.97	1005.16	1002.52	2.64	8.57	5.93	10.0	5.0
	Average - 6.72E-07											

Notes and Abbreviations:

- K values based on falling head data except for GW-975(S) which is based on rising head data.
- GW-977(S) was dry.
- 4 in. diameter casing radius = 0.167 ft; 10 in. diameter borehole radius = 0.417 ft.
- Rainfall of 0.67 in. recorded at Y-12 West Tower from 2-7am on 10/29/14.

bgs below ground surface
cm/sec centimeters per second
Cpv Pumpkin Valley Shale
Crg Rogersville Shale ft feet
Crt Rutledge Limestone (Friendship Formation)
GS ground surface
TOC top of casing

The Phase I slug test results are relatively low compared with the K values from the LLWWDD site, but the Phase I results were determined from wells completed with filter packs and screens in regolith soils and not from open hole wells completed within the upper portion of bedrock. Hydraulic conductivities typically range over several orders of magnitude on the ORR as a result of natural variations in subsurface conditions. Heterogeneities, anisotropy, and preferential pathways for ground water are associated with variations in regolith materials (residuum/alluvium/saprolite), bedrock lithologies, stratigraphic changes, and structural features (fracture density/spacing, joints, bedding planes, folds, faults, shear fractures, etc.). The Phase I slug test data is quite limited. Additional hydraulic conductivity testing is recommended for a Phase II investigation both from regolith and bedrock boreholes/wells.

<u>Shelby Tube Hydraulic Conductivity Results</u>

Laboratory test results for hydraulic conductivity from the Phase I Shelby tube samples are presented in Table 13 along with sample depth intervals and laboratory descriptions of the regolith materials. K values range from 3.9×10^{-7} to 6.5×10^{-6} cm/sec with a mean value of 3.2×10^{-6} cm/sec. Each of the tube samples were collected from saprolite, described by the laboratory as silty clay (decomposed shale or decomposed to weathered shale), typical of the highly weathered bedrock residuum present above competent bedrock. The samples from GW-973(S) and GW-977(S) were collected from the vadose zone; the other three samples were collected from within the zone of water table fluctuation of shallow ground water. No obvious correlation exists between sample depths and K values.

Bulk soil samples were collected from two test pits within the EMWMF footprint in 2000 for laboratory analysis that included K by ASTM method D5084. The samples were collected from TP-12 at a depth of 4 ft and TP-16 at a depth of 8 ft and classified as silt (ML) and clay (CH), respectively. TP-12 was located within the outcrop belt of the Rutledge Limestone, and TP-16 was located in the outcrop belt of the upper Maryville Limestone (see locations shown on Figure 7). The results of the tests, $K = 2.9\times10^{-6}$ and 1.8×10^{-7} cm/sec from TP-12 and TP-16, respectively, are within the same order of magnitude as the Phase I tests. Results of the laboratory testing of test pit samples are summarized in the tables in Exhibit A.19. The original report (CH2MHill 2000) should be referenced for additional details.

<u>Packer Test Hydraulic Conductivity Results</u>

Nine packer tests were conducted in one or more select intervals in each the five open (uncased) bedrock boreholes of the deep Phase I wells. The packer testing equipment was configured to isolate and test a ten foot interval. Depth intervals were selected based on potential fracture zones identified from the rock cores and borehole geophysical logs. Limitations on the total number of tests precluded systematic vertical profiling for K in each borehole. Only one test was conducted in GW-968(I) and GW-974(I); two tests in GW-972(I) and GW-976(I); and three tests in GW-970(I). Test intervals were selected in part to avoid depths where caliper logs indicated that the borehole wall was uneven or washed out to better ensure a good seal between the packers and the borehole walls. In some cases, shallow interval tests could not be tested because the packers could not be sealed at or near the isolation casing. A summary of the testing methodology and calculations for determining K are presented in Section 4.1.6.2. Detailed test data, spreadsheets, field forms, and results are provided in Exhibit A.9.

Table 13. Laboratory Test Results for Hydraulic Conductivity (K) from Phase I Shelby Tube Samples

Sample ID	Sample Depth Interval (ft bgs)	ASTM D 2487	ASTM D 5084
		Material description	Hydraulic Conductivity - K (cm/sec)
GW969-UD-1 (Cpv)	1.0–3.0	Clay, silty (decomposed shale), brown, mottled gray w/rock	3.89×10^{-7}
GW971-UD-1 (Cpv)	17.0–19.0	Clay, silty (decomposed shale), brown, maroon, mottled	6.36×10^{-7}
GW973-UD-1* (Crt)	2.0–4.0	Clay, silty (decomposed to weathered shale), brown, brown to brownish red	3.53×10^{-6}
GW975-UD-1 (Crg)	7.0–8.5	Clay, silty (decomposed to weathered shale), light brown, brown, mottled	6.54×10^{-6}
GW977-UD-1* (Cm)	10.0–10.66	Clay, silty (decomposed to weathered shale), light brown, brown, mottled	5.03×10^{-6}
		Mean hydraulic conductivity	3.23×10^{-6}

Notes and Abbreviations:

- Samples from GW-973(S) and GW-977(S) were collected from the vadose zone; all other samples were collected from within the zone of water table fluctuation of shallow ground water

Cm Maryville
Cpv Pumpkin Valley
Crt Rutledge
Crg Rogersville
ft bgs feet below ground surface
K hydraulic conductivity in centimeters per second (cm/sec)

Results of the Phase I packer tests are provided in Table 14. A maximum excess injection pressure was calculated for each test to ensure that water injection pressures during the tests would not overpressure and artificially enhance the natural K of the formation. Based on the maximum allowed injection pressures, no consistent flow conditions could be sustained for the two tested intervals in GW-972(I) and the single tested interval in GW-974(I). The results imply relatively low K values, but based on the limitations of the testing methodology, no K values could be calculated for these intervals. As previously noted, the in line flow meter used for the tests was incapable of accurate measurements below approximately 0.5 gpm over the typical time scale of the tests. This constraint appears to have limited the ability of the packer tests to measure order of magnitude K values at and below rates of 10^{-6} centimeters per second (cm/sec). Solomon et al (1992, pp. 3–25) reported a geometric mean K of 2.1×10^{-6} cm/sec (standard deviation of 2.9) from 13 packer tests of three wells in east BCV. The wells were completed in the intermediate ground water level within Conasauga Group formations. GW-972(I) and GW-974(I) are located in the outcrop belt of the Rutledge Limestone (Friendship Formation) and Rogersville Shale formations, respectively, both in the Conasauga (individual formations and test depth intervals were not provided). More sensitive packer tests or other downhole methods capable of determining very low K values on the order of 10^{-6} to 10^{-8} cm/sec are recommended for a Phase II investigation to develop vertical profiles of K for the open hole intervals of the Phase I intermediate level wells.

Elsewhere, K values were all in the range of 10^{-5} cm/sec, except for the shallowest interval in GW-970(I) where the K values were an order of magnitude higher, in the 10^{-4} cm/sec range. The three K values in GW-970(I) and two in GW-976(I) show progressive decreases in K with depth suggesting a general trend toward lower permeability with depth. The highest K values come from the shallowest interval of 44–54 ft bgs in GW-970(I). These results are consistent with the highest upward flow rates from the heat pulse flowmeter tests at 45 and 50 ft bgs (0.062 gpm and 0.039 gpm, respectively), and fluid resistivity log data in GW-970(I). The combined results suggest relatively high K in fractured bedrock near the uppermost bedrock interval in GW-970(I).

7.2.3.6 Phase I Heat Pulse Flowmeter Tests

Heat pulse flowmeter tests were conducted as part of the suite of borehole geophysical logs conducted in each of the Phase I open bedrock boreholes. The results are reviewed here as they are related to K and indicate potential fracture flow within the saturated zone of bedrock. The flowmeter testing equipment and test methodology are summarized in Section 4.1.6.1 above and in Exhibit A.8. Test results are summarized in Table 15. The results are also presented on the combination logs in Exhibit A.8 with results in gpm posted next to each test depth.

The flowmeter is capable of detecting ground water flow either vertically upward or downward within the borehole at discrete depths, but only upward flows were detected in the Phase I flowmeter tests. The flowmeter results in combination with the continuous water level monitoring data suggest that vertical gradients among the Phase I well pairs are mostly upward. An exception may occur for GW-976(I) where results are less certain as the shallow well pair (GW-977[S]) was dry and upward flows were not detected among the flowmeter data until depths of 75 and 80.5 ft bgs (see Table 15).

The lowest quantifiable flow rate for the heat pulse instrument is 0.03 gpm (equal to 1.8 gallons per hour [gph] or 43 gallons per day [gpd]), although rates less than this value were plotted on the borehole geophysical logs where multiple tests showed repeatability in two or more tests. As shown in Table 15, the lowest quantifiable flow rate of 0.03 gpm was rarely exceeded during the borehole flowmeter testing. Only four of the 39 borehole flow meter tests (10%) resulted in flow rates >0.03 gpm, 25 of the tests had zero flow, and the remaining 10 tests were all between 0.010 and 0.026 gpm. Flow rates >0.030 gpm occurred only in GW-970(I) at depths of 45, 50, and 57 ft bgs, and in GW-976(I) at a depth of 75 ft bgs. Plate 2 (attached) presents these results in vertical profiles that also illustrate the collective Phase I results from packer tests and potential fracture flow zones identified in rock cores (along with other Phase I results such as K values from slug tests, and shelby tube testing. The flowmeter tests in GW-972(I) and GW-974(I) suggest very low flow conditions over much of the open borehole. However, it should be noted that very low flow conditions on the order of rates <0.01 gpm from multiple fractures could collectively result in significant ground water flux and upward gradients when measured over a relatively large open hole interval of 100 ft or more.

7.2.4 Regolith Hydrogeology at the EMDF Site

The regolith includes all unconsolidated materials that overly competent bedrock. Depending on site topography and local conditions, the regolith at the EMDF site may include surficial soils and clayey residuum, colluvium and alluvium along flanks and floors of the NT tributary valleys, and underlying saprolite. For practical purposes, the depth of the regolith may be considered as auger refusal drilling depth. Subsurface geotechnical sampling and engineering test data are focused largely on regolith materials. Sections 7.2.4.1 and 7.2.4.2 review the results of geotechnical sampling and laboratory testing of regolith soils and saprolite from the geologic formations underlying the EMDF site.

Table 16 summarizes regolith materials and thicknesses based on the Phase I borings. Exhibits A.4 and A.5 (attached) include detailed boring log descriptions and split tube photographs of regolith materials. Vertical profiles of regolith materials are illustrated in the cross sections of Plates 2 through 4 for the Phase I borings. Because of the close proximity of the well pairs, the regolith profile was only logged during drilling of the original deep borehole and not repeated during the drilling of the shallow well pair.

Table 14. Hydraulic Conductivity Data from Packer Tests

Open Bedrock Borehole (8 in. diameter)	Test Interval (ft)	Pressure (psi) with Range in Brackets	Hydraulic Conductivity – K For each Pressure Test (cm/sec)	Average Hydraulic Conductivity – K For each Tested Interval (cm/sec)
GW-968	23-33	15	3.12E-05	3.1E-05
GW-970	44-54	15 [15-16]	1.70E-04	1.5E-04
		30	1.34E-04	
	52-62	15 [15-16]	3.17E-05	3.1E-05
		30 [29-30]	2.94E-05	
	65-75	15	1.59E-05	1.4E-05
		30	1.36E-05	
		45	1.35E-05	
GW-972	65-75	15 [14-18]	No or limited/erratic flow K indeterminate	K indeterminate
		30 [30-35]	No or limited/erratic flow K indeterminate	
		45	No or limited/erratic flow K indeterminate	
	75-85	15	No or limited/erratic flow K indeterminate	K indeterminate
		45	No or limited/erratic flow K indeterminate	
GW-974	33-43	15	No or limited/erratic flow K indeterminate	K indeterminate
		30	No or limited/erratic flow K indeterminate	
		45	No or limited/erratic flow K indeterminate	
GW-976	49.5-59.5	15	4.99E-05	5.6E-05
		30 [26-29]	5.75E-05	
		45 [40-41]	5.93E-05	
	68-78	15	No consistent flow K indeterminate	K indeterminate
		30	1.21E-05	1.2E-05
		45	1.16E-05	

Table 15. Summary of Heat Pulse Flowmeter Tests

	GW-968(I) - Heat Pulse Flowmeter Tests				GW-970(I) - Heat Pulse Flowmeter Tests				GW-972(I) - Heat Pulse Flowmeter Tests				GW-974(I) - Heat Pulse Flowmeter Tests				GW-976(I) - Heat Pulse Flowmeter Tests			
	Depth	Flow	Flow	Flow	Depth	Flow	Flow	Flow	Depth	Flow	Flow	Flow	Depth	Flow	Flow	Flow	Depth	Flow	Flow	Flow
Tests	(ft)	(gpm)	(gph)	(gpd)	(ft)	(gpm)	(gph)	(gpd)	(ft)	(gpm)	(gph)	(gpd)	(ft)	(gpm)	(gph)	(gpd)	(ft)	(gpm)	(gph)	(gpd)
1	12	0.020	1.18	28.2	***45***	***0.062***	***3.74***	***89.7***	26	0	0.00	0.0	20	0	0.00	0.0	50	0	0.00	0.0
2	17	0.022	1.33	32.0	***50***	***0.039***	***2.34***	***56.2***	30	0	0.00	0.0	26	0	0.00	0.0	62.5	0	0.00	0.0
3	25	0	0	0	***57***	***0.031***	***1.87***	***44.9***	40	0	0.00	0.0	35	0.016	0.94	22.6	67	0	0.00	0.0
4	26	0.015	0.91	21.8	70	0.017	1.00	24.0	45	0	0.00	0.0	40	0	0.00	0.0	***75***	***0.034***	***2.02***	***48.6***
5	27	0.019	1.16	27.9	77	0	0.00	0.0	51	0	0.00	0.0	46.5	0	0.00	0.0	80.5	0.022	1.35	32.3
6	35	0	0	0	90	0	0.00	0.0	61.5	0	0.00	0.0	50	0	0.00	0.0	88.5	0	0.00	0.0
7	38	0	0	0					70	0.026	1.55	37.1	64	0	0.00	0.0	93	0	0.00	0.0
8	42	0.018	1.07	25.6					76	0	0.00	0.0								
9	50	0	0	0																
10	68	0.016	0.98	23.4																
11	71	0	0	0																

Notes and Abbreviations:

- All flows were in a vertically upward direction.
- Values in ***bold italics*** exceed the minimum quantifiable flow rate for the heat pulse flowmeter instrument of 0.030 gpm. Values below this level are considered suspect, but were provided where test results showed repeatability in two or more heat pulse tests.

ft feet
gpd gallons per day
gph gallons per hour
gpm gallons per minute

Table 16. Summary of EMDF Regolith Materials Based on Phase I Results

Well ID	Estimated Topsoil Removed for Road Construction	Regolith Soil/Saprolite Thicknesses (ft)	Soil/Saprolite Split-tube & Shelby Tube Descriptions	Depth Increasing Soil Consistency (Based on SPT N Values (blows/ft)
GW-968(I)	7.19	9.8	clayey or sandy SILT (ML) w/ weathered bedrock fragments (saprolite)	very stiff to hard
		0.2	weathered sandstone & siltstone	hard
		10.0	Total Regolith Thickness (GW-968)	
GW-969(S)	4.65	13.5	Not logged - shelby tube 1.0-3.0 ft bgs - silty clay (decomposed shale)	NA
GW-970(I)	4.37	25.6	clayey or sandy SILT (ML) w/ weathered bedrock fragments (saprolite)	stiff to very stiff to hard
		25.6	Total Regolith Thickness (GW-970)	
GW-971(S)	4.31	23.8	Not logged - shelby tube 17.0-19.0 ft bgs - silty clay (decomposed shale)	
GW-972(I)	-1.15	23.5	SILT (ML), and clayey SILT (ML) w/ weathered bedrock fragments (saprolite)	medium stiff to very stiff to hard
		0.7	Weathered shale	hard
		24.2	Total Regolith Thickness (GW-972)	
GW-973(S)	0.54	23.0	Not logged - shelby tube 2.0-4.0 ft bgs - silty clay (decomposed to weathered shale)	
GW-974(I)	0.3	10.7	clayey SILT (ML) w/ weathered bedrock fragments (saprolite)	stiff to hard
		1.8	Weathered bedrock (assumed)	hard
		12.5	Total Regolith Thickness (GW-974)	
GW-975(S)	0.78	10.0	Not logged - shelby tube 7.0-8.5 ft bgs - silty clay (decomposed to weathered shale)	
GW-976(I)	1.66	7.0	clayey SILT (ML)	very stiff to hard
		17.0	clayey SILT (ML) w/ weathered bedrock fragments (saprolite)	hard
		0.4	weathered siltstone (saprolite)	hard
		24.4	Total Regolith Thickness (GW-976)	
GW-977(S)	1.87	25.1	Not logged - shelby tube 10.0-10.66 ft bgs - silty clay (decomposed to weathered shale)	

Notes and Abbreviations:

- N values based on blow counts per ASTM Method D1586 for cohesive soils; see boring logs in attached Exhibit A.4.

ft bgs feet below ground surface
SPT standard penetration test

The thickness of the regolith (i.e., depth to auger refusal) at the five Phase I well pair locations varies from 10.0 ft at GW-968(I) to 25.6 ft at GW-970(I) (see Table 16). The Phase I well pairs are located approximately 10-15 ft from each other with variations in depth to auger refusal between the well pairs ranging from 0.7 to 3.5 ft. Water level data from the Phase I monitoring wells thus far indicates that the water table occurs well up within the regolith above the top of bedrock (i.e, above auger refusal depths) across most of the EMDF footprint. The exception occurs at GW-976(I) along the spur ridge on the south side of the EMDF footprint, where the water table occurs down 20 ft or more below the top of bedrock, located at auger refusal depths of 24–25 ft bgs. The current water level data reflect the seasonally wet non-growing season when water levels are at their highest. Water level data monitoring on the ORR clearly indicates that water levels decline seasonally with the warmer growing season and depending upon topographic location may fall to levels at or below the regolith/bedrock interface.

Topsoils and a portion of the underlying clayey residuum were removed during the construction of the drilling pads and access roads. The original ground surface was not accurately surveyed prior to construction of the drilling pads so the exact vertical extent of the removal is unknown. However, removal estimates shown in Tables 1 and 16 were made by subtracting the Phase I surveyed ground surface elevations from surface elevations determined from the existing site topographical maps (displayed at 5 ft contour intervals on current site drawings). Estimated topsoil removed for road/drill pad construction are shown in Table 16 and vary from 7.2 ft at GW-968(I) to -1.2 ft at GW-972(I), where the minus sign indicates fill was apparently added to the original undisturbed location.

Because of the site grading and road construction, the Phase I boring logs do not indicate any topsoil or alluvium/colluvium at any location. Except for the GW-968(I)/969(S) location, the Phase I borings were all drilled in upland areas of the site unlikely to encounter any Recent alluvial or colluvial deposits. Any original alluvial/colluvial deposits that may have existed at the undisturbed pre-Phase I GW-968(I)/969(S) location would have been removed and locally reworked during access road and drill pad construction. While not an objective of the Phase I fieldwork, characterization of alluvium and colluvium along the NT tributary valley floors and flanks would be specifically addressed during Phase II site investigations to provide data necessary to properly design the proposed underdrain network.

Except for the upper 6–7 ft of soils at GW-976(I), the split tube samples collected at all other Phase I drilling locations were consistently logged as silt with some portion of weathered bedrock fragments. The logged regolith soils were predominantly saprolitic soils without a surficial zone of clayey/silty residuum. Most of the silty soils were logged as clayey or sandy silt. The upper 6–7 ft of soils at GW-976(I) were logged only as clayey silt and did not include weathered bedrock fragments suggesting a thicker zone of near surface silt/clay residuum there. The lower part of GW-976(I) was logged as clayey silt with weathered rock fragments, similar to the typical saprolite zone seen elsewhere at the site.

Sandy and clayey silt was logged in the regolith soils at the two locations in the Pumpkin Valley Shale (GW-968[I] and GW-970[I]). Elsewhere the logged soils did not include a sandy component. The weathered rock fragments logged in most split tube samples indicate the predominance of variably weathered saprolite soils within the regolith profile. This is consistent with field observations of shallow saprolite across the EMDF site. Cuts from access roads and exposures of large root balls from blown down trees across much of the site consistently reveal saprolite with relict bedding and highly weathered rock fragments within a few feet of the original ground surface.

The Phase I results are reasonably consistent with those from the borings logged adjacent to the EMDF site at Ogden Sites B (27 borings) and C (52 borings) (Ogden 1993a/b), except that virtually all residuum at Sites B and C were field logged predominantly as silty clay (CL), as opposed to clayey silt (ML). In addition, out of a total of 40 *residuum* soil samples submitted by Ogden for geotechnical laboratory analysis, 33 were classified (per Unified Soil Classification Sytem [USCS] laboratory classification) as lean clay (CL), seven were classified as fat clay (CH), and none were classified as silt (ML). Similarly, residuum from ten test pits excavated within the EMWMF footprint was also field logged as lean clay (CL) with underlying shale saprolite (see CH2MHill 2000). However, the laboratory classification of five residuum soil samples from these test pits showed greater variation among USCS soil classifications, ranging from CL, CH, SM, to two samples as ML. All of the samples reported by Ogden and CH2MHill were collected from the same geologic formations that occur directly adjacent to and along strike with the EMDF footprint. These soil samples should therefore be equivalent to those anticipated at the EMDF site. The five EMDF Phase I shelby tube soil samples submitted for geotechnical laboratory analysis (see Section 7.2.4.1 below) were all logged as "silty clay (decomposed to weathered shale)" (CL), and are consistent with the majority of Ogden and CH2MHill descriptions of predominantly clayey soil residuum within the same geologic formations as those below the EMDF footprint. Differences between the Phase I logged soil descriptions and those from other investigations and similar soils along strike appear to result in part from manual field descriptions that vary depending on the experience and judgment of field geologist/engineers and the subtle differences between silt and clay sized materials.

7.2.4.1 Phase I Results of Geotechnical Laboratory Tests

The laboratory results from testing of the five Phase I Shelby tube samples are shown in Table 17. The complete laboratory data sheets are provided in Exhibit A.3. The Shelby tube samples were targeted for collection from the shallow saturated zone to define the hydraulic conductivity and geotechnical index properties of the water table interval. The sample collection depths were based on water levels measured in open boreholes drilled to auger refusal during the early drilling of the deep well pairs. Water levels measured in open boreholes may vary from final water levels obtained from completed monitoring wells as time is required for water levels to equilibrate within boreholes and wells, and water levels naturally fluctuate seasonally and with precipitation/recharge events. Water level data from the completed shallow wells indicate that only two of the five Shelby tube samples were collected from the vadose zone; those in GW-973(S) and GW-977(S). The remaining samples were collected from depth intervals within the saturated zone of the other three shallow wells.

The tube samples at each location were all described by the laboratory as decomposed to weathered shale (saprolite). It is important to note that the CL and SC classification symbols and percentages of gravel, sand, silt, and clay shown in Table 17 are based on the natural crumbling and disintegration of weathered shale (saprolite) extruded from the Shelby tubes and mechanically sieved. The results therefore simply reflect the range of particle size fractions of the decomposed shale and weathered shale rock fragments. The results are based on a standardized mechanical process normally designed to measure naturally occurring *unconsolidated* "soil" like materials such as mud, sand, and gravel mixtures found in typical soils or alluvial/colluvial materials – not weathered and partially consolidated, fractured sedimentary rocks characteristic of weathered Conasauga Group rock formations. These results should therefore be used and interpreted with these precautions and considerations in mind.

The results of the hydraulic conductivity tests indicate relatively low K values ranging from 3.89×10^{-7} to 6.54×10^{-6} cm/sec, with a mean K of 3.23×10^{-6} cm/sec. Natural moisture contents range from 12.2– 21.2%. Specific gravities range from 2.68–2.73. Liquid and plastic limits range from 29–34, and 20–24, respectively.

7.2.4.2 Results of Geotechnical Laboratory Tests from Adjacent Sites

As noted above in Section 5, a considerable amount of geotechnical test data is available from sites directly adjacent to the EMDF footprint. Because the data were collected from boring locations and test pits directly along geologic strike with the same formations outcropping across the EMDF footprint, they are directly relevant to current and future planning and investigations at the EMDF. A summary of results is provided in Exhibit A. 19. The original reports should be referenced for additional details (Ogden 1993a and b; CH2M Hill 2000).

Table 17. Summary Results from Geotechnical Laboratory Analysis of Phase I EMDF Shelby Tube Samples

Sample ID	Sample Depth Interval (ft bgs)	ASTM D 2487		ASTM D 422				ASTM D 4318			ASTM D 854	ASTM D 5084
		USCS Soil Type	Material Description	% Gr	% Sd	% Si	% Cl	NM %	LL	PL	SG	K (cm/sec)
GW969-UD-1	1.0-3.0	CL	Clay, silty (decomposed shale), brown, mottled gray w/rock	15.4	34.1	26.5	24.0	15.5	29	20	2.68	3.89×10^{-7}
GW971-UD-1	17.0-19.0	CL	Clay, silty (decomposed shale), brown, maroon, mottled	0.1	42.8	41.3	15.8	20.0	34	22	2.73	6.36×10^{-7}
GW973-UD-1	2.0-4.0	SC	Clay, silty (decomposed to weathered shale), brown, brown to brownish red	16.5	49.5	25.8	8.2	21.2	34	24	2.71	3.53×10^{-6}
GW975-UD-1	7.0-8.5	SC	Clay, silty (decomposed to weathered shale), light brown, brown, mottled	19.3	59.3	14.0	7.4	15.0	32	22	2.71	6.54×10^{-6}
GW977-UD-1	10.0-10.66	SC	Clay, silty (decomposed to weathered shale), light brown, brown, mottled	18.1	53.5	15.8	12.6	12.2	30	20	2.7	5.03×10^{-6}
											Mean K	3.23×10^{-6}

Notes and Abbreviations:

- The CL and SC classification symbols and the percentages of gravel, sand, silt, and clay may be misleading because each of the five samples were composed of weathered shale (saprolite) and are not true samples of typical "soil" like materials such as clays, silts, sands and gravels found in unconsolidated residual soils or alluvial/colluvial materials. The sieve analysis results reflect the range of particle size fractions based on the natural crumbling and disintegration of weathered shale extruded from the Shelby tubes and mechanically sieved. These USCS classifications, particularly the SC classifications, therefore have little meaning and should be used with caution.
- Samples from GW-973(S) and GW-977(S) were collected from the vadose zone; all other samples were collected from within the zone of water table fluctuation of shallow ground water.

Cl clay
ft bgs feet below ground surface
Gr gravel
K hydraulic conductivity in centimeters per second (cm/sec)
LL liquid limit
NM natural moisture content
PL plastic limit
Sd sand
SG specific gravity
Si silt

7.2.5 Bedrock Hydrogeology at the EMDF Site

The bedrock interval in the 100 ft depth Phase I deep wells varies from 73–90 ft in length (from the base of isolation casing to total depth). The hydrogeology of this bedrock interval is based on and interpreted from:

- Continuous rock cores from GW-972(I) and GW-976(I)
- Borehole geophysical logging in all the deep wells over the bedrock interval (including heat pulse flowmeter results)
- Nine packer tests of selected bedrock intervals to determine K
- Continuous water level monitoring in all deep wells

The results are introduced with a review of general bedrock structures, the Phase I rock core data, borehole geophysical logs, and correlations between the rock core data and the geophysical logs. The site-specific bedrock hydrogeology (stratigraphy, lithology, structural features, and ground water conditions) are then reviewed based on the north to south outcrop belt of the geologic formations directly adjacent to and underlying the EMDF footprint (Upper Rome Formation through the Maryville Limestone). The Phase I results and interpretations are reviewed, and supplemented with sources of relevant geologic data reported from other subsurface investigations in BCV that are along geologic strike with the EMDF footprint. The key stratigraphical, lithological, structural, and hydrological features from Phase I are illustrated in the maps and cross sections of Plates 2 through 4, which should be referenced for supplemental details and visualization of subsurface conditions that are described below. Plate 2 in particular provides a comprehensive illustration of results for each of the Phase I wells/borings including results from packer tests, descriptions and interpretations of lithologies and possible flow zones based on rock core analysis, heat pulse flowmeter test results, and other borehole geophysical logs and structure logs. Plate 2 may be used as a reference tool for the following subsections along with detailed geophysical logs provided in Exhibit A.8.

7.2.5.1 Bedrock Structures

The interconnected subsurface network of naturally occurring structural features (e.g., fractures associated with bedding planes, joints, shear surfaces, folds and faults) dictates the occurrence, distribution, and flow paths of subsurface ground water in bedrock. Hydrogeological investigations on the ORR have demonstrated a tendency for ground water fracture flow to be dominantly strike parallel and for ground water flow and contaminant transport to often be stratabound (Ketelle and Lee, 1992). These features are both dictated largely by fracture systems that are dominant parallel to strike and to fracture/joint controlled systems that may be constrained within bedded intervals that typically dip on the order of 45° to the southeast. The better subsurface fracture systems are characterized, the better the subsurface fracture flow systems can be understood and simulated in site conceptual models and fate and transport modeling. Fracture intervals identified in rock cores at GW-972(I) and GW-976(I) and interpreted from evaluation of borehole geophysical logs are reviewed below by geologic formation. The locations and nature of these features are presented on the cross sections in Plates 2 through 4 (as well as on the boring logs in Exhibit A.4). Rock core photographs in Exhibit A.7 provide close-up examples of key fractured and/or stained and weathered zones suggesting potential ground water flow paths.

7.2.5.2 Phase I EMDF Rock Core Data

Rock cores were collected continuously from the bedrock intervals of two of the five deep well pairs, GW-972(I) and GW-976(I), located within the outcrop belts of the Rutledge Limestone and Maryville Limestone, respectively (see Plates 2 and 3). One of the primary objectives of the Phase I rock coring was to evaluate the occurrences of any limestone beds within the EMDF footprint and their detailed characteristics, including the nature of fracturing, weathering, or dissolution that might be conducive to ground water flow. Limestone beds have been described within these two formations from boreholes drilled elsewhere in BCV. A second important objective was to obtain direct physical evidence of lithologies and structures in the rock cores that could be correlated against and test the validity of the borehole geophysical logs.

HQ size (2.5 in. diameter) rock cores were recovered from depths at or near auger refusal down to nominal total depths of 100 ft in GW-972(I) and GW-976(I). The overall core lengths in the two boreholes were 77 and 73 ft, respectively. The cores were recovered in lengths of 5ft or less and carefully logged and photographed to document: (1) depths and thicknesses of primary lithologies, (2) the nature of important structural features (e.g., bedding planes, joints, shear fractures), and (3) fractured, weathered, and stained intervals that would be indicative of possible bedrock fractured flow zones within the intermediate ground water interval. Representative maximum dip angles were measured from intact sections of rock cores wherever bedding planes were clearly observed and measureable. Because of the disorientation of the retrieved cores, azimuth strike/dip directions cannot be determined from the core data; only the maximum dip angles are reliable and were assumed to be toward the typical southeast dip direction. Dip angles were measured using a transparent compass and are generally accurate to within ± 1°–2°.

7.2.5.3 Overview of Phase I EMDF Borehole Geophysical Logging

The results of the borehole geophysical logs are reviewed in subsequent sections below according to the Phase I deep borings drilled within the outcrop belt of each of the formations. Log interpretations and conclusions are presented separately in the attached URS geophysical report (see Exhibit A.8). However, the URS report does not include any comparisons and correlations made between the rock core data and the geophysical logs. Nor does the URS report incorporate the findings from the packer tests or the results of continuous ground water monitoring. The URS interpretations have been integrated into the presentation of collective results below drawing from the entire suite of Phase I activities.

The results from the borehole geophysical logs supplement the rock core data from GW-972(I) and GW-976(I), and were the primary source of bedrock data at the remaining three deep borings GW-968(I), GW-970(I), and GW-974(I) where no rock coring occurred. The bedrock borings at GW-968(I), GW-970(I), and GW-974(I) were drilled using an air rotary rig creating a nominal 8 in. diameter borehole before geophysical logging. After completing the rock coring at GW-972(I) and GW-976(I), these two boreholes were reamed with the same air rotary rig. The borehole geophysical logging was thus performed within consistently sized 8 in. diameter boreholes at each location.

The detailed rock core logs (see Exhibit A.4) from GW-972(I) and GW-976(I) were plotted alongside the corresponding borehole geophysical logs to systematically correlate bedrock features observed in the rock cores with corresponding geophysical signatures (if and wherever they might occur). Plate 2 presents the stratigraphic/lithologic profile, potential fractured intervals, and maximum bedding plane dip angles derived from the rock core logs alongside the borehole geophysical logs for GW-972(I) and GW-976(I). The most detailed borehole geophysical logs are provided in Exhibit A.8 which are plotted at a vertical scale of 1 in. equals 2 ft. The depths and thicknesses of fracture intervals (particularly fractures with staining/weathering indicative of possible ground water flow) and lithologic units (e.g., distinct beds and intervals of limestone, shale, and interbedded, laminated shales and limestones, and other characteristic lithologies) were compared against the geophysical signatures from the various logs in an attempt to establish positive correlations that could be used in boreholes without rock core data. With the exception of the OTV log (which is essentially a wide angle downward directed digital camera with radial lights placed at the bottom of the tool), the geophysical instruments provide indirect indications of geological characteristics based on the nature of each instrument. The OTV log is most sensitive to the clarity of the water column in the borehole (or the lack thereof) and its quality generally diminished with reduced downward water clarity in the Phase I boreholes. The SP logs could not be correlated with any features observed in the Phase I rock cores. The SP logs were therefore not useful for interpreting lithologic or structural features.

Except for the NGR log signature of some relatively thicker beds (generally > 1 ft) of shale and limestone in GW-976(I), the borehole geophysical logs were incapable of accurately defining the depths and thicknesses of distinct basic rock types such as shale, siltstone, and limestone, or of interbedded and laminated sequences comprised of these lithologies. The geophysical logs therefore cannot be used to provide an accurate continuous stratigraphic/lithologic profile at the well locations. Without rock core data there are limited means available for accurately characterizing the detailed stratigraphic/lithologic profile in a bedrock borehole.

The primary strength of the borehole geophysical logs generally came from the OTV and ATV logs, the fluid temperature and fluid resistivity logs, and the heat pulse flowmeter logs. Up to five different structural features were identified by the URS geophysicist using the OTV/ATV logs and those features were plotted on the borehole logs as a "structure log" down the center of the composite borehole logs (see Plate 2 profiles and detailed logs in Exhibit A.8). The structure log was developed by the geophysicist using an image module of WellCAD software that allows for interactive digitizing of structural features with depth. The structure log is subjective and interpretive and relies on the professional judgement of the geophysicist to maintain consistent criteria among boreholes. The structure log also depends upon the quality of the OTV/ATV logs which can vary with depth and among boreholes. The WellCAD software calculates the true strike and dip based on the "mapping" of structural features by the geophysicist. The majority of structural features identified by the geophysicist were surfaces parallel to bedding planes aligned with the regional dip toward the southeast. However, in some boreholes structural features were identified with orientations discordant to the regional bedding plane dip. Up to five different structural features were interpreted and plotted with color codes on the structure logs:

- Major open fracture/joint (red)
- Minor open fracture/joint (purple)
- Partially open fracture/joint (orange)
- Bedding plane (green - bedding/banding/foliation), and
- Filled fracture/joint (gray)

The "filled fracture/joint" features were considered least important because they do not represent features conducive to ground water flow. The open fractures/joints are the most significant features identified on the structure logs as they have the potential to represent depths conducive to ground water flow.

The results of the heat pulse flowmeter logs were reviewed above in Section 7.2.3.6, and are not repeated here. These logs were completed in a final separate phase of the borehole geophysical logging process. Flowmeter results are integrated with the interpretations presented in subsequent sections for each deep well location.

The wellbore deviation logs were run with the ACT/OTV logs and indicate the deviation in borehole angle and azimuths with depth bgs. Key results from the logs are shown in Table 18. The overall lateral deviation relative to the surface location at depths near the bottom of the borings indicates that none of the boreholes deviated significantly from the vertical (see Exhibit A.8 for detailed borehole deviation log profiles and plan views). The results indicate a tendency of the boreholes to deviate slightly toward the northwest in a direction opposite to the typical bedding plane dip direction toward the southeast.

Table 18. Borehole Deviation Results from Geophysical Logs Run in Deeper Intermediate Zone Wells

Well ID	Horizontal deviation (in feet) from surface location at depth shown with general azimuth direction from true north
GW-968(I)	2.4 ft to northwest at 89 ft bgs
GW-970(I)	6.5 ft to northwest at 96.9 ft bgs
GW-972(I)	2.3 ft to northwest at 97 ft bgs
GW-974(I)	9.8 ft to north-northwest at 97 ft bgs
GW-976(I)	1.7 ft to west at 99.6 ft bgs

Rock cores (along with the packer test results and water level monitoring data) provide the best means of validating the results of the borehole geophysical logs. Although positive correlations were identified between rock cores and the structure logs and other geophysical logs, there are many features identified in the rock cores that are not reflected in the suite of geophysical logs, nor in the structure log based on geophysical interpretations.

7.2.5.4 Correlations Between Phase I Rock Core Data and Borehole Geophysical Logs

The rock core data from GW-972(I) and GW-976(I) were plotted alongside the suite of borehole geophysical logs to evaluate potential correlations between lithologies and structures (fractures, joints, etc.) observed in rock cores, and the various borehole geophysical logs and structure logs completed in these boreholes. Correlations could then be made with greater confidence for borehole geophysical logs completed in boreholes without rock cores. The results of this cross correlation process allowed for an assessment of log features against physical data from the cores independent of interpretations made by the geophysicist solely from the geophysical logs.

The only geophysical log found to have any possible correlation with lithologies was the NGR log. Other geophysical logs may provide useful data but generally do not provide a direct indication of lithologic data. The NGR log is measured in terms of Antecedent Precipitation Index (API) units scaled on the logs from 0 to 200 API units (see Exhibit A.8, URS Geophysical report for more details). The key correlations for the two boreholes with rock cores and borehole geophysical logs are summarized below. Note that GW-976(I) was drilled within the outcrop belt of the Maryville Limestone (Dismal Gap Formation) and GW-972(I) was drilled within the outcrop belt of the Rutledge Limestone (Friendship Formation).

<u>GW-976(I) Rock Core and Borehole Geophysical Log Correlations</u>

- Shale beds in rock cores greater than about 1 ft in thickness correlate with higher NGR curves, but the API values in these shale beds are comparable with those found in interbedded laminated siltstone and shale sequences higher in the unsaturated section of the borehole (i.e., above approximately 44 ft bgs). The NGR curve therefore does not appear to provide a unique and diagnostic signature for distinguishing between siltstone and shale (or mudstone).
- Shale beds of 1.1, 2.4, and 4.2 ft in rock core thickness showed a relatively high average maximum baseline of approximately 155 API units on the NGR curve.

- Two thicker limestone beds in GW-976(I) rock cores had the lowest API unit readings; much lower than the API responses in predominantly clastic formations.
  - A 1.5 ft thick limestone bed at approximately 91.5 ft bgs reached a low of 92 API units
  - A 1.8 ft thick limestone bed at approximately 76.5 ft bgs reached a low of 85 API units
- Thinner limestone beds less than 1 ft in thickness show relatively higher API units, apparently as a result of shaly beds surrounding the thinner limestone beds, raising the overall API values.
- Interbedded (saturated) laminated shale and limestone sequences from 48-60 ft bgs correlate with API readings typically averaging 120–130 API units (with an overall range of approximately 102–140 API units).
- Interbedded (unsaturated) laminated siltstone and shale (without any calcareous layers) sequences from 27.5–44 ft bgs correlate with API readings averaging approximately 156 API units (with an overall narrower range between approximately 145–165 API units).
- Assuming no influences from saturated versus unsaturated conditions or other unknown factors, the correlations suggest that lower API units may be associated with greater carbonate content.
- A baseline shift occurs in the NGR curve at 45–47 ft bgs that is coincident with the change from an upper non-carbonate to lower carbonate sequence (verified by HCl acid effervescence). The shift is also roughly parallel with changes in fluid resistivity/temperature logs that occur over a 3–4ft interval just below the water table at that time (at 44.3 ft bgs). The shift represents a decrease of about 40 API units.
- Some portions of the caliper log indicating a widened borehole from "washout" intervals correlated reasonably well with intervals of significant core loss (near depths of 45, 52, 72, 74.5, and 77.5 ft bgs). In these intervals borehole diameters widened from 8.5–9.8 in. from the nominal 8 in. diameter borehole (these intervals may represent weak fractured shale beds prone to disintegration during the coring process).

GW-972(I) Rock Core and Borehole Geophysical Log Correlations

- No consistent correlation is evident between shale beds and higher NGR curve API units, but the shale beds are mostly relatively thin (less than 0.5 ft thick). Even in the two shale beds with thicknesses of approximately 1.1–1.5 ft thick at depths of approximately 35 and 46 ft bgs, the API units were not elevated, averaging 140 API units.
- The overall NGR curve for GW-972(I) displays far less variation in API units than does the NGR curve for GW-976(I), apparently reflecting the predominant shale/mudstone lithology (approximately 80%) and relatively thin (i.e., <0.2-0.3 ft thick) and limited occurrence of limestone/calcareous siltstone lamina/beds (approximately 20%) in GW-972(I).
- This overall NGR curve shows an average of 142 API units with a range of approximately 121–167 API units.
- The NGR curve appears consistent with the relatively monotonous sequence of interbedded laminated shale and intermittent limestone/calcareous siltstone sequence logged in the rock cores over the entire length of the borehole (see core photographs in Exhibit A.7).

Direct comparisons between the Phase I rock cores and the borehole geophysical logs indicate that none of the geophysical logs are sensitive enough to develop a detailed and accurate stratigraphic section for each of the deep borings. This is particularly true for the relatively thin beds (typically < 1.0 ft thick) and laminated sequences logged in the rock cores of GW-972(I) and GW-976(I), and inferred at the other boring locations. Table 19 summarizes the NGR curve statistics from each of the deep boreholes, illustrating the range and average values for NGR readings, and their relationships with the geologic formations. The results suggest an average (overall baseline) NGR reading that is lowest in the Maryville, presumably associated with the limestone beds logged in GW-976(I) that have lower API values than the shale beds. The results also suggest a slightly wider range of NGR readings within the Maryville and Rogersville formations than in the other formations.

Table 19. Statistics for Natural Gamma Ray Logs run in Phase I Deep Borehholes

	Natural Gamma Ray Curve Readings in API Units				
	GW-968(I)	**GW-970(I)**	**GW-972(I)**	**GW-974(I)**	**GW-976(I)**
Average	147	146	142	139	131
Max	173	175	167	171	166
Min	107	127	121	85	85
Range	66	47	46	86	81
Geologic Formation	Cpv	Cpv	Crt	Crg	Cm
Bedrock Coring	No	No	Yes	No	Yes

Abbreviations:

Cm Maryville
Cpv Cambrian Pumpkin Valley
Cr Rutledge
Crg Rogersville

7.2.5.5 Other bedrock data in Bear Creek Valley relevant to the EMDF site

Rock core data and geophysical logs from the geologic formations penetrated in the Phase I deep borings were compared against bedrock lithologic data reported elsewhere in BCV along strike to the EMDF. Probably the most extensive rock coring in WBCV (a total of 8,698 ft of rock core) occurred at the former LLWDDD site located approximately 3.5 miles to the southwest of and along geologic strike with the EMDF. Rock coring at the LLWDDD included the entire continuous stratigraphic section from the Upper Rome through the Lower Maynardville formations (Lee and Ketelle, 1989). Each of the geologic formations present below the EMDF site were described by Lee and Ketelle based on the extensive coring completed at the LLWDDD site. Their descriptions also included the basis for establishing formation contacts.

Rock coring data were also compiled and evaluated by King and Haase to define the geological conditions along BCV at and near Y-12. Their report (King and Haase, 1987) includes geologic cross sections at the S-3 Ponds east of the EMDF, and at the Bear Creek Burial Grounds southwest of the EMDF that illustrate the thicknesses of and contacts between Conasauga Group formations underlying the EMDF site. Bedrock lithologic data are also extensively reviewed for the Conasauga Group formations in Hatcher et al (1992).

Table 20 provides descriptions of the geologic formations occurring at the EMDF site (Upper Rome Formation through the Maryville Limestone) based on interpretations of rock cores from the LLWDDD site (Lee and Ketelle, 1989). This report included the most detailed lithologic descriptions for comparison to the Phase I results. The table also includes formation thicknesses (borehole thicknesses and estimated true thicknesses). The table allows for a comparison of the geological data from the limited Phase I investigation results described below with that collected from the same formations along strike in BCV.

Bedrock data from previous investigations at the EMWMF and from investigations at other sites such as the Bear Creek Burial Grounds have included far less extensive and non systematic rock coring data. Much of the bedrock data nearest the EMDF site comes from drilling of boreholes using air rotary rigs which provide very limited detailed lithologic and structural information to accurately characterize the nature and extent of individual fractures or groups of fractures that are fundamental to assessing ground

Table 20. Descriptions of Geologic Formations Used for Comparison with Phase I Results

Geologic Formations at the EMDF Site	Downhole Thickness (in ft)	Equivalent True Thickness Assuming 45˚ dip to SE (in ft)	Descriptions from Lee & Ketelle 1989 Based on Extensive Rock Cores Collected at the Proposed LLWDDD Site in WBCV - 3.5 Miles Southwest and along Strike with the Proposed EMDF Site
Maryville Limestone - Cmr (Dismal Gap Formation)	430	304	The Maryville consists of oolitic, intraclastic (flat pebble conglomerate), and thin-bedded limestone interbedded with dark gray shale that typically contains thin, planar, and wavy-laminated, coalesced lenses of light gray limestone and calcareous siltstone. Fine-grained glauconite often occurs at the tops of the thin-laminated limestone lithology. Several isolated dark maroon shale beds typically occur in both the upper and lower Maryville. Although considerable mixing of limestone lithologies is noted, the upper Maryville generally contains greater amounts of intraclastic limestone, while thin-laminated and oolitic limestone is more prevalent in the lower portion. The contact separating these two upper and lower portions is gradational over tens of feet of section. Limestone intraclasts are randomly oriented and roughly 2 to 10 cm in length. In roughly the lower 40 ft of the Maryville, a variable number of prominent, coarse-grained, pinkish limestone beds occur which contain coarser and more abundant glauconite pellets than those higher in the section.
Crg/Cmr Contact			Abrupt Contact: The Rogersville is terminated abruptly by the occurrence of the comparatively thick limestone beds of the overlying Maryville, with the contact placed at the bottom of the first such limestone.
Rogersville Shale - Crg	90 & 150	64 & 106	The lower Rogersville consists dominantly of dark gray shale containing thin- laminated and bioturbated argillaceous limestone lenses less than 1 in thick. When maroon shales occur in the lower portion, they are thinner and more chocolate brown than the maroon shales in the upper portion. Glauconite partings are commonly interlaminated with the limestones but also occur as bioturbated beds several inches thick. The Craig Member, recognized elsewhere in East TN, is not present at the WBCV site. In the approximate position of the member are a few thin limestone beds which may represent the Craig Member at the site. The beds are 4 to 6 in. thick and composed of interlaminated, light gray, silty limestone and dark gray shale. These beds differ from those in the lower Rogersville principally in thickness and may be more appropriately considered the uppermost portion of the lower Rogersville at the site. The upper Rogersville consists dominantly of maroon shale containing thin (less than 1 in. thick), wavy, light gray, calcareous siltstone or argillaceous limestone lenses in varying amounts. Thin glauconitic partings are liberally incorporated within the siltstone and limestone lenses. The interlamination of these variably colored lithologies gives the upper Rogersville an overall thinly laminated appearance. Thicker beds (more than 1 ft thick) of clean, maroon-to-brownish-maroon shale are occasionally interspersed within the thin-laminated lithology.
Crt/Crg Contact			Abrupt Contact: The contact with the Rogersville is abrupt and recognized by the absence of 1-ft-thick limestone beds and the introduction of maroon shale. The contact is placed at the top of the uppermost such limestone bed.
Rutledge Limestone - Crt (Friendship Formation)	124 & 126	88 & 89	The Rutledge consists of light gray, bedded limestone, often containing shaley partings interbedded with dark gray or maroon thin-bedded or internally clean shale in beds from 2 to 5 ft thick. Limestones are generally evenly divided between wavy laminated and bioturbated. Horizontal burrows are frequently observed. Maroon shale is more common in the lower Rutledge, and two distinctive beds on the order of 3 ft thick occur at the bottom of the formation, separated by three limestone beds of similar thickness. These limestones are referred to as the "three limestones" of the lower Rutledge, but their lithologic similarity with limestones in the bulk of the Rutledge makes them less distinctive than the two maroon shales. The relatively clean, dark maroon shales in the lower Rutledge give way to dark gray shale with thin calcareous siltstone interbeds. Upper Rutledge interbeds are generally thinner than those below, and more coalescing of lithologies is recognized. Limestone beds are often ribbon or wavy bedded, and some are heavily bioturbated with abundant glauconite pellets. Glauconite stringers also occur commonly within the calcareous siltstone interbeds.
Cpv/Crt Contact			Abrupt Contact: The contact with the overlying Rutledge is abrupt and placed at the top of generally uninterrupted, thin-bedded, reddish-brown shale and below the interbedded limestone and dark maroon shale of the Rutledge.
Pumpkin Valley Shale - Cpv	376 & 398	266 & 281	The Pumpkin Valley Shale is readily divisible into upper and lower units of nearly equal thickness. The lower Pumpkin Valley consists of reddish brown and gray-to-greenish-gray shale with thin interbeds of siltstone and silty, fine-grained sandstone. Shales typically contain thin, wavy laminated siltstone drapes and discrete laminae of fine-grained glauconite. Silty sandstone interbeds are typically wavy laminated to thin bedded but are often heavily bioturbated. High concentrations of large glauconitic pellets occur in the bioturbated lithology. Decreasing silty sandstone content upward within the lower Pumpkin Valley attests to its transitional nature above the Rome. The upper Pumpkin Valley is laminated to thin-bedded, dominantly reddish-brown, reddish-gray, and gray shale with thin, wavy, and planar-laminated siltstone lenses. Shales are generally fissile and may be massive or thin laminated. Thin partings of fine-grained glauconite pellets are ubiquitously interlaminated within the siltstone lenses.
Crm/Cpv Contact			Gradational Contact: The contact with the overlying Pumpkin Valley Shale is gradational and placed at the top of the uppermost thick, clean, planar laminated, 8 to 12 in. thick, sandstone bed of the Rome.
Rome Formation - Crm	>>195	>>138	The Upper Rome consists of thick beds of gray or pale maroon, fine-grained, arkosic to subarkosic sandstone with occassional interbeds of maroon shale that often contain thin siltstone bands. Sandstones are typically planar to wavy-laminated or current-rippled. Vertical burrows are in great abundance in the interbedded lithology but are also recognized in the sandstone-dominated lithology. Burrows diminish in abundance down section. Upper Rome sandstone/shale interbeds occur nonuniformly at the two site locations from which core was acquired. The common occurrence of such interbeds on the western portion of the site is almost entirely replaced in the center of the site by gray or pale maroon sandstone couplets with a total absence of shale. Such lateral facies changes within roughly 1000 ft suggest the Upper Rome was subject to locally variable clastic influx in a low-relief paleodepositional setting.

Adapted from Lee & Ketelle, 1989

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water flow conditions. The Site B and C investigations by Ogden (Ogden 1993a/b) included rock coring in bedrock to depths of over 100 ft bgs, however, the coring was limited to locations within the outcrop belts of the Rome and Pumpkin Valley and did not include bedrock borings into the Rutledge, Rogersville, or Maryville formations which also underlay much of the EMDF footprint.

The results from the Phase I rock coring and borehole geophysical logging were compared primarily with the descriptions at the LLWDDD site in WBCV, as these are based on the most extensively characterized site data available within the same fault block as the EMDF bedrock strata. The Phase I rock core intervals comprise only a fraction of the entire stratigraphic section below the proposed EMDF footprint (GW-972[I] and GW-976[I] rock core lengths are 77 ft and 73 ft, respectively), as do the borehole geophysical log intervals in GW-968(I), GW-970(I), and GW-974(I) at 89, 97, and 97 ft, respectively. However, the Phase I results provide initial site-specific data useful for identifying the subsurface conditions at the EMDF, particularly with respect to the more carbonate rich Rutledge and Maryville Limestone formations.

7.2.5.6 Rome Formation Bedrock Hydrogeology

The Rome Formation does not outcrop below the proposed EMDF footprint. The contact between the Rome and Pumpkin Valley occurs about 200 ft north of the proposed waste limits. Detailed conceptual design cross sections indicate that the top of the Rome would occur at minimum depths of 130–150 ft bgs along the northern border of the proposed waste limits (assuming an average dip of 45° to the southeast). South of the northern EMDF border, depths to the Rome would increase significantly as the Rome dips steeply into the deeper subsurface.

No Phase I borings were drilled within the outcrop belt of the upper Sandstone Member of the Rome Formation that outcrops along the spine of Pine Ridge. However, Ogden Site B and C borings drilled within the Rome outcrop belt along the upper slopes and ridge top of Pine Ridge adjacent to and along strike with the EMDF provide useful lithologic and structural data relevant to the EMDF (see locations on Figure 7 and Ogden reports [Ogden 1993 a/b] for additional details and cross sections in Exhibit A.19). These results are useful for properly planning subsurface Phase II investigations in the Rome at the EMDF site. TDEC staff has indicated a desire to monitor ground water conditions in the Rome at the EMDF (see Exhibit A.1).

At Site B northeast of the EMDF, two Ogden borings were drilled in the outcrop belt of the Rome just downslope and south of the top of Pine Ridge. Two other borings were drilled slightly more southward in the outcrop belt of the Pumpkin Valley that penetrated the Rome in the lower bedrock portions of the borings. The borings ranged in depth from 70–108 ft bgs and all were continuously cored into bedrock. The regolith of the two borings in the Rome outcrop belt encountered sand and weathered sandstone saprolite to auger refusal. The Rome bedrock at these locations was logged exclusively as sandstone except for a 10 ft thick siltstone bed logged in one of the borings. In the two other borings, the Pumpkin Valley Shale regolith was logged as surficial clay and weathered shale to auger refusal at competent bedrock. The uppermost bedrock in both borings was logged as siltstone, with the underlying Rome identified exclusively as sandstone to total depths. The contact between the Pumpkin Valley and Rome was placed by Ogden at the interface between the siltstone beds and the underlying sandstone.

At Site C, on the north side of the EMWMF footprint southwest of the EMDF, six borings were drilled within the outcrop belt of the Rome Formation. The borings varied from 30–100 ft in depth. Most were drilled into bedrock, and all the bedrock intervals were continuously cored. Detailed logs and cross sections of these boring show a relatively thinner surficial residuum with much more sand and silt than the clayey residuum further downslope within the outcrop belts of the Pumpkin Valley, Rutledge, Rogersville, and Maryville formations. The saprolite in these borings is similarly more likely to include weathered sandstone and siltstone than weathered shale except for some borings that penetrated thicker intervals of weathered shale. The Rome bedrock below the regolith was logged as shale, sandstone, and interbedded shale and sandstone. The lithologic variation and thickness of these sequences varies greatly between locations among these borings. Ogden identifies apparent contacts between the Rome and Pumpkin Valley in their detailed cross sections. The fracture density and orientation logged in all the Site B/C bedrock borings varies widely from location to location (see cross section plates in Ogden 1993 a/b). Some borings were logged with few fractures, others show extensively fractured/weathered bedrock intervals, and others are intermediate in terms of fracture density and spacing. The logs suggest that bedrock fracturing is highly variable from location to location.

If the EMDF site is approved, the Phase II site characterization would presumably include borings and monitoring wells to define hydrogeological conditions within the outcrop belt of the Rome Formation along Pine Ridge. Geotechnical data would be collected to support design needs, particularly in relation to slope stability along the steep south facing slope of Pine Ridge.

7.2.5.7 Pumpkin Valley Shale Bedrock Hydrogeology

Two Phase I wells were drilled to nominal 100 ft depths in bedrock at locations within the outcrop belt of the Pumpkin Valley Shale (GW-968[I] and GW-970[I]) using air rotary drilling. Rock coring was not conducted at these locations. The geophysical logs were therefore relied upon to provide an indication of the lithologic sequence and structural features in these boreholes conducive to ground water flow. Comparisons were also made with bedrock lithologic descriptions of the Pumpkin Valley from other investigations in BCV along strike to the EMDF.

Lithologic Descriptions from BCV Sites along Strike with the EMDF

Lithologic descriptions of rock core data from the LLWDDD site indicate that the upper Pumpkin Valley is composed predominantly of shale with siltstone lenses, while the lower Pumpkin Valley is composed predominantly of shale with thin interbeds of siltstone and silty, fine-grained sandstone (see Table 20; adapted from Lee and Ketelle 1989, for more detailed formation descriptions). The surface locations of GW-968(I) and GW-970(I) fall within the outcrop belt of the Pumpkin Valley Shale (see Figure 1, Plate 3, and Plate 4). The outcrop pattern of the formation contacts are approximate and based on the work of King and Haase (1987), projected from coreholes located distant to the EMDF site. The GW-968(I) surface location is near the middle of the outcrop belt so that the 100 ft borehole should penetrate portions of the middle to lower part of the Pumpkin Valley. The GW-970(I) surface location is close to the contact between the Pumpkin Valley and Rutledge, so that the 100 ft borehole should penetrate the uppermost section of the Pumpkin Valley.

Ogden Site B and C borings adjacent to and along strike with the EMDF provide useful lithologic and structural data relevant to the EMDF. Boring locations are shown on Figure 7 (see Ogden reports [Ogden 1993 a/b] for additional details and the detailed cross sections in Exhibit A.19). At Site B northeast of the EMDF, nine shallow Ogden borings were drilled in the regolith of the Pumpkin Valley Shale (typical depths of 20 ft bgs). All nine borings were logged with a shallow clay residuum and underlying weathered shale interval. Four deep borings drilled into bedrock (to depths on the order of 70–100 ft bgs) in the Pumpkin Valley and the Pumpkin Valley and Rome formations logged the Pumpkin Valley as predominantly siltstone with minor shale and sandstone beds, and no carbonates.

At Site C (within the EMWMF footprint southwest of EMDF), 12 shallow borings drilled into the regolith of the Pumpkin Valley were also consistently logged with a surficial clayey residuum and underlying weathered shale to total depths typically 20 ft or more bgs. Six deep borings continuously cored in bedrock to depths of 75–115 ft bgs were logged with siltstone and shale or as interbedded sandstone and shale sequences with siltstone intervals. The fracture density and orientation logged in all the Site B/C bedrock borings varies widely from location to location.

Phase I Borehole Geophysical Logs and Packer Tests for GW-968(I) and GW-970(I)

Natural Gamma Ray Logs: Correlations between rock cores and NGR logs in GW-972(I) and GW-976(I) suggest that the NGR logs in GW-968(I) and GW-970(I) reflect a predominantly shaley clastic bedrock sequence in both boreholes. As noted above, the geophysical logs are not sensitive enough to develop a detailed and accurate stratigraphic section for each boring. But the average NGR readings and the relatively narrower range of API readings in these logs are similar to the dominantly clastic intervals described from the rock cores over the entire borehole in GW-972(I) and the upper part of GW-976(I).

Fluid Temperature/resistivity Logs: The fluid resistivity log is a reflection of total dissolved solids (TDS) concentrations in well or borehole water, and water producing and water receiving zones may be identified by changes in fluid resistivity (USGS 1996). The fluid resistivity log in GW-968(I) and GW-970(I) both show low resistivity intervals covering the bottom 15–30 ft of the boreholes that transition upward to much higher fluid resistivity values at intermediate to shallower depths. These appear on the logs as "ramps" over specific depth intervals. These transitions suggest possible zones of water level flux assuming that TDS concentrations (particularly colloids) increase with mobilized ground water entering and migrating vertically within the borehole. The transition in GW-968(I) occurs between 39 ft bgs and about 60 ft bgs, with relatively stable resistivity values in the upper and lower sections of the borehole on either side of this interval. Resistivity values decline again within the uppermost 10–15ft of the borehole suggesting potential ground water flux in the uppermost portion of bedrock just below the base of the isolation casing. A narrow zone of very low resistivity at the bottom of the hole from 86–90 ft bgs is reported by URS to be associated with suspended fines at the bottom of the open hole.

The overall appearance of the fluid resistivity log in GW-970(I) resembles that in GW-968(I) with a primary transitional zone between 44 and 67 ft bgs (see detailed logs in Exhibit A.8 and on Plate 2). This transition suggests that ground water flux may be occurring over this interval from one or more fractures. As with the lower portion of the borehole in GW-968(I), the very low and steady values of fluid resistivity from 67–97 ft bgs suggests that ground water flux within the bottom 30 ft of the borehole is very low to nonexistent. This is consistent with the general tendency for bedrock fractures and ground water flux to decrease with depth within clastic formations on the ORR (Solomon et al, 1992). Alternatively this may simply reflect zones of very low permeability and little or no fractures within the lower part of these boreholes. A small decrease in resistivity occurs near the very top of the open hole from about 34–36 ft bgs suggesting limited ground water flux just below the bottom of the isolation casing. The heat pulse flowmeter data from the Phase I deep boreholes suggests that the potential ground water flux indicated by these resistivity curve transitions is probably upward in both wells.

Structure and Heat Pulse Flowmeter Logs, and Packer Tests – GW-968(I): The structure logs, heat pulse flowmeter logs, and packer tests were the most reliable indicators of potential bedrock fractures/joints that might be conducive to ground water flow. Results are reviewed for GW-968(I) followed by those for GW-970(I).

As noted above, a structure log was developed by the URS geophysicist for each of the five deep boreholes based on interpretations of features shown on the ATV and OTV logs. The structure log for GW-968(I) includes a total of 59 structural features that were all "mapped" as parallel to bedding planes (see Figure 34 and structure log in Exhibit A.8). The structure log and related ATV/OTV logs for GW-968(I) do not indicate cross-cutting features that might represent shear fractures, faults, or joints oriented roughly perpendicular to bedding planes (i.e., green features on Figure 34). The logs suggest a relatively undisturbed structural profile in the bedrock borehole of GW-968(I). The mean of these bedding plane features as shown in Figure 34 is:

- Strike: N52°E (perpendicular to the 142° mean dip azimuth)
- Dip: 46° southeast

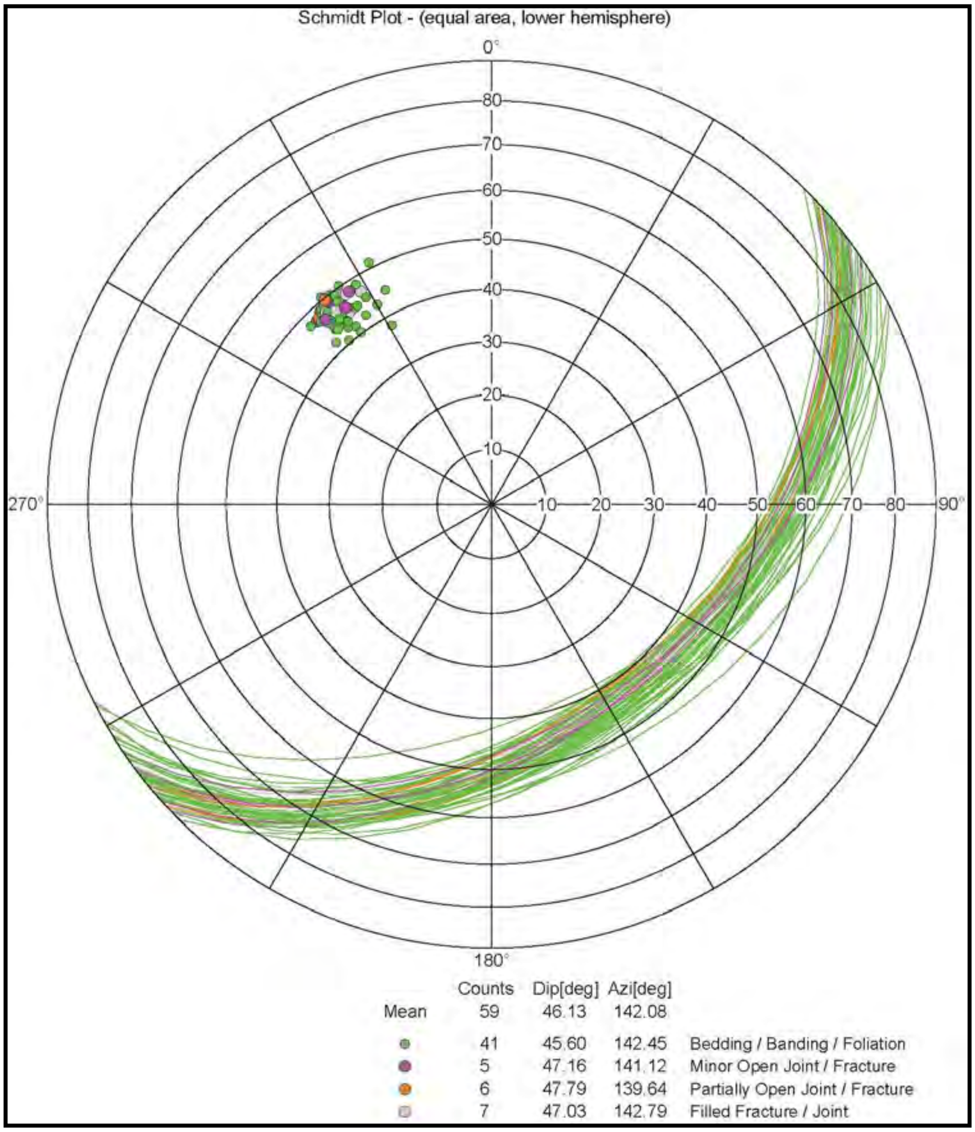


Figure 34. Schmidt Plot of Interpreted Structure Log Features in GW-968(I) Bedrock – Pumpkin Valley Shale

Eleven minor to partially open possible joints/fractures were identified on the structure log (identified in purple and orange in Figure 34 and on the detailed structure log provided in Exhibit A.8). Eleven heat pulse flowmeter tests were conducted at various depths from 12–71 ft bgs in GW-968(I). However, none of the tests indicated flow rates above the minimum quantifiable flow rate of 0.03 gpm (see Table 15 above and combination log in Exhibit A.8). Flows less than the quantifiable flow rate are suspect, but they were presented on the logs as there was continuity between repeated measurements at these depths. Six of the tests recorded very low flow rates ranging from 0.015– 0.022 gpm, while the remaining five tests recorded zero flow rates. All measured flow rates were upward (as with all the heat pulse flowmeter tests where flow was indicated). The highest flow rates of 0.020–0.022 gpm were recorded within the upper ten feet of the bedrock interval at depths of 12–17 ft bgs, respectively. These rates may be associated with the four fracture/joint features identified between 13–20 ft bgs, but could be associated with flow from deeper fractures/joints mapped on the structure log. The deepest fractures/joints identified on the structure log come from three features identified near 70 ft bgs. A flowmeter test located just above those features at 68 ft bgs, recorded a very low flow rate of 0.016 gpm.

Only one packer test was conducted in GW-968(I) (Phase I project budget constraints limited the total number of packer tests). The packer test was conducted over a ten foot interval from 23–33 ft bgs encompassing one fracture/joint identified on the structure log and two flowmeter tests recording very low flow rates of 0.015 and 0.019 gpm at depths of 26 and 27 ft bgs, respectively. Packer test results indicated a K value of 3.1×10^{-5} cm/sec. The packer test results suggest the possibility that this interval could be contributing ground water to the borehole, but the tests are based on controlled water injection and do not indicate natural ground water flow at this interval.

Overview of Fracture/flow Data in GW-968(I): The flowmeter tests did not indicate any upward flow above the quantifiable limit of the instrument anywhere within the vertical profile of the bedrock borehole. Upward flows were recorded below the quantifiable limit at six of the eleven test depths. The packer test results (order of magnitude K of 10^{-5} cm/sec) indicate that the interval from 23–33 ft bgs is conducive to ground water flow. The continuous water level monitoring data indicate that upward flow is occurring in GW-968(I). Water levels in the GW-969(S) and GW-968(I) well pair indicate consistent upward vertical gradients in GW-968(I). In addition, artesian flow overflowing the TOC has been observed in GW-968(I) (and in GW-969[S]) since shortly after the original open bedrock borehole was drilled. It is clear that upward flow is occurring within the bedrock section of GW-968(I), however, the precise depth(s), rates, and conditions of the upward flow are unclear.

The absence of any measurable flow above the quantifiable limit of the heat pulse flow meter, suggests that the overall ground water flux within the borehole (and subsequent completed well) is occurring at a very low rate (<0.03 gpm, or 1.8 gph/43 gpd). Whether or not the flow is contributed from multiple fractures/joints at various depths or from one or more fractures/joints more localized to a particular interval is unclear based on the available data and interpretations. In addition, the structure log which is based on interpretations from the ATV/OTV logs is unlikely to identify all fractures/joints within a borehole. The Phase I results from GW-968(I) do not provide a clear indication of fractures or flow rates contributing to the artesian flow seen in GW-968(I). Other more sensitive and systematic testing methods including methods for vertical profiling of K would be required for this determination.

Structure and Heat Pulse Flowmeter Logs, and Packer Tests – GW-970(I): The structure log for GW-970(I) includes a total of 45 features (see Figure 35 and structure log in Exhibit A.8). Most (55%) are bedding plane features (green), but a smaller portion (31% - red, purple, orange) were identified as possible joints/fractures with cross-cutting orientations that differ from the mean bedding plane strike and dip. These cross-cutting features all occur within the upper half of the borehole at depths between the 34 ft isolation casing depth and 56 ft bgs. Four have relatively steep dips approaching vertical (79°–87°S) with an approximate east-west strike; two others with intermediate dip angles toward the west are oriented with a more north-south strike direction These cross-cutting features may represent shear fractures, faults, or joints oriented roughly perpendicular to bedding planes. The mean strike and dip of the 25 bedding plane features in GW-970(I) is:

- Strike: N50°E (perpendicular to the 140° mean dip azimuth)
- Dip: 52° southeast

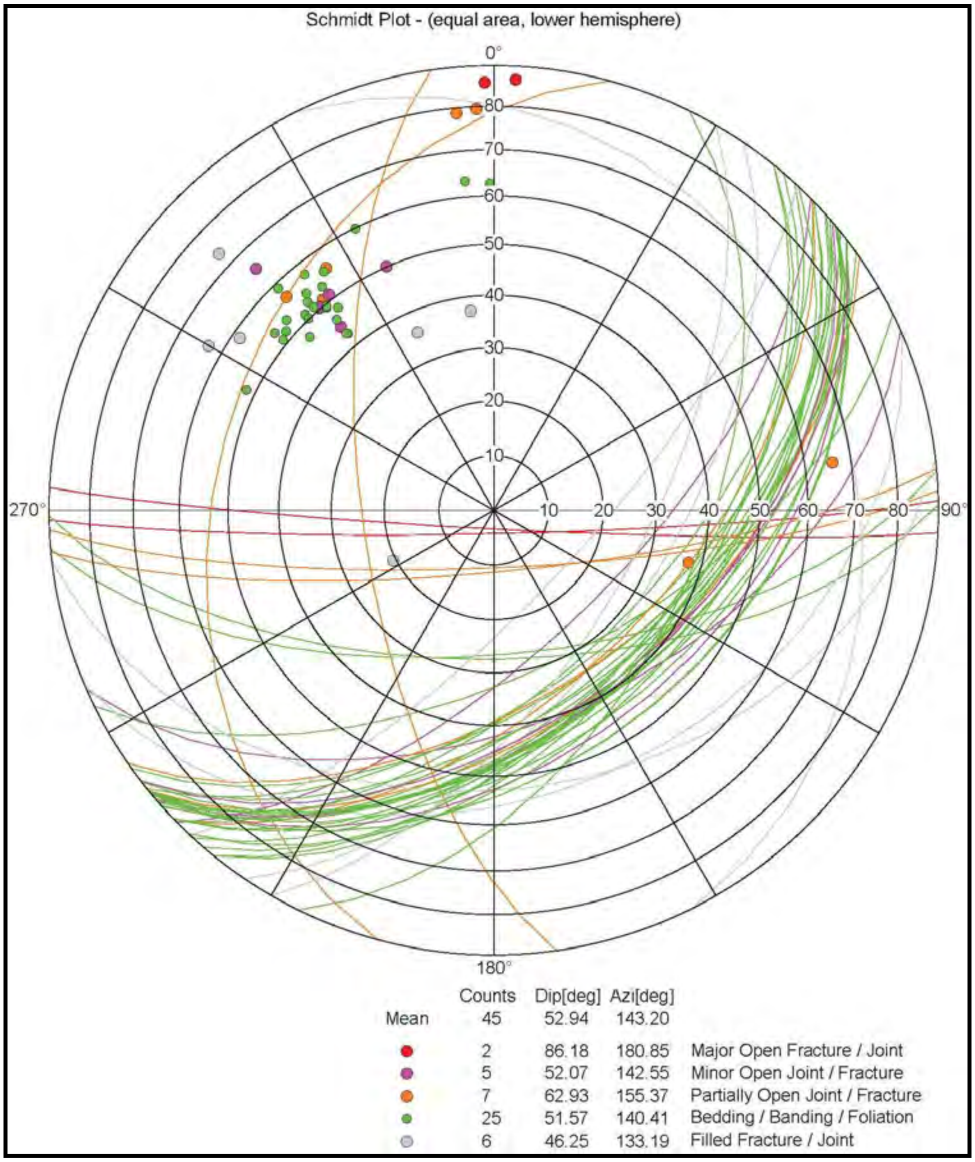
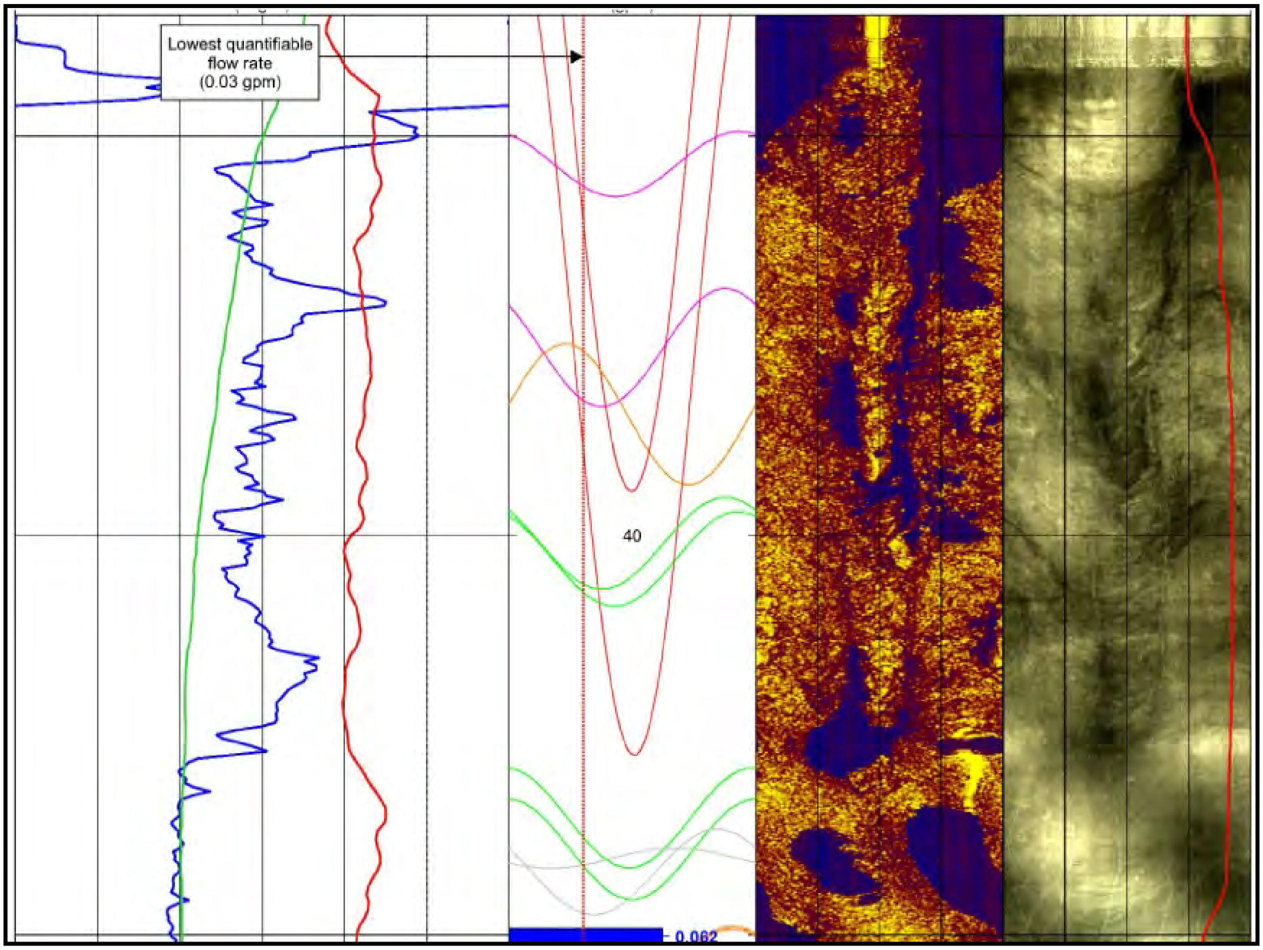


Figure 35. Schmidt Plot of Interpreted Structure Log Features in GW-970(I) Bedrock – Pumpkin Valley Shale

Fracture Interval 34–43 ft bgs: The two uppermost steeply dipping fractures/joints (shown in red on Figures 35, 36, and on the structure log in Exhibit A.8) are clearly visible on the ATV/OTV logs starting at the top of the open borehole (34.1 ft bgs) down to a depth of 43 ft bgs. The OTV log suggests these fractures may in fact represent one relatively large curvilinear joint/fracture or joint/fracture set. Three other fractures/joints with intermediate dip angles similar to regional bedding plane dips were mapped at depths of 35–38.5 ft bgs within this upper zone of fracturing. This shallowest fractured bedrock interval was not tested with the heat pulse flowmeter or by packer testing, but these features may represent joints/fractures with relatively high K values, particularly the prominent steeply dipping features This fracture/joint interval is also coincident with a "washout" interval on the caliper log, where a widening of the borehole extends from the nominal 8 in. diameter to as much as 9.4 in. in diameter (see caliper log in Figure 36 and Exhibit A.8). It should be noted that the uneven borehole from the washout interval and the proximity of the isolation casing, precluded packer testing of this shallow interval. The nearly vertical orientation of the steeply dipping feature(s) also suggests that it could extend upward into the saprolite zone. Discrete depth K testing of this interval is recommended if a Phase II investigation occurs. These high and intermediate angle features and borehole widening are shown in Figure 36, extracted from the uppermost portion of the combination log for GW-970(I).

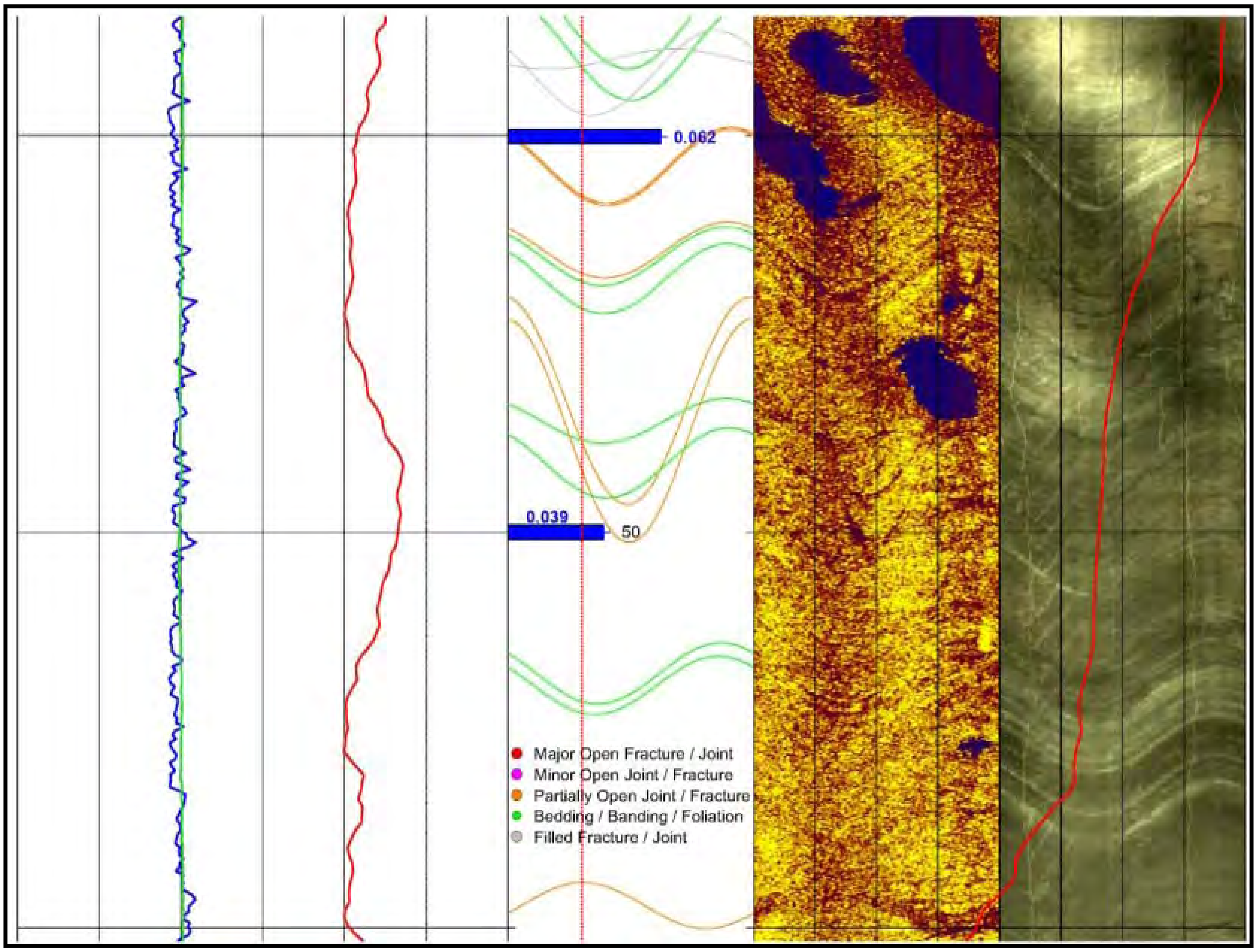


The high and intermediate angle features are shown by the darker patterns on the ATV/OTV logs on the right third of the log that mimic parts of the two parabolas on the structure log in the middle of the figure. Also note the washout interval indicated by the caliper log in blue. See the detailed logs in Exhibit A.8 for log definitions, scales, units, and depths.

Figure 36. Portion of GW-970(I) Combination Log Showing High Angle Fracture Features from ~34–43 ft bgs

Fracture interval 45–50 ft bgs: Immediately below these shallowest bedrock features, heat pulse flowmeter and packer testing were completed to characterize other fractures/joints identified on the structure log at depths of 45–50 ft bgs. Two steeply dipping fracture/joints were identified at depths between 48 to 50.2 ft bgs (see Figure 37). These features are most obvious on the ATV log but also appear faintly on the adjacent OTV log. Two heat pulse flowmeter log tests were conducted near this interval at depths of 45 and 50 ft bgs. The results indicated upward flow at both of these depths at rates of 0.062 gpm and 0.039 gpm, respectively (above the lowest quantifiable flow rate of 0.03 gpm). Note that these were the highest flowmeter rates (all upward) recorded among the five bedrock boreholes.

A packer test was also conducted over the interval 44–54 ft bgs, encompassing these apparent fractures/joints. The average K of this interval was 1.5×10^{-4} cm/sec (the highest K of any packer tested interval from the Phase I packer testing). The combined flowmeter and packer test data indicate that these fractures/joints and/or others between 45 and 50 ft bgs are conducive to ground water flow.



Structural features mapped by the geophysicist between 45-55 ft bgs are shown in orange. The high angle features are shown by the darker patterns primarily on the ATV log. Also note the change in the fluid resistivity curve across this interval shown on the right third of the log. See the detailed logs in Exhibit A.8 for log definitions, scales, units, and depths.

Figure 37. Portion of GW-970(I) Combination Log Showing Potential Fracture Features Discordant to Bedding

Fracture Interval 55–60 ft bgs: Three possible fractures/joints were identified on the structure log centered at depths of 54.7, 56.2, and 59.9 ft bgs. A flowmeter test conducted at 57 ft indicated an upward flow at a rate of 0.031 gpm (at the lowest level of quantifiable flow), suggesting some natural gradient flow from below 57 ft, possibly including flow from the feature at 59.9 ft. A second packer test was conducted in GW-970(I) from 52–62 ft bgs, encompassing these possible fractures. The average K value was 3.1×10^{-5} cm/sec, further suggesting the potential for ground water flow from this interval.

Potential Fractures at 72 and 91 ft bgs: One fracture/joint feature was identified on the structure log at 71.7 ft bgs, with a strike and dip similar to nearby bedding planes. A flowmeter test conducted at 70 ft suggested the potential for a slight upward flow at a rate of 0.017 gpm, however, this flow rate is about half the lowest level of quantifiable flow of 0.03 gpm. A third and final packer test was conducted from 65–75 ft bgs, encompassing this feature with an average K value of 1.4×10^{-5} cm/sec, suggesting the potential for ground water flow from this interval. One last fracture/joint parallel with bedding planes was identified at 91.0 ft bgs, but this feature was not tested.

Fluid Temperature/resistivity Logs: The fluid resistivity log is a reflection of TDS concentrations in well or borehole water, and water producing and water receiving zones may be identified by changes in fluid resistivity (USGS 1996). The fluid resistivity log in GW-970(I) appears reasonably consistent with an upward flux of ground water as described above, assuming that TDS concentrations (particularly colloids) increase with mobilized ground water entering and exiting the borehole. In addition, the very low fluid resistivity from 67–97 ft bgs suggests that ground water flux within the bottom 30 ft of the borehole is very low to nonexistent. This appears consistent with the general tendency for bedrock fractures and ground water flux to decrease with depth within clastic formations on the ORR (Solomon et al, 1992).

Overview of Fracture/flow Data in GW-970(I:) The collective borehole log data and packer test data indicate that vertical flow is occurring within the upper 30 ft of the bedrock borehole in GW-970(I). Ground water from fractures/joints within the interval of 45–60 ft bgs appears to be moving into and upward within the borehole, and exiting the borehole within fractures/joints across a nine foot interval within the uppermost part of the open borehole between the bottom of the isolation casing at 34.1 ft bgs and about 43 ft bgs. This upward flow is artificially induced through the creation of the open borehole but illustrates naturally occurring upward vertical gradients within the upper 25 ft of competent bedrock (i.e., below auger refusal) at GW-970(I). The results also indicate the interconnection between these borehole fractures/joints and upgradient/upslope fractures transmitting relatively shallow ground water from upslope areas of Pine Ridge toward lower elevation downgradient discharge zones along the NT valleys. These findings are consistent with the hydrogeological site conceptual model for the EMDF, and for the Conasauga Group formations of the ORR (see Solomon et al, 1992; and Clapp 1997).

7.2.5.8 Rutledge Limestone (Friendship Formation) Bedrock Hydrogeology

Monitoring well GW-972(I) was drilled within the outcrop belt of the Rutledge Limestone. Rock coring was completed over a 76 ft bedrock interval from depths of 24.2–100.3 ft bgs. A detailed boring log with descriptions and interpretations of the rock cores is provided in Exhibit A.4. Photographs of the rock core are provided in Exhibit A.7. The regolith and bedrock stratigraphic sequence encountered at GW-972(I) is also illustrated in the cross sections of Plates 2 through 4. In addition to the lithologic/stratigraphic profile at GW-972(I), these cross sections include the locations of fractured intervals identified in the rock cores that may indicate zones of potential ground water flux, and maximum bedding plane dip angles (toward the southeast) measured from intact portions of the rock cores.

The surface location of GW-972(I) is situated about 30 ft north of the approximate outcrop trace of the Rutledge/Rogersville contact at the EMDF (see Plate 3). This would place the boring at a position to intercept much of the Rutledge.

Lithologies in GW-972(I) Based on Rock Cores

The percent recovery and quality of rock cores in GW-972(I) was relatively good. The cores showed little signs of intense weathering or staining, even in the uppermost parts of the core. The zone of water table fluctuation in the adjacent shallow well, GW-973(S), occurs around 3–9 ft bgs, so that the upper bedrock surface at about 24 ft bgs appears to occur well below the base of the unsaturated oxygen rich vadose zone.

The cored interval in GW-972(I) is predominantly a sequence of interbedded mostly laminated shale/mudstone and limestone or calcareous siltstone layers. The darker shale/mudstone laminae are gray to maroon, and the lighter limestone or calcareous siltstone laminae are light to dark gray to white. The limestone/calcareous siltstone layers showed consistent effervescence with hydrochloric acid (10% HCl), and typically comprise a much smaller fraction (roughly estimated at <10-30%) of the typically more predominant shale/mudstone layers. The lighter colored laminated limestone/calcareous siltstone layers were never found to exceed about 0.1-0.3 ft in thickness. A few shale beds ≤0.5 ft to about 1 ft in thickness occur intermittently within the cored section. Siltstone beds occur infrequently and mostly within the upper 3 ft of bedrock. The uppermost 4 ft of the core is completely clastic. At and below this uppermost interval, the intermittent laminae of limestone/calcareous siltstone occur with moderate to strong HCl effervescence to the total depth of the borehole at 100 ft bgs. None of the limestone/calcareous siltstone layers showed any indication of dissolution. The boring log and rock core photos should be reviewed for additional details. The rock core photos illustrate the entire cored Rutledge sequence and provide representative closeup views of features noted above (see Exhibit A.7).

The absence of any significantly thick limestone beds (i.e., >0.5–1 ft thick) across the cored interval in GW-972(I) appears inconsistent with descriptions of the Rutledge from other reports (Lee and Ketelle, 1989, King and Haase 1987, and Hatcher et al, 1992). The downhole thickness of the entire Rutledge formation based on two rock cored boreholes at the LLWDDD was 124 ft and 126 ft (125 ft of downhole thickness at a 45° dip angle is equivalent to 88 ft true thickness). Assuming the formation thickness at the EMDF is roughly equivalent to that at the LLWDDD site, the 76 ft of thickness penetrated at GW-972(I) would comprise about 60% of the total formation thickness. The absence of thicker limestone beds as reported elsewhere in BCV, could simply be the result of facies changes along strike. Alternatively, the projected formation contacts and boring location may simply have resulted in the cored interval not penetrating equivalent sections of the Rutledge Limestone encountered in cores elsewhere in BCV. The difference may also represent some combination of these factors.

Rock Core Fractures in GW-972(I)

The cores from GW-972(I) indicate some orthogonally fractured beds of shale that appear to be natural fractures not artificially induced by the mechanical process of coring. The most visually obvious of those occur at four intervals within the bottom three feet of the borehole. These fracture intervals are shown in the rock core photos in Exhibit A.7. Fractures were observed elsewhere within shaly intervals in the GW-972(I) cores but the nature of the fracturing is less certain because of the relatively poorer quality of the core. The rock core fragments in these intervals are less intact and more freely broken apart. The natural condition and in-situ orientation of the fractures in the recovered core fragments are dislocated and sometimes worn and mechanically fragmented. These apparent fractured intervals may represent naturally occurring fracture zones, or may only reflect mechanical fracturing and reworking of the recovered rock fragments by the coring process. The depths of these fractured shaley intervals in GW-972(I) that *may* be conducive to ground water flow are shown on the detailed boring logs in Exhibit A.4, and vertical profile composite logs on Plate 2. Thirty one possible fracture zones were identified in the rock cores between 33 ft and 97 ft bgs.

None of the fractures (natural or mechanically induced) in the cores of GW-972(I) showed any obvious visual indications of staining or weathering (e.g., orange/brown discoloration from FeO/MgO stained surfaces). In addition, none of the thin and intermittent carbonate layers (i.e., laminated limestone/calcareous siltstone layers) showed signs of dissolution. Most of the fractures observed within intact portions of the rock cores of GW-972(I) are mechanical breaks associated with weak shaly bedding plane partings, with no apparent relationship to natural fractures conducive to flow. No slickensides were observed in the rock cores. White calcite filled extensional fractures occur intermittently but none showed indications of weathering, dissolution, or staining that would reflect potential ground water flow.

Results from Borehole Geophysical Logs in GW-972(I)

Caliper Log: The caliper log shows an average borehole diameter of about 8.25 in. except for a widening in the bottom 17 ft of the borehole ranging from 8.5 to 9 in. in diameter between 80.5 and 97.5 ft bgs (the total depth of the log).

Acoustic and Optical Televiewer Logs: The ATV and OTV logs show bedding plane dips that are consistent with the relatively uniform bedding plane dips observed in the rock cores. The quality of the optical log diminishes progressively with depth. This is associated with an assumed increase in turbidity with depth in the borehole, particularly below about 85 ft bgs. After coring, the bedrock borehole was reamed to 101 ft bgs on September 11, 2014, and the logs were completed on October 1, 2014, allowing 20 days for settling of fines within the borehole water column prior to logging. Interpretations of structural features visible on the ATV and OTV logs were plotted by the geophysicist on the Structure Log as described below.

Natural Gamma Ray Log: The NGR log varies from 125–165 API units in GW-972(I), with an average of around 140 ±5 API units. Intermittent shale beds observed in the rock cores and varying in thickness from 0.3 or less to 1.1 ft were plotted against the gamma ray log. No distinct correlation could be made between these beds and the gamma ray log and the gamma ray log could not be used to define bed boundaries. The average gamma ray readings around 140 API units appear to be representative of the overall sequence of interbedded laminated shale and limestone/calcareous siltstone described in the rock cores for GW-972(I). This average value appears to be reasonably consistent with the average gamma ray readings for interbedded laminated shale and limestone observed in the rock cores and gamma ray log in GW-976(I) within the Maryville Limestone formation.

Structure Log: Thirty one planar features were identified on the ATV and OTV logs at irregular depths between 24 and 81.5 ft bgs (the 10 in. diameter casing was set at 24 ft bgs). These features all trend parallel to bedding planes and are consistent with those observed in the rock cores. Most of the features were identified by the geophysicist as bedding surfaces (26); five features were identified as possible joints/fractures ("partially open joints/fractures"). The direct correlation between these features and the ATV/OTV borehole logs are shown by depth on the composite logs in Exhibit A.8. Figure 38 shows these features on a Schmidt plot. The mean value of these bedding plane oriented features in GW-972(I) is:

- Strike: N62°E (perpendicular to the 152° mean dip azimuth)
- Dip: 47° southeast

The structure log and related ATV/OTV logs for GW-972(I) do not indicate any cross-cutting features that might represent shear fractures, faults, or joints oriented roughly perpendicular to bedding planes. The logs suggest a relatively undisturbed structural profile in the bedrock borehole similar to that seen in the rock cores for GW-972(I), and in similar geophysical logs from the bedrock interval of GW-968(I) (compare relatively uniform data plots in both Figures 34 and 38).

Heat Pulse Flowmeter Log: Eight depths were selected in GW-972(I) for flowmeter testing. All but one indicated no flow. The test at 70 ft bgs measured an upward flow rate of 0.026 gpm (1.6 gph, or 37 gpd), however, this value is below the lowest quantifiable flow rate for the instrument of 0.03 gpm (1.8 gph, or 43 gpd). The result is therefore suspect but was included because of similar flow rates in two of the four measurements made at that depth. Packer testing over the interval 65–75 ft bgs, centered on this depth, also resulted in no flow. These results suggest that GW-972(I) does not penetrate bedrock fractures transmitting ground water at relatively higher flow rates such as those observed in GW-970(I).

Temperature and Fluid Resistivity Logs: The 10 in. isolation casing for GW-972(I) was set at 23.75 ft bgs (per the OTV log where it is clearly shown). The temperature and fluid resistivity logs were run from about 10 ft bgs within the casing down to 97 ft near the total depth of the open hole. So there are data for these logs within the casing that are not presented on the geophysical logs in Exhibit A.8 and elsewhere, but were used in interpreting the results from these logs as described below.

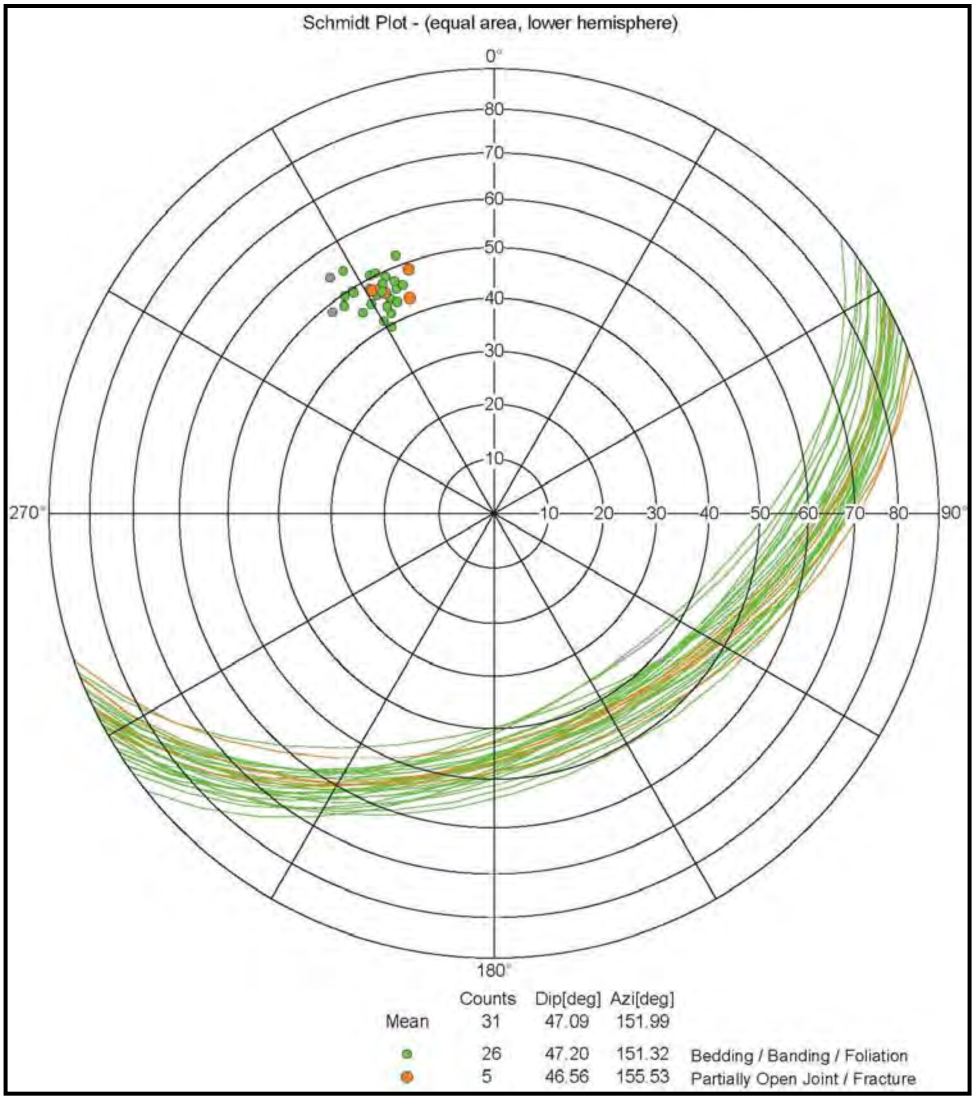


Figure 38. Schmidt Plot of Interpreted Structure Log Features in GW-972(I) Bedrock – Rutledge Limestone

Overall the temperature log shows a steady cooling decline that levels out to a baseline not far below the depth of the 10 in. casing. This appears to reflect a natural thermal gradient between warmer outside air temperatures (at that time) and colder ground water. The temperature log shows a progressive drop in water temperature of about 0.25° C from the bottom of the casing at about 24 ft bgs down to a depth of 30 ft bgs. Below the 30 ft depth, temperatures remain fairly constant, except for an apparent very slight temperature (warming by only about 0.02˚ C) increase that occurs at about 44 ft bgs and remains relatively constant thereafter to total depth. Other than the slight change in temperature at 44 ft bgs, the temperature log suggests nothing associated with possible ground water fracture flow.

The fluid resistivity log suggests potential ground water fluxes are occurring at two places in the borehole; (1) near the junction of the casing and open borehole from 24-25 ft, and (2) from about 44–60 ft bgs. The more subtle gradient change at the lower interval suggests that the ground water flux there may be considerably less than the flux occurring near the bottom of the casing. Baseline resistivity readings change dramatically near the bottom of the casing from about 35 ohm-meters (ohm-m) to a baseline around 46 ohm-m up within the 10 in. casing. This suggests that shallow ground water may be entering the borehole near the casing/borehole junction and flowing upward and commingling with the water column in the casing interval. A more subtle gradient change occurs deeper within the borehole starting abruptly at 44 ft bgs where resistivity declines by about 1 ohm-m within about a one foot interval, and then continues to gradually decline by over another 1 ohm-m down to a baseline level at about 60 ft bgs that continues to total depth (Note that the ohm-meter scale on the geophysical logs varies among the Phase I logs and the resistivity scale difference for GW-972[I] varies by only 6 ohm-m which accentuates this change relative to other resistivity logs).

As previously noted, changes in dissolved solids are reported to correlate with fluid resistivity and may indicate changes in ground water flux within a borehole or well. Relative to the fluid resistivity interval from 44–60 ft bgs, potential fracture zones were identified in the rock cores at nine separate locations between 40 and 60 ft bgs (40.6. 41.1, 42.0, 42.7, 44.8, 45.6, 46.7, 49.7, 54.9, and 59.3 ft bgs). Three of these zones were coincident with possible joint/fractures identified on the structure log. However, the flowmeter tests measuring no flow within and near this interval (at 40, 45, 51, & 61.5 ft bgs) would suggest that the flux if it exists is quite low (well below the 0.03 gpm rate). Packer tests were not conducted near this interval.

Bedding Plane Dip Angles Measured from Rock Cores

Bedding plane dip angle measurements were made at 24 depths along the length of the rock cores of GW-972(I) (see rock core photographs and boring logs in Exhibits A.7 and A.4, respectively). The finely laminated bedding planes common throughout the cores provided ideal locations for visually determining maximum dip angles using a transparent compass within accuracies of about ±2°. The bedding plane dips observed in the cores in GW-972(I) were relatively uniform across the entire cored sequence. The dips range from 35°–50° to the southeast with typical dips of 40°–45°. These measurements are reasonably consistent with the structure log data shown in Figure 38 above. No intervals of extreme or anomalous dips were observed that would suggest zones of tight folding, crumpled beds, or shear fractures. This is also consistent with results from the ATV/OTV and structure logs.

Fracture Interval Packer Testing

Two Phase I packer tests were conducted in GW-972 (I) at depths of 65–75 ft bgs and 75–85 ft bgs. These test intervals included some of the broken shaley intervals thought to represent potential fractured intervals described above, the single flowmeter test zone at 70 ft bgs that suggested potential upward flow, and two possible fracture/joints identified at 81 ft on the structure log. Neither test interval would sustain any flow under the injection flow pressure limitations of the tests (which are designed to not overpressure and artificially induce fracture flow into the formation). The no flow results from the packer tests were inconclusive but suggest that the potential fracture locations identified in the rock cores and structure logs within the tested intervals do not represent zones of higher hydraulic conductivity or significant ground water flux. Depth discrete downhole testing of fracture zones provides the most conclusive means of determining the permeability of possible fracture zones identified in rock cores or on borehole geophysical logs. More sensitive and depth discrete borehole testing is recommended for Phase II investigations, including the interval between 40–60 ft bgs where the fluid resistivity/temperature gradient occurs.

Overview of Fracture and Flow Data in GW-972(I)

Continuous water level readings from the GW-972(I)/GW-973(S) well pair indicate water level elevations that consistently track each and differ periodically by no more than about 0.1 ft. During recharge events these water levels track one another at almost identical elevations. During periods of declining and baseline water levels, the water level elevation in GW-972(I) is about 0.1 ft higher than that in the adjacent shallow well. These data, in combination with the results described above, suggest that shallow regolith ground water may be intersecting the open borehole in GW-972(I) at and just below the bottom of the isolation casing. With regard to the deeper section of the open borehole, the collective results from GW-972(I) (from rock cores, geophysical logs, packer tests, and continuous water level monitoring) suggest that only the interval from 44–60 ft bgs may be yielding a very slight amount of ground water to the borehole. This could account for the slight increase in head between GW-972(I) and GW-973(S) noted above. More sensitive depth-discrete flow testing could be used to quantify the potential low hydraulic conductivity and/or ground water flux of this interval (as well as others) during a Phase II investigation.

7.2.5.9 Rogersville Shale Bedrock Hydrogeology

One Phase I well, GW-974(I), was drilled to 100 ft in bedrock within the outcrop belt of the Rogersville Shale using air rotary drilling. Rock coring was not conducted at this location. The geophysical logs were therefore relied upon to provide an indication of the lithologic sequence and structural features in the bedrock portion of this borehole. The surface location of GW-974(I) is situated about 60 ft north of the approximate outcrop trace of the Rogersville/Maryville contact at the EMDF (see Figure 1 and Plate 4). This positions the boring to intercept the middle to lower sections of the Rogersville.

Lithologic Descriptions from BCV Sites along Strike with the EMDF

Lithologic descriptions of rock core data from the WBCV site (LLWDDD) indicate that the upper Rogersville consists dominantly of maroon shale with thin calcareous siltstone or argillaceous limestone lenses (see Table 20 for more detailed lithologic descriptions from Lee and Ketelle 1989). The lower Rogersville consists dominantly of dark gray shale with thin laminated limestone lenses (a few thin limestone beds may represent the Craig member near the top of the lower Rogersville).

Ogden Site B and C borings adjacent to and along strike with the EMDF did not penetrate the bedrock section of the Rogersville, and other borings/wells drilled within the EMWMF footprint did not include extensive rock coring to provide detailed descriptions of the Rogersville for comparison to the EMDF.

Results from Borehole Geophysical Logs

Natural Gamma Ray Log: The NGR log from GW-974(I) provides the only general indication of lithologies for the Rogersville at the EMDF. The NGR log shows a number of deflections with lower API units suggesting the potential for limestone beds within the bedrock sequence of GW-974(I). However, only two of those deflections centered at 23.3 and 52.0 ft bgs fall below 100 API units. Note that two relatively thicker limestone beds (1.5 and 1.8 ft thick) identified in the rock cores of GW-976(I) correlated with lower readings of 85 and 92 API units, whereas thinner limestones interbedded with shales correlated with higher API readings. Without rock core data for confirmation it is impossible to confirm whether or not these or other lower API deflections reflect limestone beds. The majority range of NGR log readings between 120 and 160 API units suggests that most of the bedrock in GW-974(I) is likely to be comprised of the dominant clastic shale and siltstone sequences described elsewhere along strike in BCV.

Structure log The quality of the OTVATV logs from GW-974(I) are poor relative to other boreholes because of relatively high turbidity water in the borehole. Alliant/URS purged the borehole water and ran the OTV log through the open air column of the borehole but the log quality remained relatively poor, although some bedding plane surfaces are clearly visible. However, the image quality of the OTV log below the water level at 59.4 ft bgs was completely obscured by the turbid water. Seventeen planar features were identified on the ATV and OTV logs at irregular depths between 27 and 88 ft bgs (the 10 in. diameter casing was set at 12.5 ft with the inner 8 in. diameter casing set at 15.0 ft bgs). These features all trend parallel to bedding planes. Only one of the features was identified by the geophysicist as a possible joint/fracture. The direct correlation between these features and the ATV/OTV borehole logs are shown by depth on the composite logs in Exhibit A.8.

Figure 39 shows these features on a Schmidt plot. The mean value of the seventeen bedding plane oriented features in GW-974(I) is:

- Strike: N61°E (perpendicular to the 151° mean dip azimuth)
- Dip: 54° southeast

As illustrated in Figure 39, the structure log data have a relatively wider range of strike and dip than in other boreholes, with strike directions ranging from about N45°E to N80°E, and dips ranging from about 42°–73° southeast. Some of this variation may be influenced by the poorer quality of the OTV/ATV logs, but some may result from a greater natural variation in deformation of the Rogersville.

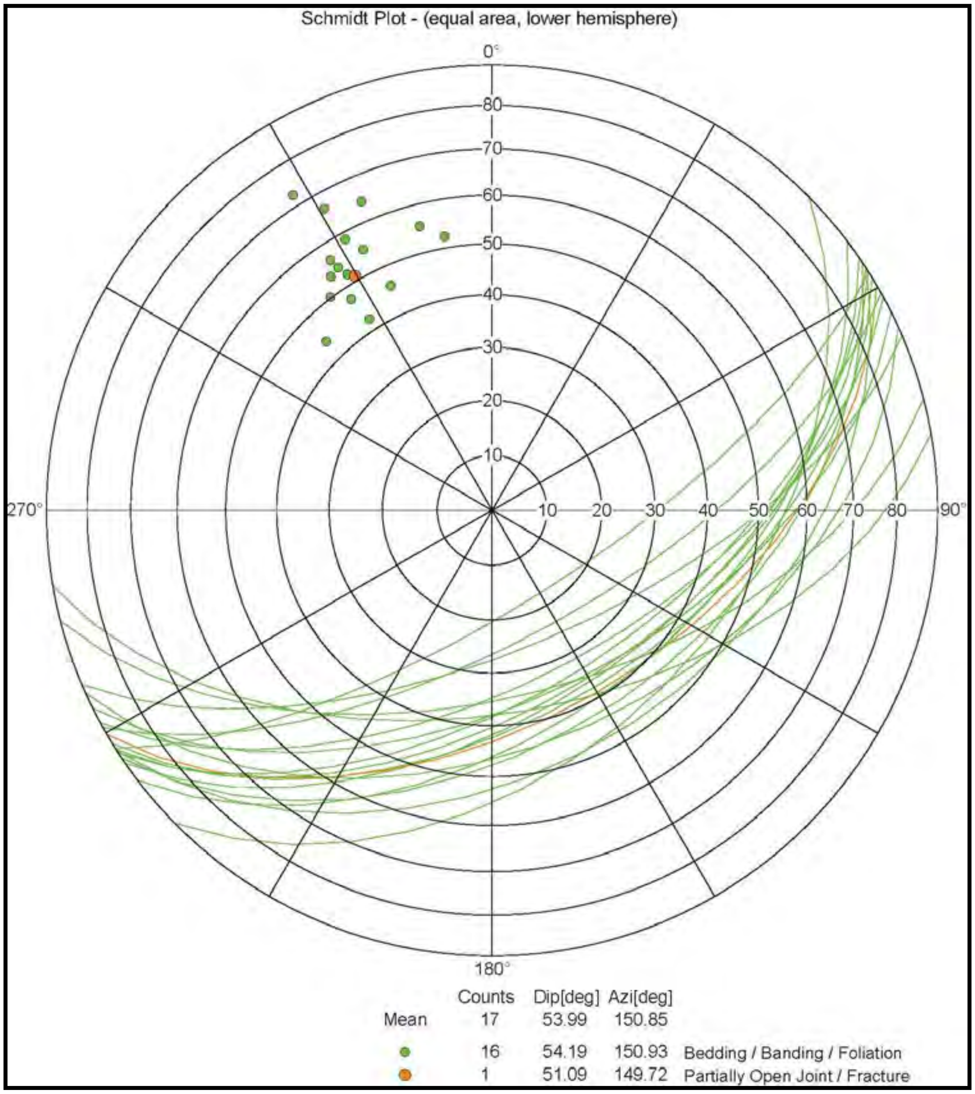


Figure 39. Schmidt Plot of Interpreted Structure Log Features in GW-974(I) Bedrock – Rogersville Shale

Heat Pulse Flowmeter Log: Seven depths were selected in GW-974(I) for flowmeter testing at intervals above 65 ft bgs. All but one indicated no flow. A number of tests at 35 ft bgs suggested an average upward flow rate of 0.016 gpm. However, this average value is below the lowest quantifiable flow rate for the instrument of 0.03 gpm, and the overall results from the series of tests at 35 ft bgs were considered by the geophysicist to represent noise and to not reflect a valid flow measurement (see Exhibit A.8 for additional details of these tests). The single packer test conducted in GW-974(I) over the interval 33–43 ft bgs (encompassing the 35 ft depth) also resulted in no flow, within the limits of the packer testing methodology.

Temperature and Fluid Resistivity Logs: The isolation casing for GW-974(I) was set at 15 ft bgs. The temperature and fluid resistivity logs were run from about 10 ft bgs within the casing down to about 95 ft near the total depth of the open hole. So there are data for these logs within the casing that are not presented on the geophysical logs in Exhibit A.8 and elsewhere, but were used in interpreting the results from these logs as described below.

Overall the temperature log shows a steady cooling decline from about 17.8° C within and just below the isolation casing that levels out to a baseline low temperature of about 13.7° C around 25 ft bgs. From 35–95 ft bgs, the fluid temperature then shows a gradual steady increase. This appears to reflect a natural thermal gradient between warmer outside air temperatures at that time and colder ground water.

The fluid resistivity log suggests a potential ground water flux occurring between 16.9 and 17.7 ft bgs where a sharp increase in resistivity occurs from about 24 to 43 ohm-m over a depth interval of less than one foot. This change occurs at 17 ft bgs, about 2 ft below the bottom of the isolation casing at 15.0 ft bgs. Below this sharp resistivity break the fluid resistivity remains steady at around 44 ohm-m to total depth. The data suggest the possibility of a short interval of ground water flux centered around 16.3 ft bgs followed by little or no flux below that depth. There is a suggestion of a possible steeply dipping fracture on the OTV/ATV log from about 18–19.5 ft bgs, however, this feature is visually subtle and may be considered speculative. No packer tests were conducted near this interval to corroborate the results from the resistivity log. More sensitive vertical profiling of ground water flux is recommended for the GW-974(I) borehole to distinguish very low hydraulically conductive intervals/depths from intervals with little or no ground water flow.

Fracture Interval Packer Testing

Only one Phase I packer test was conducted in GW-974 (I). The test was conducted over the interval 33–43 ft bgs, based on the results of the flow meter test at 35 ft bgs and a possible joint/fracture at 37.5 ft bgs interpreted by the geophysicist. No flow could be established within the flow and pressure constraints of the packer testing methodology (i.e., tests cannot overpressure the formation and artificially induce flow above anticipated formation pressures at the selected depth of the test).

Overview of Fracture/flow Data in GW-974(I)

Continuous water level readings from the GW-974(I)/GW-975(S) well pair indicate water level elevations that consistently track each other and differ by approximately 1.0 to 1.5 ft during baseline flow periods. The water levels in the deeper well pair occur consistently above those in the shallow well, except during relatively brief recharge periods when these water levels track one another at closer elevations. The paired water level data indicate upward ground water flow gradients. The fluid resistivity suggests that ground water could be entering the borehole through a fracture(s) around 17-19 ft bgs. However, the flowmeter tests and packer test performed in GW-974(I) did not identify intervals of potential ground water flux (Note that the flowmeter tests at 20 ft bgs just below the 17-19 ft interval recorded no flow). The collective results suggest that upward flow in GW-974(I) must be occurring at relatively slow rates (incapable of detection by the heat pulse flowmeter or packer tests) at one or more intervals in the borehole that are unclear. More sensitive depth-discrete flow testing could be used to quantify potential zones of ground water flux within the borehole of GW-974(I) during a Phase II investigation. The Phase I results indicate that as in GW-972(I), the overall ground water flux in GW-974(I) is relatively low and much lower than that observed in GW-970(I).

7.2.5.10 Maryville Limestone (Dismal Gap Formation) Bedrock Hydrogeology

Monitoring well GW-976(I) was drilled at the crest of the east-west trending spur ridge that aligns roughly with the southern edge of the EMDF footprint. The surface location is situated about 220 ft south of the approximate outcrop trace of the Rogersville/Maryville contact at the EMDF (see Figure 1 and Plate 3). This locates the boring at a position to roughly intercept the lower one third of the Maryville. Rock coring was completed over a bedrock interval of 71.7 ft from depths of 28.4–100.1 ft bgs (auger refusal occurred at 24.4 ft bgs with 10 in. PVC isolation casing set at 28.4 ft bgs). A detailed boring log with descriptions and interpretations of the rock cores is provided in Exhibit A.4. Photographs of the rock cores are provided in Exhibit A.7. The regolith and bedrock stratigraphic sequence encountered at GW-976(I) is illustrated in the cross sections of Plates 2 through 4. In addition to the lithologic/stratigraphic profile at GW-976(I), these cross sections include the locations of fractured intervals identified in the rock cores that could indicate possible zones of ground water flux. Other structural features such as maximum bedding plane dip angles (toward the southeast) are shown. The azimuth and dip angles of structural features such as bedding planes and potential fractures/joints based on interpretations of the OTV/ATV logs were plotted on the structure log and on a Schmidt plot as shown below and in Exhibit A.8.

Lithologic Descriptions from BCV Sites along Strike with the EMDF

Lithologic descriptions of rock core data from the WBCV site (LLWDDD) indicate that the Maryville Limestone consists of limestone interbedded with dark gray shale that typical contains thin lenses of light gray limestone and calcareous siltstone. Maroon shale beds occur in both the upper and lower Maryville. More intraclastic limestone occurs in the upper Maryville, while the lower Maryville includes more thin laminated and oolitic limestone. Pinkish limestone beds occur in the lower 40 ft (see Table 17 for more detailed lithologic descriptions from Lee and Ketelle 1989).

Ogden Site B and C borings adjacent to and along strike with the EMDF did not penetrate the bedrock section of the Maryville, and other borings/wells drilled within the EMWMF footprint did not include extensive rock coring to provide detailed descriptions of the Maryville for nearby comparison to the EMDF.

Lithologies in GW-976(I) Based on Rock Cores

Unlike the rock cores from GW-972(I), those from GW-976(I) show evidence of intense weathering and leaching within the uppermost part of the cored section. The upper section of cores from the isolation casing (set at 27.75 bgs) down to about 50 ft bgs has an overall brownish hue that transitions into a lower interval of bedrock with an overall grayish hue. The brownish section correlates with a heavily weathered and chemically leached vadose and upper water table bedrock zone. The lower grayish section correlates with a saturated zone that is far less weathered and less subject to oxidation and chemical leaching. The transition occurs from about 50–54 ft bgs (see rock core photos in Exhibit A.7).

Also in contrast to GW-972(I), the percent recovery and quality of rock cores in GW-976(I) is relatively poor, but improves with depth as the boring was advanced into more competent bedrock. Much of the recovered upper core interval consists of broken rock fragments separated by typically shorter core intervals of intact rock. The upper part of the cored interval from 28–44 ft bgs is composed of interbedded shale, siltstone, and laminated shale and siltstone, with the lowermost 10 ft consisting of laminated shale and siltstone. None of this upper interval contains any limestone or calcareous material that reacts to HCl. Below this upper part of the cored interval, and near the water table (or potentiometric surface), is a 3.2 ft interval from which no core was recovered. The upper part of this interval of no recovery is coincident with an interval (43.5–44.7 ft) where the caliper log indicates a "washout" where the nominal 8 in.

borehole diameter increases from 8.5 –10 in. in diameter (these “washout” zones are highlighted in yellow on the caliper logs of Plate 2). This interval and several others like it, where core was only partially recovered, may be coincident with weaker shaley intervals whose fine-grained clay/silt size particles and shaley rock fragments are disintegrated during the coring process which uses water as a circulation and cooling fluid. These intervals of lost or poor rock core recovery may or may not be coincident with fractured zones conducive to ground water flow. Borehole camera logging (downward and side projected) and discrete depth flow testing could be used to determine the hydraulic conductivity of these intervals in a Phase II effort.

Limestone lamina and beds first occur at and below depths of 47.7 ft bgs, directly below the zone of lost core just noted. All limestone throughout the cores responded readily with HCl effervescence. A relatively thick sequence of laminated shale and limestone about 12.5 ft thick occurs immediately below the upper washout interval at 44 ft bgs, and is followed to total depth with a variable sequence of interbedded limestone, shale, and laminated shale/limestone. The gray limestone beds vary from about 0.9–1.8 ft in thickness, the shale beds vary from about 0.5 ft to as much as 4.2 ft in thickness, and the laminated shale/limestone intervals vary from about 0.5 to 2.3 ft in thickness. The detailed stratigraphic profile is described and illustrated in the boring logs in Exhibit A.4, and illustrated in the cross sections of Plates 2 through 4.

Fractures Identified in Rock Cores

Among the lower 60% of the bedrock cored sequence in GW-976(I), are eleven separate intervals of limited/lost core that vary from about 0.5–1.7 ft. As noted above, these may represent intervals composed of weak and possibly fractured shale that were disintegrated during the coring process. The quality of the OTV/ATV logs and sensitivity of other geophysical logs are insufficient to identify the in-situ conditions and structural features of these intervals.

No intervals with voids or sudden sharp losses in circulation were encountered during the drilling and rock coring, or indicated on the geophysical logs that would suggest large scale karst dissolution features or fractures associated with the limestones identified in the rock cores. The driller did note a loss of approximately 30 gallons of fluid during the coring between Pulls 10 and 13, which span the 8.1 ft interval from 49.7–57.8 ft bgs. In addition, fractures with iron oxide staining and weathering were noted in the cores at several depths as indicated on the boring logs. Some of these occur near or above the potentiometric surface in the vadose zone. Four were identified within the saturated zone and may represent fractures conducive to ground water flow. The presumed shaly intervals noted above where core was not recovered may also possibly represent weaker fractured intervals that could be conducive to flow. Discrete borehole interval testing is recommended to determine the hydraulic conductivity of these features during a Phase II investigation.

The rock cores recovered from GW-976(I) vary from highly weathered intervals composed of loose and broken rock fragments to intact sections of core where fractures are easily discerned. Only within the intact portions of the cores can the nature and orientation of fractures be accurately defined. Many of the fractures in the intact sections of cores are mechanical breaks along weak bedding plane surfaces. Other fractures within intact sections of cores judged to be associated with naturally weathered fractures were identified on the detailed boring logs and rock core photos.

Bedding Plane Dips and Possible Folds Based on Rock Cores

Maximum bedding plane dip angle measurements were made at representative intervals (37 total) throughout the rock cores of GW-976(I) wherever intact cores were obtained. The bedding planes common throughout the cores along planar laminations provided ideal locations for visually determining maximum dip angles using a transparent compass with accuracies of about ±2°. The azimuth of the rock cores is unknown relative to true north so the in-situ strike of the beds is unknown. The bedding plane dips observed in GW-976(I) rock cores were not as uniform as those seen in GW-972(I) cores. While relatively uniform dips were observed across some sections of the cored interval, steeper dips in some core segments suggest that intervals of flexed or folded beds occur within some intervals of the Maryville penetrated in GW-976(I). The dips vary from 40°–85° and are assumed to be generally toward the southeast. Relatively steep dips in the range of 70°–85° were identified at depths of 41, 42.5, and 51 ft bgs, and at depths from about 70–74 and 80–85 ft bgs. Steeper dips at these depths and intervals may reflect the effects of localized drag folds or shear fractures consistent with local and regional tectonic stresses and thrusting toward the northwest.

A zone of deformation was reported in the upper part of the Maryville at the WBCV tumulus site (Lee and Ketelle, 1989). This zone contained a relatively thin interval several inches to several feet thick with drag folding, gouge, or vertically extensive shears, observed in six core holes. The zone varied slightly in thickness and character but was found in approximately the same stratigraphic interval between 46 and 79 ft below the Maryville/Nolichucky contact. This deformed interval is stratigraphically well above the location and depth range of the middle to lower Maryville interval cored in GW-976(I), but the steep beds observed in the GW-976 cores may reflect similar structural features. Tight chevron folds are visible in road cuts at Dismal Gap within the lower Maryville about 13 miles northeast of the EMDF along strike with Pine Ridge, suggesting that structural deformation is not uncommon within the Maryville.

Results from Borehole Geophysical Logs

As noted above, the bedrock boring log from GW-976(I) based on detailed descriptions of the rock cores were compared with the suite of geophysical logs to establish potential cross correlations between the two sets of data. Results of the log interpretations and correlations with rock cores are reviewed below. GW-976(I) is the only deep borehole location where the unsaturated zone was exposed below the bottom of the isolation casing (at 27.75 ft bgs). The water level in the borehole at the time of the logging was 44.25 ft bgs, exposing a 16.5 ft interval of unsaturated bedrock in the upper portion of the borehole (see geophysical logs in Exhibit A.8).

Natural Gamma Ray Log: In general, the NGR log from GW-976(I) was found to correlate with some of the relatively thicker limestone and shale beds on the order of 1.5–2.0 ft thick. Only rough baseline correlations can be observed between thinner interbedded limestones, shales, and siltstones and the NGR logs. Further interpretations and correlations between rock cores and the NGR log for GW-976(I) are reviewed above in Section 7.2.5.4, and should be referenced for more detail.

Caliper Log: The caliper log for GW-976(I) was placed alongside the bedrock boring log to correlate “washout” intervals with rock core data (i.e. - lithologies, fractures, core recovery, core quality, etc.). The caliper log shows seven “washout” intervals where the nominal 8 in. diameter borehole widens to diameters from 8.5–9.0 in. (shown on Plate 2). The most shallow of these intervals (43.5–44.7 ft) occurs near the potentiometric surface at about 44 ft bgs where a 1.2 ft interval widens to almost 10 in. Other intervals were centered at 52.0 ft bgs (0.7 ft long), 63.7 ft bgs (0.2 ft), 72.2 ft bgs (2.0 ft), 74.4 ft bgs (0.5 ft), 77.9 ft bgs (0.9 ft), and 83.7 ft (0.3 ft). Each of these intervals coincide with depth intervals where core losses occurred. These intervals may represent zones of fractured shale that are more easily broken up and pulverized as the outer core barrel and diamond bit is advanced and recirculating core fluids slurry the soft fine grained clay particles away and slightly widen the borehole in the process. Unfortunately with no core recovery from these intervals, the true lithologic composition and potential fracturing of these zones is uncertain.

Structure Log: A total of 44 structural features were identified on the ATV and OTV logs at irregular depths across the length of the bedrock borehole. Most of the features were identified by the geophysicist as bedding plane surfaces (green - 25); 15 are identified as possible open joints/fractures (orange, red, purple), with four identified as filled joints/fractures (gray). The direct correlation between these features and the ATV/OTV borehole logs are shown by depth on the composite logs in Exhibit A.8. Figure 40 shows these features on a Schmidt plot. The mean orientation of the 25 bedding plane features in GW-976(I) is:

- Strike: N43°E (perpendicular to the 133° mean dip azimuth)
- Dip: 58° southeast

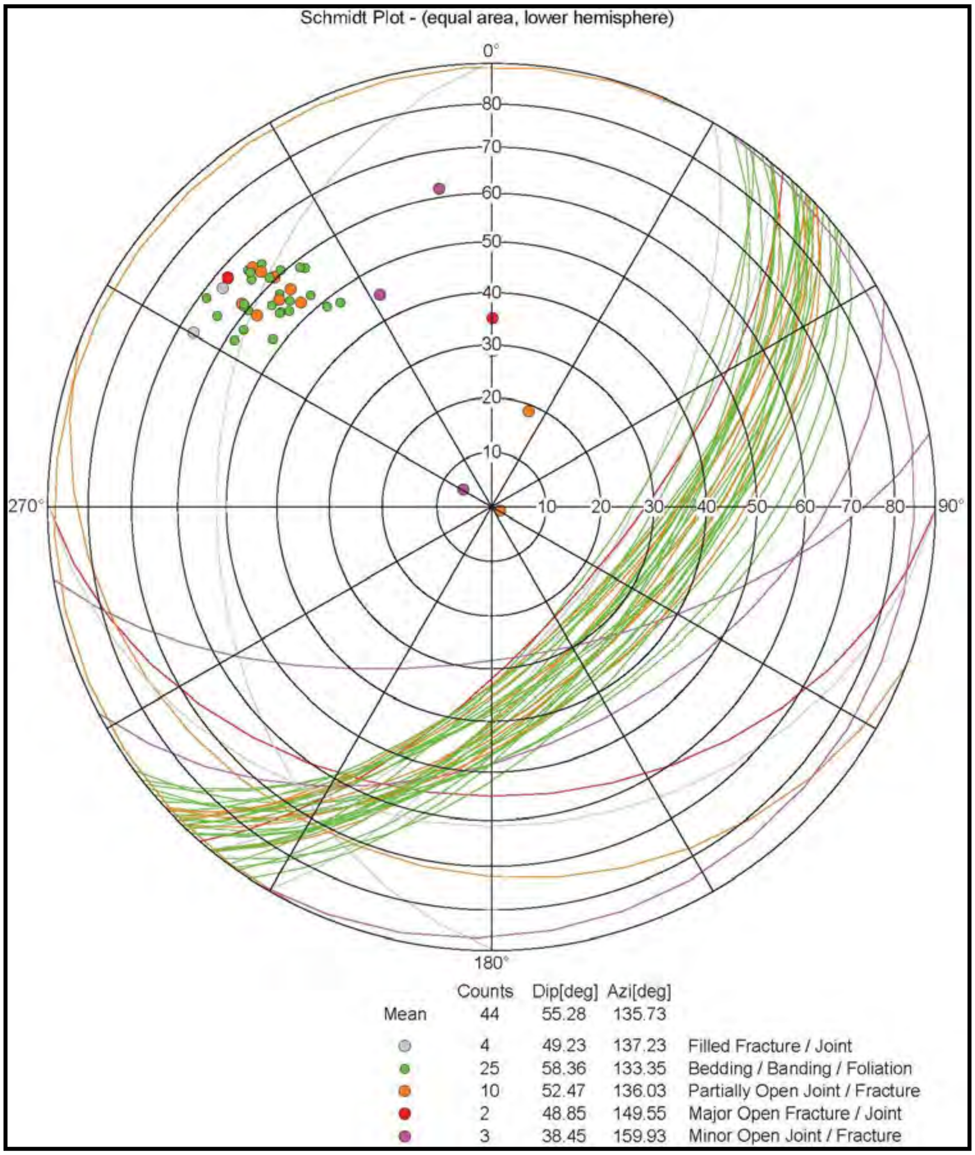


Figure 40. Schmidt Plot of Interpreted Structure Log Features in GW-976(I) Bedrock – Maryville Limestone

As shown on Figure 40, six of the 15 possible open joints/fractures have orientations discordant with the bedding planes, while seven of the 15 are within the overall range of the bedding plane features. The structure log bedding plane features show a narrower range of bedding plane dips mostly between 50°–70°, whereas the bedding plane dip measurements made from the rock cores vary from 40°–85°. The specific depths and intervals with steeper dips noted above as measured within intact sections of the rock cores occur where the ATV/OTV log quality is relatively poor and subject to variable interpretations. The rock core dip angles are believed to be more reliable indicators of true maximum dip angles at depths where measured (see boring logs for depths of maximum dip angles measured in rock cores). The number, range, and variation among the features mapped on the structure log is consistent with the wider range of features and dip angles observed in the rock cores of GW-976(I) (compare the relative uniformity of the Schmidt plot data for GW-972[I] versus that for GW-976[I]).

Heat pulse Flowmeter Log: Seven depths were selected in GW-976(I) for flowmeter testing at intervals between 50 and 93 ft bgs. Five of the seven indicated no flow. Two of the tests at 75 and 80.5 ft bgs recorded upward flow rates: 0.034 gpm (2.02 gph or 48.6 gpd) at 75 ft, and 0.022 gpm (1.35 gph or 32.3 gpd) at 80.5 ft. These results suggest ground water flow entering the borehole below 80.5 ft with additional flow contributions between 75 and 80.5 ft bgs increasing the total upward flow rate to levels slightly above the lowest quantifiable flow rate of 0.03 gpm (1.8 gph or 43 gpd). One horizontal feature was identified on the structure log at a depth of 77.7 ft bgs (identified by the geophysicist as a possible "minor open joint/fracture"). This feature is coincident with a significant "washout" interval about 0.7 ft long and interpreted to be the location of 0.9 ft of lost core recovery in Pull 20. This interval as well as other zones of lost core may be associated with relatively weak and fractured shale beds that are disintegrated during the rock coring process. Actual in-situ lithologic and structural conditions are unknown, but the OTV/ATV logs do indicate a horizontal feature at 77.7 ft that may represent a water bearing fracture. One of the two packer tests conducted in GW-976(I) was completed over the interval 68-78 ft bgs. This tested interval encompasses the 77.7 ft feature, as well as two other minor open joints/fractures mapped on the structure log at depths centered near 71.5 and 72.5 ft bgs (but located above the heat pulse test at 75.0 ft with the upward flow rate of 0.034 gpm). The packer test results from 68-78 ft indicated an average K value of 1.2×10^{-5} cm/sec.

The general correlations between the heat pulse flowmeter tests indicating upward flows at 75 and 80.5 ft bgs and the lower packer test and boring/structure log data were not observed at the shallower depths in GW-976(I). Zero flow heat pulse tests at 50, 62.5, and 67 ft bgs suggest either no or extremely low flow (unquantifiable with the heat pulse instrument) within the shallower sections of the open borehole. The shallower packer test in GW-976(I) over the interval from 49.5-59.5 ft bgs indicated an average K value of 5.6×10^{-5} cm/sec. The packer test results suggest that this interval is capable of transmitting ground water, and several possible fractures fractures/joints were identified on the structure log between 51 and 57 ft within this tested interval. In addition, the boring log rock core data also indicate several fractures with evidence of staining/weathering within this packer tested zone. The caliper log also shows a "washout" interval of 0.7 ft from 51.7–52.4 ft bgs that suggests the potential for a weak fractured zone capable of transmitting ground water flow. It is unclear why the heat pulse flowmeter did not detect flow above or below these apparent hydraulically conductive features.

Temperature and Fluid Resistivity Logs: The temperature and fluid resistivity logs both show a similar overall decline from near the water table or potentiometric surface at 44.3 ft bgs down to 65 ft bgs where both curves level off to fairly constant levels between 65 and 81 ft bgs. From 81 ft to total depth around 100 ft, the temperature continues to decline very slightly by around 0.1° C to a low near 13.8° C. Between 81 ft and total depth the fluid resistivity curve increases only very slightly. If changes in fluid resistivity gradients correlate with fluid flow in the borehole (as noted by the USGS 1996), then the resistivity curve would suggest that flow (presumably upward) begins to occur near 65 ft bgs and continues to gradually increase up toward the water table at 44.3 ft. The zero flow data from the heat pulse flowmeter at

50 ft bgs suggests that if borehole flow is occurring across this shallower interval, the flow rates must be very low rates or they may be occurring more laterally across the borehole rather than vertically.

Overview of Fracture/Flow Data in GW-976(I)

The saturated zone at GW-976(I) is relatively deep compared with the other Phase I well pairs and located as much as 20 ft below auger refusal down within the zone of competent bedrock. The absence of a shallow well screened exclusively at the water table interval precludes a determination of vertical gradients based on well pair methods such as those described above in Section 7.2.3.3. However, GW-976(I) is located along the crest of a spur ridge more distant and more hydraulically isolated from Pine Ridge. This location means that GW-976(I) is far less likely to be subject to the influence of steep pressure gradients that may occur along the lower flanks immediately south of Pine Ridge (e.g., at locations such as GW-968(I) and GW-970(I). The area available for ground water recharge near GW-976(I) is also considerably less than that for locations directly along the lower slopes of Pine Ridge. The water level hydrograph for GW-976(I) appears to clearly reflect these conditions. The effects of recharge from precipitation events is much more subdued for GW-976(I) relative to the other eight Phase I wells, yet longer term cumulative increases in water levels are seen in relation to precipitation events (at least for the wet non-growing season record so far).

A number of potential fracture intervals were identified in the rock cores from GW-976(I). Potential fractures were also identified at various depths on the structure log. The heat pulse flowmeter results indicated upward borehole flow at 75 ft slightly above the quantifiable flow limit of the instrument and a suggestion of upward flow at a lower flow rate from below the 80.5 ft bgs test depth. Other heat pulse tests above and below these depths indicated no detectable borehole flow up or down. The two packer tests in GW-976(I) indicated intervals with intermediate K values (10^{-5} cm/sec) suggesting that fractures within these ten foot intervals are conducive to ground water flow. Overall vertical gradients cannot be independently assessed at this location without a shallow well pair for comparison of shallow/deep hydraulic heads. The single well at this location precludes a determination of vertical gradients at the GW-976(I) location. More sensitive depth-discrete flow testing could be used to systematically quantify potential zones of ground water flux within the borehole of GW-976(I) during a Phase II investigation. The Phase I results suggest that upward borehole flow may be occurring from a fracture near 78 ft bgs. Borehole flow elsewhere is unclear but the presence of other potential fractures along with the results of the packer tests suggest that other intervals within the borehole are conducive to ground water flow.

7.2.5.11 Nolichucky Shale Bedrock Hydrogeology

The contact between the top of the Maryville Limestone and the overlying Nolichucky Shale occurs at distances 400 ft or more south of the southern edge of the proposed waste limits of the EMDF and south of the existing Haul Road. Because of the southeasterly regional dip of the beds, the Nolichucky does not underlay the EMDF footprint, and was excluded from the Phase I investigation.

8. CONCLUSIONS AND RECOMMENDATIONS

The limited Phase I site characterization results were intended to provide TDEC and EPA with enough information to make an informed decision regarding site suitability for the EMDF. The major conclusions of the limited Phase I investigation are summarized below in Section 8.1. The key Phase I results related to the EMDF engineering conceptual design and related to questions of site suitability are summarized in Section 8.2. General recommendations for a follow on Phase II investigation are presented in Section 8.3, contingent upon site approval from TDEC and EPA.

8.1 PHASE I CONCLUSIONS

General conclusions from the Phase I investigation are presented below according to the same general categories presented above in Section 7. It should be emphasized that the Phase I results were limited in scope to five well pair locations, three stream gaging locations, six observational monitoring locations, and the current three month period of continuous monitoring. The spatial and temporal range of these data are therefore limited, but provide useful baseline data for a follow on Phase II investigation should the site be approved for further investigation and design.

8.1.1 Surface Water Hydrology and Water Quality

8.1.1.1 Surface Hydrology

Total rainfall during the three month reporting period from December 2014 through February 2015 is similar to long-term averages and does not constitute a particularly dry or wet condition relative to climatic normals. The largest and most intense precipitation events recorded during the reporting period are not high magnitude events in terms of historical precipitation frequencies. Storms of similar magnitude are expected to occur several times in an average year in the vicinity of the EMDF site. Estimated total surface runoff relative to precipitation inputs analysed for nine runoff events was within a reasonably expected range for the winter wet season. The SWG-2 catchment exhibited low total runoff relative to rainfall, probably due to disturbance of surface drainage patterns and ungaged runoff during high flow events. The SWG-2 and SWG-3 subcatchments responded more quickly to precipitation than did the SWG-1 subcatchment in most cases, reflecting differences in catchment area and hydrologic travel times.

The ranges of peak flow rates observed at the gaging stations during nine runoff events are:

- SWG-1: 0.14-9.63 cfs (62.84–4322 gpm)
- SWG-2: 0.02-0.64 cfs (8.98–287.3 gpm)
- SWG-3: 0.13-2.17 cfs (58.35–974 gpm)

Baseflow rates for SWG-1, SWG-2, and SWG-3 during the current monitoring period fall below the minimum quantifiable flow rates set by the flume vendor of 0.096 cfs (43.3 gpm) for SWG-1 and SWG-3, and 0.037 cfs (16.8 gpm) for SWG-2. Flow rates at the three headwater springs were all estimated at <1gpm for each of the 12 quasi-weekly measurement events to date. Baseflow rates at the downstream intermediate stream channel locations EMDNT3-ST1, -ST2, and –ST3 are quite low and range from 0.007–0.056 cfs (3.1–25.0 gpm).

8.1.1.2 Surface Water Quality

Observed variations in surface water temperatures were consistent with trends in air termperature and with temperatures measured at the six observational monitoring sites. Temperatures recorded at the three spring observational monitoring sites were typically one to three degrees C higher than water temperatures at the surface water gaging stations.

SpC recorded at the surface water gaging stations ranged from approximately 0.05–0.35 mS/cm over the reporting period. The pH values at the surface water gaging stations were generally between 6 and 7. During the early weeks of the pH record for SWG-1 and SWG-3 observed pH was greater than 7.0

Continuous records of SpC from the surface water gaging stations were consistently higher than SpC values measured at the six observational monitoring sites. The pH values measured at the six observational monitoring sites were generally similar to or slightly lower than pH at the surface water gaging stations.

Variations of surface water SpC and pH during runoff events were complex and variable among the three surface water stations and among events. Rapid decreases in SpC and pH during surface flow increases was the most common pattern of variation observed. These patterns are consistent with the arrival of relatively dilute, slightly acidic runoff at the surface water gaging stations.

8.1.2 Hydrogeology

Collective Phase I results in Plate 2 illustrate the key hydrogeological features among the ten wells at the EMDF site. Key data shown on Plate 2 include:

- As-built boring/well construction features (i.e., screen, filter pack, bentonite plug, grout).
- Maximum/minimum water levels for the period of continuous hourly monitoring from November 21, 2014, through February 26, 2015, representing a portion of the wet Winter season.
- Profiles of soils/saprolite and bedrock lithologies based on split tube samples, rock cores, and geophysical logs.
- K values from Shelby tube analysis and slug tests in the regolith zone, and from packer tests in the bedrock zone.
- Heat pulse flowmeter test results indicating depths with no to slight upward flow below the quantifiable flow rate of 0.03 gpm, and depths with upward flow above the quantifiable flow rate of 0.03 gpm.
- Possible fracture flow zones based on rock cores.
- Possible fracture flow zones/depths plotted on Structure logs based on ATV/OTV log interpretations.

Plates 3 and 4 illustrate hydrogeological features in relation to primary elements of the EMDF conceptual design. These illustrations along with other report tables and graphics are useful guides for reviewing the conclusions summarized below.

8.1.2.1 Ground Water

Ground Water Depths and Water Level Fluctuations

A representative high water table surface and maximum/minimum water levels are shown on the contour map of Figure 29 and cross sections (see Plates 3 and 4). The water table surface and water level fluctuations shown are representative of the typical wet winter/spring non-growing season when water levels are annually at their highest. Winter season depths to ground water are relatively shallow across much of the EMDF footprint (from near surface to 12.7 ft bgs). The water table occurs within regolith soils and saprolite above bedrock, except below the spur ridge area along the south and southeast sides of the EMDF footprint where ground water occurs in bedrock well below the regolith/bedrock interface at depths from 38–44 ft bgs for the current monitoring period.

The overall range in water level fluctuations thus far between highest and lowest elevations varies from 4.0 ft in GW-974(I) to 8.4 ft in GW-970(I). Water levels in all wells (shallow and deep) rise and fall relatively quickly in response to precipitation/recharge events. The only exception occurs in GW-976(I) where responses are subdued and where water levels rose progressively over December and through mid January where they plateau. The unique behavior of water levels in GW-976(I) appears related in part to its location below the spur ridge where recharge may be more restricted and slower, and its isolation from greater hydraulic pressure heads below and more directly south of Pine Ridge. The water level responses to precipitation events and seasonal fluctuations are consistent with well clusters monitored at the EMWMF and elsewhere in BCV. The highest Phase I water levels are representative of higher water table conditions that always occur during the non-growing winter/spring wet seasons.

Ground Water Flow Directions and Gradients

Shallow and intermediate level ground water migrates from upland recharge areas to discharge zones along the valley floors of NT-2/NT-3. Ground water seepage and discharge supports baseflow along portions of the larger NT-2/NT-3 tributaries cross cutting the EMDF site. Shallow ground water flow directions and horizontal gradients mimic surface topography and range from 0.33 to <0.05, between the steepest upland areas and relatively flat valley floors. Vertical upward gradients between the intermediate and shallow water table ground water intervals occur consistently at three of the five Phase I well pairs (GW-968[I]/GW-969[S], GW-972[I]/GW-973[S], GW-974[I]/GW-975[S]), and range from 0.003–0.065 based on representative data from January 12, 2015. Vertical gradients between the GW-970(I)/GW-971(S) cluster wells have varied up and down over time. Upward vertical gradients in each of the well clusters may disappear over short timeframes when water levels rise quickly in response to precipitation/recharge events. Vertical gradients at the GW-976(I) location are unclear as the shallow well (GW-977[S]) is dry, although two HPF meter tests suggest upward gradients may exist associated with bedrock fracture flow at depths of 75–80 ft bgs. The relatively large uncased intervals of the bedrock wells limits a precise determination of which depth interval(s) are contributing most to vertical hydraulic gradients.

Artesian conditions at GW-968(I)/GW-969(S) are the result of site grading cuts made well below the original undisturbed ground surface at the base of a narrow ravine below Pine Ridge. Site traverses prior to the Phase I investigation, did not identify springs or seeps at this location indicating that shallow ground water there did not previously intersect the surface.

Hydraulic Conductivity and Heat Pulse Flow Meter Tests

Slug tests were conducted in four shallow wells screened across saturated regolith (soils/saprolite) above bedrock. Hydraulic conductivity values from the tests ranged from 1.2×10^{-7} cm/sec to 1.5×10^{-6} cm/sec with an average K of 6.7×10^{-7} cm/sec. Hydraulic conductivity values from laboratory analysis of Shelby tube samples from soils/saprolite range from 3.9×10^{-7} cm/sec to 6.5×10^{-6} cm/sec with an average K of 3.2×10^{-6} cm/sec.

A total of nine injection packer tests were conducted over ten ft intervals in the open bedrock boreholes of the deep Phase I wells. No flow or limited and erratic flow for the two tests in GW-972(I) and the single test in GW-974(I) precluded a determination of K in those wells. While the results were indeterminate for K, the tests suggest that the tested intervals in these wells have relatively low permeabilities ($<<10^{-6}$ cm/sec). The relatively low permeability of the bedrock sequence in these wells was also supported by the HPF meter tests. The HPF meter tests in these two wells measured no flow in 13 out of 15 HPF meter tests with only two tests recording slight possible upward flows below the minimum quantifiable flow rate (0.03 gpm).

Packer test results for the other six tests conducted in the three remaining deep wells (GW-968[I], GW-970[I], and GW-976[I]), indicated K values ranging from 1.4×10^{-5} cm/sec to 1.5×10^{-4} cm/sec. The relatively higher K values from these wells were supported in part by relatively higher and more numerous HPF meter flow rates in these wells. The highest flow rates in the HPF meter tests were coincident with relatively higher K values in the packer tests. The only exception occurred in GW-976(I) where a shallow HPF meter test indicated no flow at 50 ft bgs where the packer test results indicated a relatively high K value over the interval encompassing 50 ft bgs. All of the HPF meter tests indicated upward flow directions.

The range of the K values from the bedrock packer tests is two orders of magnitude greater than those conducted from the shallower saturated and unconsolidated regolith materials. However, the packer tests were limited in number and test depths. In addition, the flow meter used for packer testing limited results to determinations of K values on the order of 10^{-5} cm/sec or higher. Additional K testing capable of determining lower K values in the range of 10^{-6} to 10^{-8} cm/sec (or lower) are recommended for the Phase II investigation to better characterize the full range of K values in bedrock. With the limited amount of Phase I data it is unclear whether the range of K values in regolith materials is relatively lower on average than those in the underlying fractured bedrock or whether biases exist among the Phase I testing methods. Biases inherent to variations in sampling, testing methodologies, equipment, and analytical methods used for calculating K were not evaluated but could have a significant influence on variations among the results.

A total of 39 HPF meter tests were conducted at various depths among the five deep open bedrock boreholes. The HPF meter tests identified upward flows >0.03 gpm (minimum quantifiable flow rate) at depths of 45, 50, and 57 ft bgs in GW-970(I), and at 75 ft bgs in GW-976(I). Flow at these test depths were corroborated by packer test results indicating relatively higher K values from test intervals encompassing these HPF meter test depths. Elsewhere the HPF meter tests indicated no to very slight flows below the quantifiable limit. In particular, the HPF meter tests were consistent with the no to limited/erratic flow results from the packer tests in GW-972(I) and GW-974(I) suggesting that fracture flow in these bedrock wells is relatively low compared with the other three Phase I bedrock wells.

8.1.2.2 Regolith Hydrogeology

Results from the ten Phase I wells indicate regolith thicknesses that vary from 10.0 to 25.6 ft bgs. Phase I split tube samples from the regolith were logged predominantly as clayey silt (ML) with weathered rock fragments (saprolite). The thin topsoil layer was removed during site grading at the well locations. The split tube log descriptions and engineering geotechnical descriptions and properties from the five Phase I Shelby tube samples are reasonably consistent with clayey/silty soils and saprolite described from hundreds of regolith samples at adjacent sites along geologic strike immediately to the east and west (EMWMF/Ogden Sites B and C; Ogden 1993a/b, and CH2MHill 2000).

SPT “N” values (blow counts) indicate that soil/saprolite consistency increases progressively with depth from stiff to hard as silty/clayey residuum and saprolite grades downward into less weathered saprolite at auger refusal. Natural moisture contents range from 12.2– 21.2%. Specific gravities range from 2.68–2.73. Liquid and plastic limits range from 29–34, and 20–24, respectively.

The Phase I water level data for the wet non-growing season to date suggest that the water table across much of the EMDF footprint occurs within the middle to upper parts of the regolith well above competent bedrock at auger refusal. Regolith materials below the higher elevations of the spur ridge near the southern part of the EMDF footprint are unsaturated where the water table occurs below top of competent bedrock. Micro and macropores and relict features within the saprolite (bedding planes, joints, shear fractures) provide avenues for ground water migration vertically through the vadose zone and laterally through the shallow water table interval. Lateral ground water flow within the regolith provides baseflow for the small surface streams along the NT-2/NT-3 tributaries at and near the EMDF footprint.

8.1.2.3 Bedrock Hydrogeology

Detailed lithologic/stratigraphic sequences were developed from rock cores over bedrock intervals in GW-972(I) and GW-976(I). Natural fractures, particularly those with evidence of staining and weathering, were identified and plotted on logs to indicate zones that might be conducive to fracture flow. The rock cores were cross correlated with the suite of geophysical logs to support the identification of possible fracture flow zones and the selection of zones for packer testing and to evaluate the validity of the various geophysical logs. Rock cores from GW-972(I) in the Rutledge reveal a vertical sequence predominantly composed of shale/mudstone with relatively minor lamina of limestone/calcareous siltstone with a limited number of possible fracture intervals. In constrast, the rock cores from GW-976(I) in the Maryville, reveal a mixed sequence of rocks from shallow non-calcareous shales and siltstones to a lower sequence of mostly interbedded shales and limestone. Intervals of possible fracture zones that may be conducive to ground water flow are identified in detailed logs and cross sections (Plate 2). Heavily weathered and stained rocks were logged in the uppermost 20 ft of bedrock in GW-976(I) that transition to progressively more unweathered and more competent bedrock at depth. No evidence of staining/weathering was observed in the rock cores of GW-972(I). The rock cores in GW-972(I) indicate relatively uniform bedding plane dips to the southeast, whereas zones of steeply dipping bedding planes in GW-976(I) suggest intervals of folding and/or shearing. No voids or cavernous intervals or evidence of extensive limestone dissolution were identified during drilling or in the cores. The driller noted a loss of 30 gallons of water over the course of rock coring between 50–58 ft bgs. This interval was subsequently packer tested and found have an average K of 5.6×10^{-5} cm/sec.

General types of lithologies can be approximately determined from the NGR logs, but the borehole geophysical logs are incapable of accurately defining detailed lithologic and stratigraphic sequences in the Phase I bedrock wells. The results from fluid resistivity logs, ATV/OTV logs, the interpretive structure logs, and the HPF meter logs were useful for identifying the depths of potential fracture and flow zones. Those results were used in combination with packer tests to identify intervals within each of the bedrock wells that may be conducive to ground water flow and influencing upward vertical gradients. Most of the structural features interpreted by the geophysicist as possible fractures/joints are parallel to bedding planes, but exceptional discordant fractures were identified in the upper bedrock sections of GW-970(I), someof which are coincident with relatively high HFP results and packer tests.

Water level differences between most of the shallow/deep well pairs and the consistent upward flow directions indicated by the HPF meter tests suggest that upward vertical gradients may be common within fracture flow zones of the upper to intermediate levels of saturated bedrock. The potentiometric surface data from the five deep Phase I wells are similar to those for the shallow water table interval, generally differing by less than 1–2ft. Potentiometric surface contour maps for the intermediate ground water interval will therefore be very similar to that shown for the water table surface (see Figure 29). Lateral (horizontal) ground water flow paths within the intermediate interval should thus mimic those shown for the water table interval, except that upward gradients will be expressed along with the horizontal flow gradients along three dimensional convergent flow paths toward discharge zones along the NT tributary valleys. The three dimensional flow conditions for intermediate level ground water below the spur ridge area near GW-976(I) are less clear without a shallow well pair (GW-977[S] is dry). The progressive and gradual increase in water levels in GW-976(I) over a period of several weeks are distinctly different from the relatively rapid up and down fluctuations seen over just a few days in all other Phase I wells. The data suggest that recharge and flow conditions below the elevated areas spur ridge are uniquely different from those elsewhere at the EMDF site. The single upward HPF meter test at 75 ft bgs of 0.034 gpm (above the minimum quantifiable flow rate) suggests that upward gradients may exist at depth below the spur ridge area.

The combined results of packer tests, HPF meter tests, structure and fluid resistivity logs, and rock core evaluation, indicate that GW-970(I) has the highest K and HPF meter flow rates. In addition, the structure log indicates high angle fractures discordant to bedding planes in the uppermost bedrock section (34–43 ft bgs) that were not tested for flow or K but suggest a significant potential fracture zone that may be conducive to flow. Similar combined Phase I data suggest bedrock flow conditions in GW-968(I) and GW-976(I) that are less than those in GW-970(I), but greater than those in GW-972(I) and GW-974(I) where the combined results suggest relatively lower K values and the lowest indications of borehole flow according to the HPF meter test results.

8.2 PHASE I RESULTS RELATED TO CONCEPTUAL DESIGN AND SITE SUITABILITY

The cross sections on Plates 3 and 4 illustrate the relationships between the Phase I water table and the primary components of the conceptual design for the EMDF. The water table or potentiometric surface of the shallow water table interval shown for December 25, 2014, is representative of the relatively higher water levels that occur each year during the wet non-growing winter and spring seasons. The cross sections accurately illustrate the surface topography, key hydrogeological conditions identified in Phase I wells, and the configuration of the geobuffer, liner system, and lower and upper boundaries of the waste. The cross sections also illustrate the model predicted post-construction steady state configuration of the water table. After landfill construction, the current recharge area and recharge rates to the shallow water table interval is effectively eliminated across the EMDF footprint. A narrow zone of open recharge to the undisturbed ground surface would remain post construction along the uppermost south facing slopes of Pine Ridge, but elsewhere across the EMDF site, ground water recharge will be greatly reduced to a very low infiltration rate on the order of 0.41 in. per year. The lowered post construction water table reflects the combination of the greatly reduced recharge area and extremely low recharge rates created by the low permeability cap/cover materials (enhanced by the lateral drainage diversion system in the cap/cover). In addition, the conceptual design and the model assume the EMDF underdrain system is functioning effectively to encourage and maintain natural ground water drainage below the landfill footprint. The combined effect is to lower and maintain the current naturally occurring water table to a much lower elevation that does not rise or encroach on the geobuffer, liner system, or waste.

It is also assumed that the ground water mound below the boot shaped spur ridge area below GW-976(I) would be effectively dewatered and reduced during landfill construction. The current conceptual design assumes that a sizable portion of the north side of the spur ridge would require excavation and grading for the placement of the underdrain along the main branch of NT-3, followed by placement of engineering fill, low permeability geobuffer clays, and the liner system. These elements are presented at the south end of cross section in Plate 3. The remaining undisturbed southerly section of the spur ridge would remain as a natural buttress along the southern edge of the landfill. Elsewhere across the EMDF footprint, the water table surface(s) mapped using the highest water table elevations from Phase I data remains below the bottom elevations of the geobuffer, providing ample vertical distance between the waste and the water table.

Surface water conditions associated with springs, seeps, and stream flow along the NTs at the EMDF site are consistent with those originally found at the adjacent EMWMF site and in similar upper watersheds elsewhere in BCV flowing across Conasauga Group formations. The stream channels at the EMDF are relatively small, even at their largest only 1–3 ft wide and a few inches deep. The Phase I results indicate continuous baseflow along the NT stream channels during the wet non-growing season, however, the flows are considered easily manageable during construction and would not place significant constraints on the engineering design for the EMDF. A properly designed and constructed underdrain system, along with surface water runoff controls during construction, and waste limits that are elevated well above base levels would ensure the long-term separation of waste materials from surface and shallow ground water.

The Phase I results do not conflict with the basic elements and configuration of the current conceptual design. Additional borings, wells, monitoring, and testing recommended for a more comprehensive and detailed Phase II investigation will provide additional data necessary for the detailed design of the EMDF.

8.3 RECOMMENDATIONS

Assuming the EMDF site is approved for CERCLA disposal, the Phase II site characterization would build on the baseline results from the Phase I investigation. The details of the Phase II site characterization will be formulated among the DOE, TDEC, and EPA in accordance with the data quality objectives (DQO) process which is designed to ensure that data are collected to meet specific needs of a project and end users of the data. DOE and DOE-support contractor(s) would develop preliminary DQOs and host DQO working sessions with the regulatory agencies to reach general agreement on the scope of the Phase II effort. Work plans would then be developed to document the detailed plans for the Phase II investigation and implementation schedule.

The results from ongoing Phase I surface water and ground water monitoring activities should continue to be plotted, analyzed, and periodically presented to project stakeholders. In particular, the future Phase I monitoring of ground water levels and runoff conditions during the coming warm growing season of 2015 warrant analysis and comparison with the current wet non-growing season when water levels and runoff are typically at their highest levels. Future Phase I results will provide data to verify ground water level declines and lower runoff conditions site-specific to the EMDF site that typically occur in the warm growing season.

The Phase II investigation of the proposed EMDF site may include the following general site investigation techniques and methods:

- Additional soil borings to further characterize regolith and bedrock conditions with soil samples and rock coring.
- Geotechnical sampling and field/laboratory testing.
- Soil/rock sampling for laboratory determinations of soil/water partition coefficients (K_d) for key contaminants of concern.
- Monitoring well clusters (shallow and intermediate) to define ground water conditions and hydraulic gradients.
- Test pits to characterize the nature and extent of alluvium/colluvium for underdrain design.
- Nested piezometers to evaluate spatial and temporal variations in vertical gradients and surface and ground water interactions along the NT-2/3 valleys.
- Subsurface testing to determine K, and ground water flux and gradients (e.g., conventional depth-discrete K tests such as slug and packer tests, and other borehole flow testing and borehole logging methods).
- Ground water monitoring (via continuous and/or other periodic synoptic measurements [e.g., weekly/monthly] of water levels or other parameters of interest).
- Surface water monitoring (via continuous and/or other periodic synoptic measurements [e.g., weekly/monthly] of water levels or other parameters of interest).
- Soil and ground water sampling and analyses for contaminants, both to ensure site suitability and as to establish background values. Detection limits must be below regulatory limits (e.g., Maximum Contaminant Levels [MCLs] for Preliminary Remediation Goals [PRGs]).

Specific recommendations for consideration in planning for a Phase II investigation include:

- Conduct continuous vertical sampling of regolith soils and saprolite in selected borings to characterize preferential pathways for fluid flow within the vadose and water table intervals above bedrock. Supplement those results with in-situ tests of K to more accurately define the range of K values within regolith materials.
- Consider retrofitting of the open hole intervals in the deeper Phase I well pairs (i.e., GW-970[I], GW-972[I], GW-974[I], GW-976[I]) with “bundled” or nested wells with small diameter casing (e.g., 1 in. or 2 in. diameter PVC) and short screen intervals (2.5 ft , 5 ft, or 10 ft) to more accurately determine vertical gradients across the open hole intervals in these wells (this is low cost, effective, and easily implemented).
- Employ more sensitive packer tests or other downhole methods capable of determining very low K values on the order of 10^{-6} to 10^{-8} cm/sec to develop vertical profiles of K for the open hole intervals of the Phase I intermediate level wells (and in similar Phase II wells).

- Conduct research into and implement available technologies for determining accurate K values in regolith and bedrock with a much greater level of sensitivity and accuracy, particularly those within or below the range of 10^{-6}–10^{-8} cm/sec or lower.
- If packer testing methodologies are employed they should be optimized for accurately determining very low flow injection rates well below 1 gpm, which may require flow monitoring devices more sensitive than those commonly employed by drilling companies.
- Consider the use of best available borehole video cameras with downward and sideward viewing options and variable lighting to identify and map the depth intervals of in-situ fracture zones conducive to ground water flow with open-hole sections of bedrock.
- In concert with use of those video cameras, consider rapid draw down of water levels in open holes with high flow rate pumps immediately followed by video logging to identify and film ground water flow from fractures directly into the uncased borehole. Subsequent borehole testing could be performed on those fracture intervals to determine K values from fractured water producing intervals.
- Consider the use of other best available methods and technologies for borehole surveying, testing, and geophysical logging (e.g., HydroPhysical™ logging by COLOG and other logging companies)
- Consider the use of the electromagnetic borehole flowmeter for vertical sequencing of K across the entire of open boreholes in bedrock. This instrument was developed by the Tennessee Valley Authority (Young and Pearson, 1995) and used in previous investigations on the ORR and is commercially available for use.
- Consider the use of ultrasonic drilling for continuous sampling/coring of regolith and bedrock intervals at selected locations across the EMDF site. This method can provide high quality samples/cores that offer advantages over other conventional drilling and sampling methods.
- Consider the acquisition and testing of samples for determination of site-specific partition coefficient (K_d) values. Reliable K_d values are essential to accurate fate and transport modeling. Experts should be engaged in the process to ensure the proper collection of representative samples and appropriate methods for testing and reporting.

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APPENDIX E – ATTACHMENT B:

ADDENDUM TO THE PHASE I CHARACTERIZATION REPORT OF THE ENVIRONMENTAL MANAGEMENT DISPOSAL FACILITY OPTION 5 SITE IN EAST BEAR CREEK VALLEY

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CONTENTS

FIGURES

TABLES

EXHIBITS

(Provided on DVD)

PLATES

(Provided on DVD)

ACRONYMS

BCV	Bear Creek Valley
DOE	U.S. Department of Energy
D	Draft
EBCV	East Bear Creek Valley
EMDF	Environmental Management Disposal Facility
EMWMF	Environmental Management Waste Management Facility
NT	Northern Tributary
NWS	National Weather Service
ORP	oxidation/reduction potential
RI/FS	Remedial Investigation/Feasibility Study
SpC	specific conductivity
SWG	surface water gaging
TDEC	Tennessee Department of Environment and Conservation
U.S.	United States
UPF	Uranium Processing Facility
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
Y-12	Y-12 National Security Complex

1. INTRODUCTION

This Addendum provides the complete results for a full year of surface water and ground water monitoring at the proposed Environmental Management Disposal Facility (EMDF) Option 5 site in East Bear Creek Valley (EBCV) on the Oak Ridge Reservation. The monitoring began around December 1, 2014, and extended through most of November 2015. Monitoring results for the first three months of monitoring were presented in Attachment A to Appendix E of the Draft (D) 3 version of the Remedial Investigation/Feasibility Study (RI/FS) Report published in March 2015. The Phase I site characterization activities were conducted in response to concerns voiced by the local United States (U.S.) Department of Energy (DOE) Oversight Office of the Tennessee Department of Environment and Conservation (TDEC) about suitability of conditions at the proposed Site 5 in EBCV, referred to in Attachment A as the EMDF site. The TDEC comments were presented to DOE in response to the D2 RI/FS Report (DOE 2013a) and related in part to concerns regarding springs, seeps, and the shallow water table at and near the footprint of the Site 5 option. The D4 version of the RI/FS Report was broadened to include three other candidate sites for the EMDF in Bear Creek Valley (BCV) in addition to Site 5.

The current Addendum focuses only on the results of surface water and ground water monitoring and interpretations and findings associated with surface water hydrology and ground water conditions at Site 5. Attachment A should be reviewed for background information concerning the drivers, objectives, and limited scope of the Phase I investigation at Site 5. Attachment A should also be reviewed for details associated with the installation, calibration, and maintenance of monitoring equipment and the field methods used for monitoring. Figure 1 illustrates the Phase I monitoring locations reviewed in subsequent sections.

Section 2 reviews the objectives of the Phase I investigation. Sections 3 and 4 presents the Phase I results under the general headings of surface water hydrology and ground water monitoring and hydrology, respectively. Section 5 lists all references cited.

Exhibit B.1 provides weekly documentation for all of the Phase I continuous surface water and ground water monitoring. Exhibit B.2 provides documentation for all of the Phase I weekly surface water observational monitoring. Plates with detailed large scale site drawings and cross sections are provided as attachments along with a cut/fill thickness map for Site 5 based on the current conceptual design.

2. MONITORING OBJECTIVES AND BACKGROUND

One of the primary objectives of the limited Phase I characterization was to monitor variations in stream, spring, and seep flow, ground water level fluctuations, and basic water quality parameters at Site 5 over a period of one year or more. The data would be used to assess seasonal/temporal variations and to correlate those data with meteorological data collected at the adjacent Environmental Management Waste Management Facility (EMWMF) and the Y-12 National Security Complex (Y-12) west tower meteorological station. The data would provide baseline environmental data needed for landfill design and satisfy regulatory requirements and guidance.

Instrumentation and data loggers were placed at each of the five well cluster locations and at three surface water stream gage locations to provide nearly continuous data for evaluating temporal and spatial relationships between stream discharge rates, ground water level fluctuations, precipitation, and key elements of the proposed conceptual design (e.g., the physical relationships between surface and ground

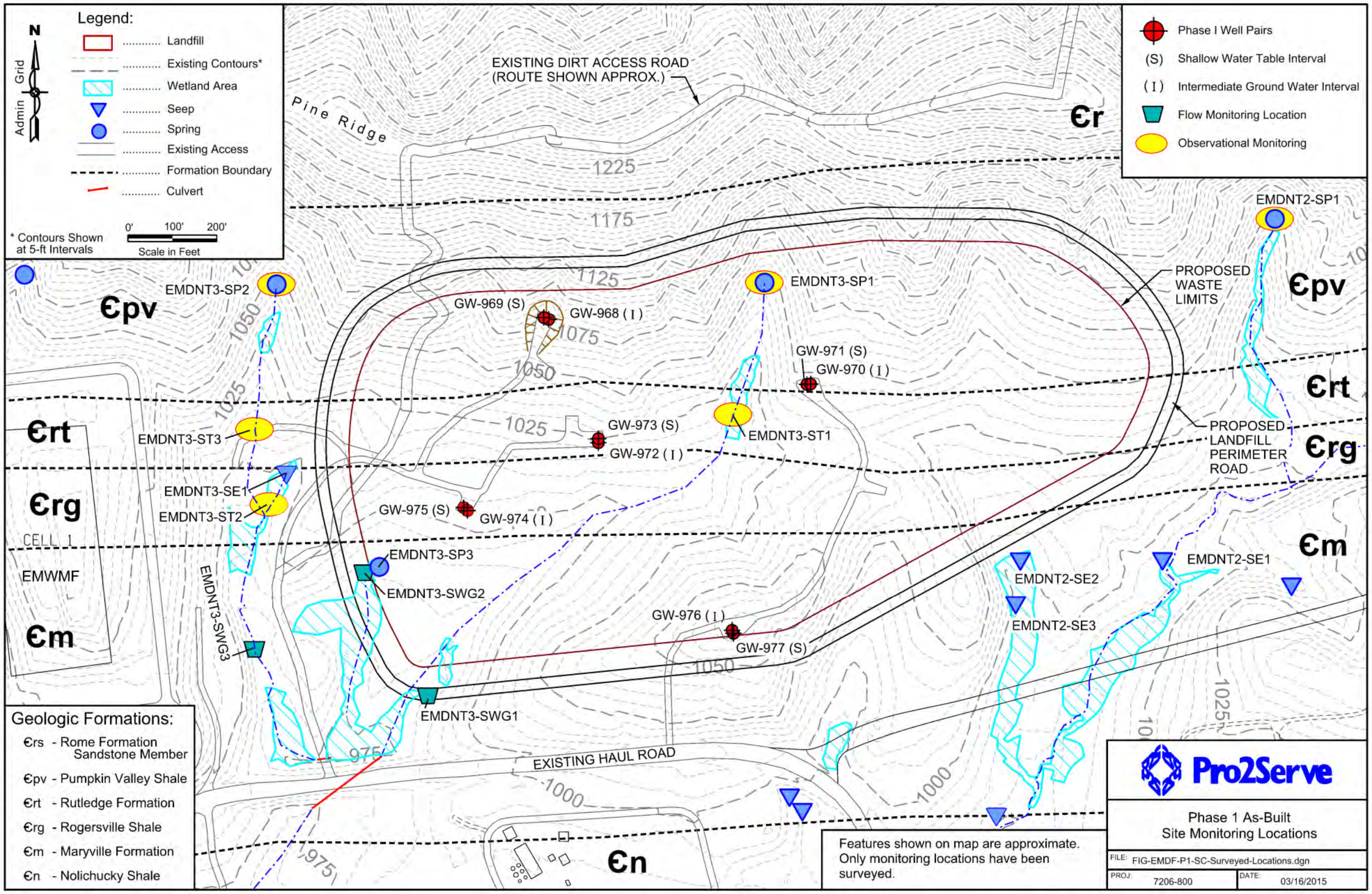


Figure 1. Phase I monitoring locations at the proposed Option 5 EMDF Site in EBCV

water level fluctuations and key elements of the conceptual design such as the base of the geologic buffer and underdrain system).

The Phase I surface and ground water monitoring provides baseline data for assessing spatial and temporal relationships between surface water runoff, relatively rapid shallow subsurface stormflow zone discharge to streams, and relatively slower ground water discharge to surface streams, springs, and seeps. Surface water data from previous investigations (USGS 1994a and b, and BJC 1999) and recent field observations along the Northern Tributary (NT) tributaries at and near Site 5 indicate that baseflow along the NT streams varies considerably between the wetter and colder Winter/Spring nongrowing season, and the drier and warmer growing season of late Spring, Summer, and early Fall. During the wetter, cooler, nongrowing season, base flow along the NT streams is typically continuous downstream from headwater springs and flow rates are much higher than during the drier, warmer, growing season when flow is much lower and may be intermittent during the late Summer and early Fall when rainfall is often minimal.

The Phase I monitoring results more accurately define these seasonal changes in stream baseflow and the range of variations for peak flow and baseflow. Depending on seasonal conditions, sections of the NT-2 and NT-3 tributaries may be gaining baseflow from ground water discharge, or losing surface water to the shallow water table. The Phase I monitoring results also provide baseline data for ground water conditions at Site 5. Ground water and stream flow conditions are fundamentally important to the design of the proposed underdrain system for the EMDF, and to a design that ensures waste materials remain sufficiently elevated above the water table over the long-term time span of the proposed disposal facility. If the EMDF is approved at Site 5, additional characterization would be performed in one or more follow on field investigations supported by data quality objectives to support detailed landfill design, fate and transport modeling, and other project needs.

3. SURFACE WATER MONITORING AND HYDROLOGY

The Phase I surface water monitoring program included two main components: (1) instrumented surface water monitoring at three stream gage locations along tributaries of NT-3, and (2) weekly monitoring of six locations upstream from the stream gage locations (see the nine surface water monitoring locations in Figure 1). The original Phase I site characterization report (Attachment A to Appendix E of the D3 RI/FS Report) provides detailed specifications and measureable flow ranges for the three cutthroat flumes installed at the instrumented stream gage locations along the lower reaches of the main eastern branch of NT-3 (EMDNT3-SWG1), and the middle (EMDNT3-SWG2) and western (EMDNT3-SWG3) branches of NT-3 that drain the western two thirds of the Site 5 watershed area.

The weekly observational monitoring locations shown in Figure 1 include the three headwater spring locations where the NT-2 and NT-3 tributary stream flows originate (EMDNT2-SP1, EMDNT3-SP1, and EMDNT3-SP2), and the three stream flow monitoring stations (EMDNT3-ST1, -ST2, and –ST3) at intermediate locations between the headwater springs and the flume stream gage locations. Results of the Phase I surface water monitoring and surface water hydrology at Site 5 are reviewed in the following subsections.

3.1 SURFACE WATER HYDROLOGY

The surface water and ground water hydrology at Site 5 are addressed below in separate sections but interactions between surface and ground water are clearly significant at the site and throughout BCV, as shallow ground water supports seasonal baseflow to the uppermost tributaries of NT-2 and NT-3 and discharge to springs and seeps within and adjacent to the Site 5 footprint. If Site 5 is approved, interactions between surface and ground water would presumably be further characterized during a Phase II investigation, particularly in support of a detailed engineering design for the proposed underdrain system.

3.1.1 Local Climate and Precipitation During the Monitoring Period

Current climate normal values (1981–2010) from the National Weather Service (NWS) for the Oak Ridge area are 50.91 in. for annual precipitation and 58.8° F for mean annual temperature. Precipitation is distributed uniformly through most of the year, with normal monthly precipitation for August through October averaging about 1 in. lower than during other months (see Figure 2). These three months of lower precipitation and high temperatures tend to comprise a seasonal dry period in which evapotranspiration losses are large relative to inputs of rainfall.

Cumulative monthly precipitation data since 1999 (NWS station KOQT in Oak Ridge, see Figure 3) and corresponding recent records from the Y-12 West Tower meteorological station (Y-12W) located near the EMDF site suggest that precipitation amounts for the 2014 and are close to averages observed over the last decade (see Figure 4). Hourly precipitation data for Y-12W are utilized in this report to represent rainfall at the EMDF site.

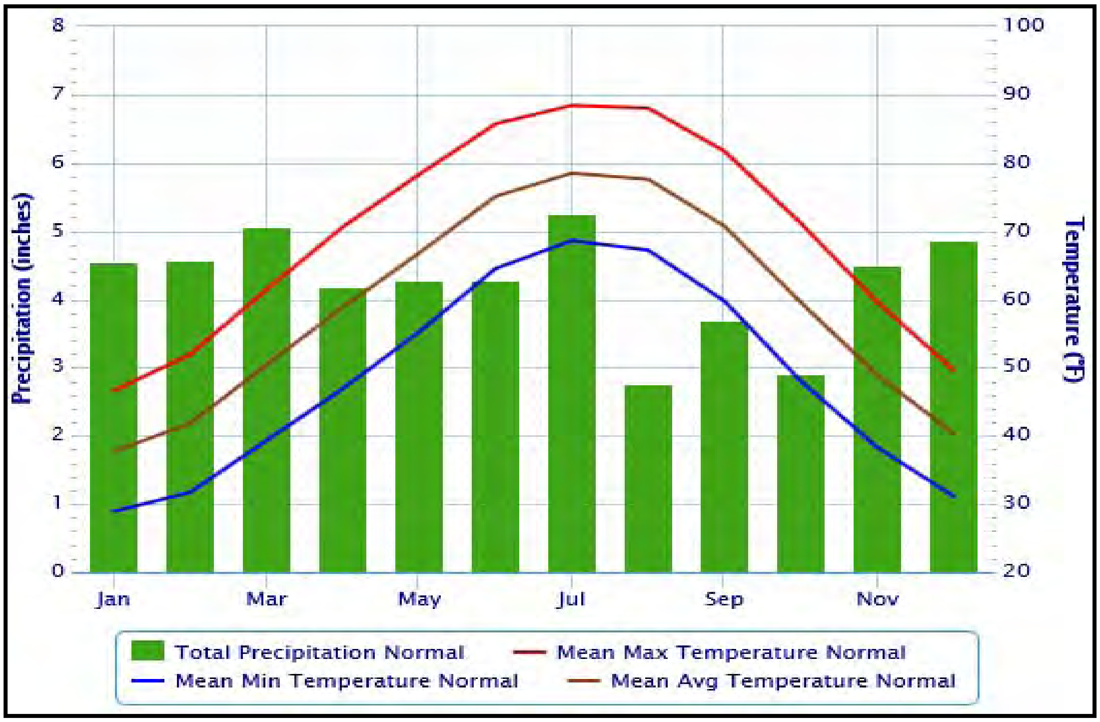
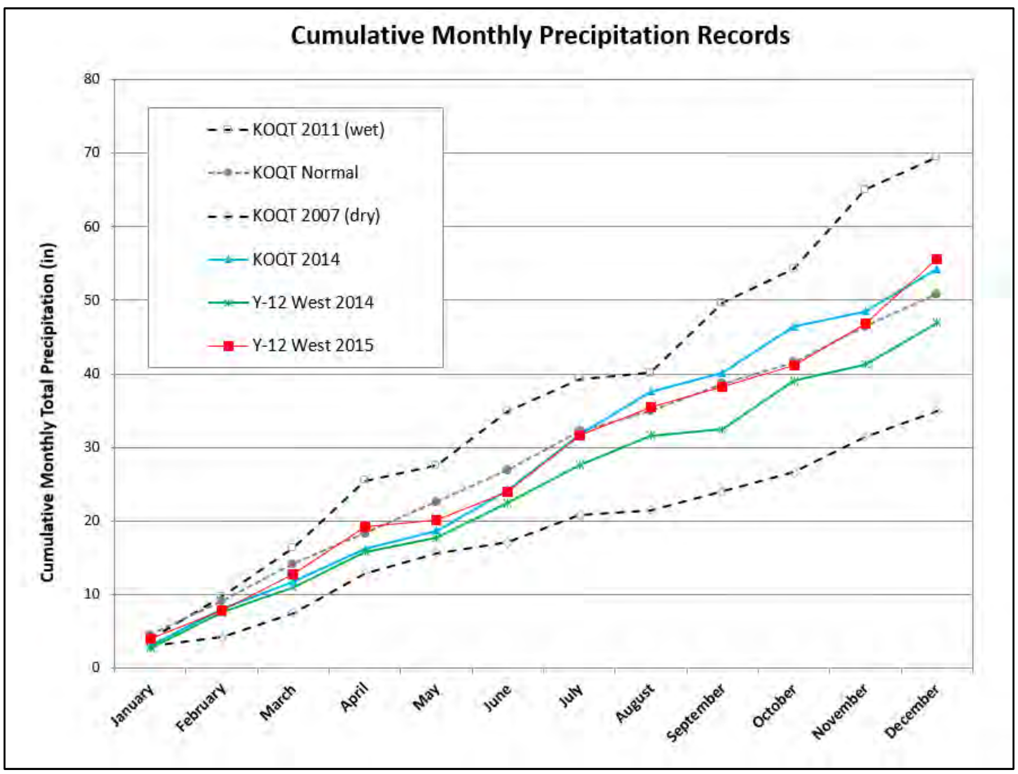


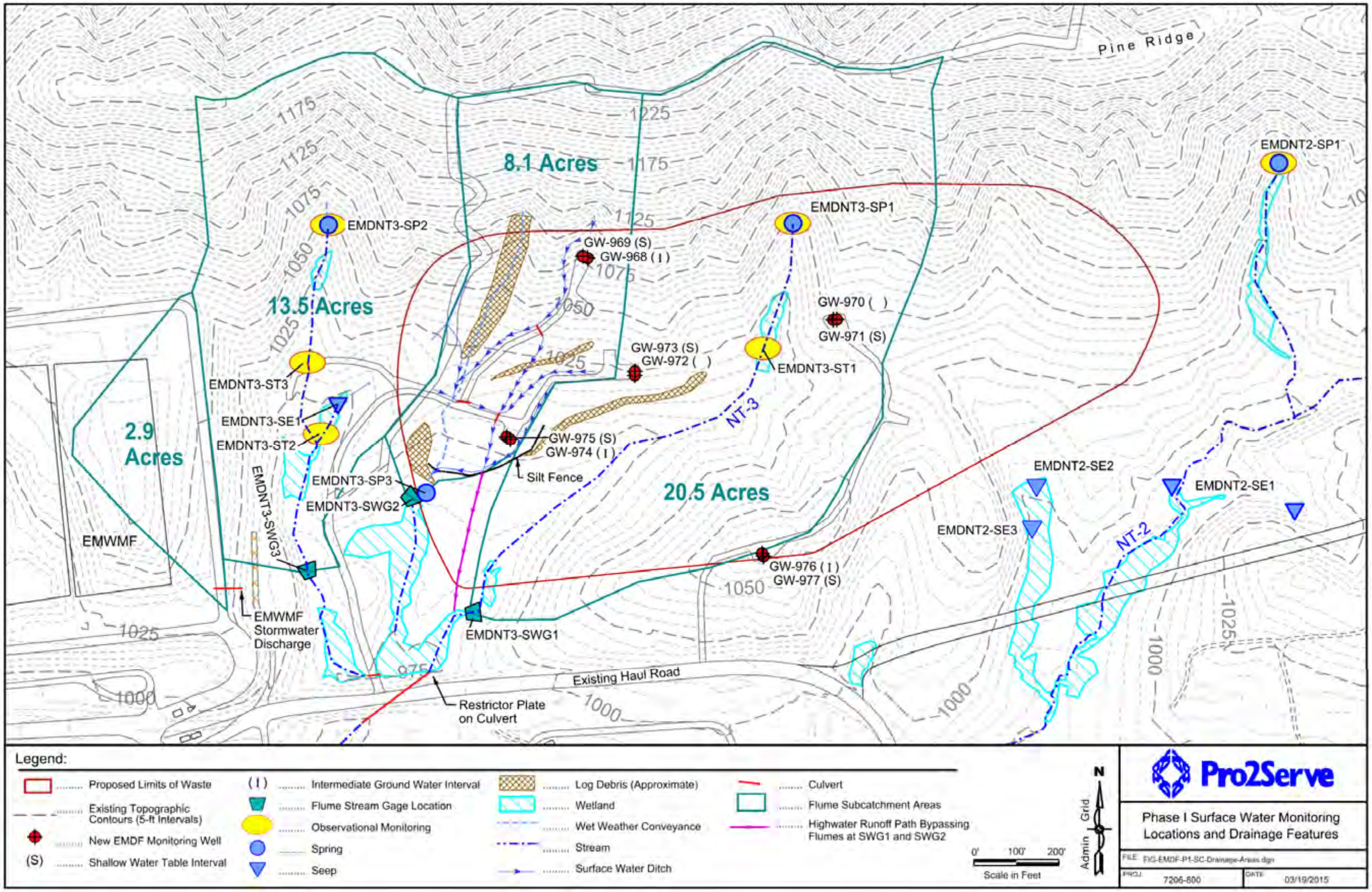
Figure 2. Monthly Climate Normals (1981–2010) – Oak Ridge Area, Tennessee

Figure 3. Location Map for Meterological Stations



KOQT records for the year of highest (2011) and lowest (2007) total annual precipitation illustrate the observed range of variability since 1999. Refer to Figure 12 for locations of KOQT and Y-12W.

Figure 4. Cumulative Monthly Precipitation Records for NWS Station KOQT and the West Tower Meteorological Station at Y-12 (Y12 West)



New runoff patterns associated with Phase I road construction/culverts and the high flow bypass route are shown with blue and magenta arrow lines.

Figure 5. Phase I Monitoring Locations and Approximate NT-3 Subcatchment Areas and Runoff Pathways for Flumes SWG-1, SWG-2, and SWG-3

3.1.2 Stream Flow Response to Precipitation

Stream hydrographs recorded at the three surface water gaging (SWG) stations illustrate relatively rapid hydrologic response to rainfall, as expected for a small, fairly steep, recently disturbed watershed. Refer to Figure 5 for approximate subcatchment drainage divides and recently modeified drainage pathways. Attachment A of the Phase I monitoring report includes a discussion of recent storm damage and land use at the site. The streamflow data are consistent with precipitation inputs and appear to be generally reliable (see Figure 6), although for flow depths less than 0.1 ft, the manufacturer's rating for the flumes is subject to uncertainty resulting from the site-specific geometry of the flume installation and flume entrance hydraulics. Flow rates corresponding to this lower flow accuracy limit for the larger (SWG-1 and SWG-3) and smaller (SWG-2) flumes are indicated by dashed horizontal lines on the hydrographs in Figure 6.

An additional source of error in estimated flow rates is related to the accuracy and precision of flow depth measurements. The factory-calibrated pressure transducers are accurate to +/- 0.01 ft and uncertainty in precisely positioning transducers (datum control) is at maximum +/- 0.05 ft. Changes in estimated flows corresponding to datum shifts of this magnitude and greater are evident in the flow record on some occasions when instruments were serviced and data downloaded.

Peak flows during the Phase I monitoring period varied seasonally and among the three gaged subcatchments. SWG-1 winter peaks were generally higher than dry season peaks, whereas for the SWG-3 catchment, dry season peak flows in response to intense precipitation were similar to winter high flow rates. The largest measured SWG-1 peak flows were greater than 3 cfs, while for SWG-3 the largest measured peak flows were between 1 and 2 cfs. SWG-2 flows were much smaller, due to the smaller catchment areas and disruption of surface runoff patterns during salvage logging and Phase I site preparation.

Longer-term stream flow data are available from a flume gaging station, BC-NT3, located on NT-3 at a location about 100 ft upstream of the junction with Bear Creek. The BC-NT3 station is located approximately 1200 ft downstream of the NT-3 culvert at the Haul Road along the southwest corner of the EMDF site (culvert shown on the lower portion of Figure 5). Since September 2002, a restrictor plate on the culvert inlet has constrained the runoff rates from the upper NT-3 watersheds at the EMDF site and created artificial wetland areas immediately above Haul Road. Analysis of the relationships between hydrologic response at the EMDF site and the downstream BC-NT3 gaging station is recommended to place the short term records collected during the Phase 1 effort in the context of the longer fifteen year historical record of NT-3 flows.

Given that the precipitation totals recorded during the Phase 1 reporting period are relatively small magnitude, high frequency storm events, peak flow rates higher than those reported here are almost certain to occur. The U.S. Geological Survey (USGS) Tennessee Water Science Center has developed a web-based application (http://water.usgs.gov/osw/streamstats/tennessee.html) for estimating peak flows for unregulated Tennessee streams (Law and Tasker, 2003, Ladd and Law, 2007). Peak flows for the SWG-1 subcatchment (0.3 square miles) predicted with this tool are presented here as a rough indication of possible high flow rates in the future, and should not be considered to be statistically robust predictions (see Table 6).

Table 1. Peak Flow Rates Estimated for the SWG-1 Subcatchment

Return Period (years):	2	5	10
Annual Maximum Peak Flow Rate (cfs)	9.77	16.8	22.5

Rates estimated using data obtained from Tennessee StreamStats using the regression model of Law and Tasker, 2003.

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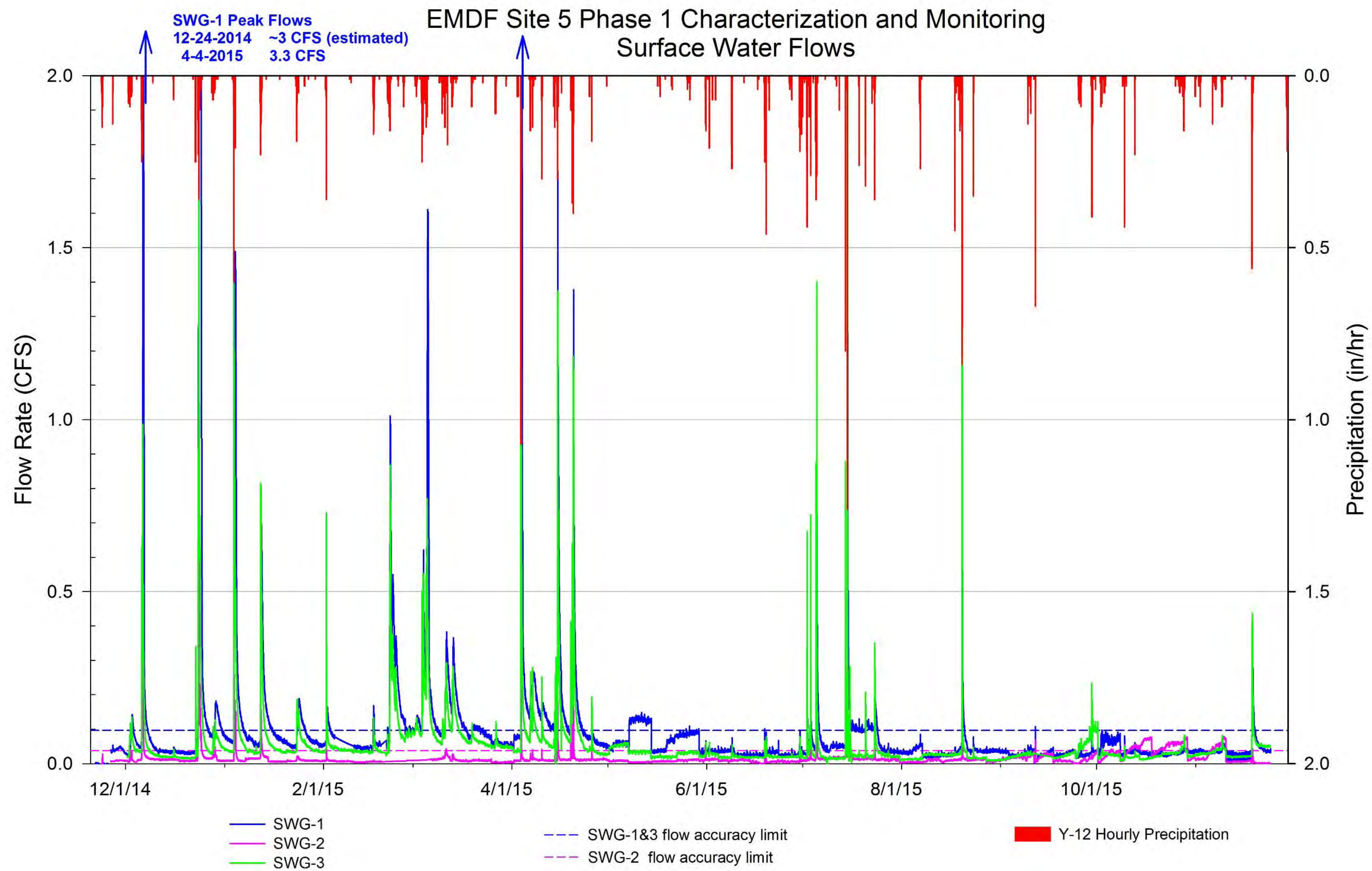

Figure 6 December 2014–November 2015 Streamflow Hydrographs for the Three Phase I SWG Locations and Precipitation Data from the Y-12W Meteorological Station

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3.1.3 Surface Water Observational Monitoring Results

The six Phase I quasi-weekly observational monitoring stations are highlighted on Figure 1 with yellow ovals. The locations include the three headwater springs originally identified by USGS surveys of BCV in 1994, and three locations along the east and west upper tributaries of NT-3 at locations intermediate between the headwater springs and the SWG flume locations. Details of the monitoring activities were previously described in Attachment A to Appendix E. The results of weekly water quality parameter readings, photographs, and estimates of flow rates are provided in Exhibit B.2 along with spreadsheet compilations of data for each of the 51 weeks of monitoring (from December 10, 2014, through November 24, 2015).

Part of the rationale for weekly monitoring was to determine the nature of spring and stream flow along the upper most reaches of the NTs at Site 5 over the course of a full year. The weekly observational data would document whether or not the headwater springs and upper sections of the stream channels become dry or flow is intermittent during the summer and fall growing season when evapotranspiration is highest and baseflow is typically at its lowest between storm rainfall events. Field traverses before the Phase I investigation indicated that each of the three springs mark the beginning of the stream channels with surface water runoff along the uppermost sections of the NT-2 and NT-3 tributaries. The three springs are relatively small features no more than 1–2 ft wide and only a few inches deep. The natural stream channels below the springs follow the primary NT tributary valley floors as shown by the dashed lines on Figure 1. The spring at EMDNT3-SP3 (not monitored during Phase I) located just above the middle flume location at EMDNT3-SWG2 marks the start of a relatively smaller and shorter stream channel between the two primary NT-3 sub-tributaries crossing the middle and western parts of Site 5. No other springs or seeps have been identified along the other narrow ravines that drain the steep south facing slopes of Pine Ridge. The locations of other individual seeps and broad flat seepage areas are indicated by the delineated wetlands shown on Figure 1 within and adjacent to the proposed Site 5 footprint. These areas represent important ground water discharge areas that would be capturd and dewatered by the proposed underdrain system. Road construction for the new Uranium Processing Facility (UPF) haul road included reworking of the seepage/wetland areas along the southeast part of the EMDF footprint (see EMDNT2-SE1, -SE2, and SE3 locations on Figure 1 and UPF road construction drawings in Appendix E). Outlets for the proposed underdrain systems would be located along these valleys where ground water discharge occurs. Water within the newly constructed UPF wetland mitigation pond near EMDNT2-SE2 is maintained by shallow ground water discharge even during the dry season (See Appendix E for details).

The results of the weekly surface water observational monitoring flow data are presented below. The results from the weekly observational water quality data are reviewed separately in subsequent sections in conjunction with the water quality results from continuous monitoring at SWG-1, SWG-2, and SWG-3.

3.1.3.1 Weekly Observational Monitoring Flow Data

The weekly Phase I data indicate that flows during the wetter winter/early spring season are continuous at and below the springs, but that flow is variable and sometimes absent during the dry season. Table 2 presents stream flow statistics for the three locations EMDNT3-ST1, -ST2, and -ST3, located between the SWG locations 1 and 3. It should be noted that these flow measurement calculations are relatively inaccurate and based on simple measurements of flow rates and cross sectional areas of the stream channels (the flume data above the minimum 0.1 ft level are much more accurate and reliable than the observational data). Flows at EMDNT3-ST3 may be considered slightly more accurate in that measurements were made there using the culvert outfall to contain and time water flow. Measurements during the drier summer/fall seasons indicate that these stream paths hold water in puddles along the channel but that the movement of base flow water is barely perceptible. Observations at the headwater springs during the monitoring period indicate very low flow throughout the dry season with complete cessation of flow observed only at EMDNT3-SP1.

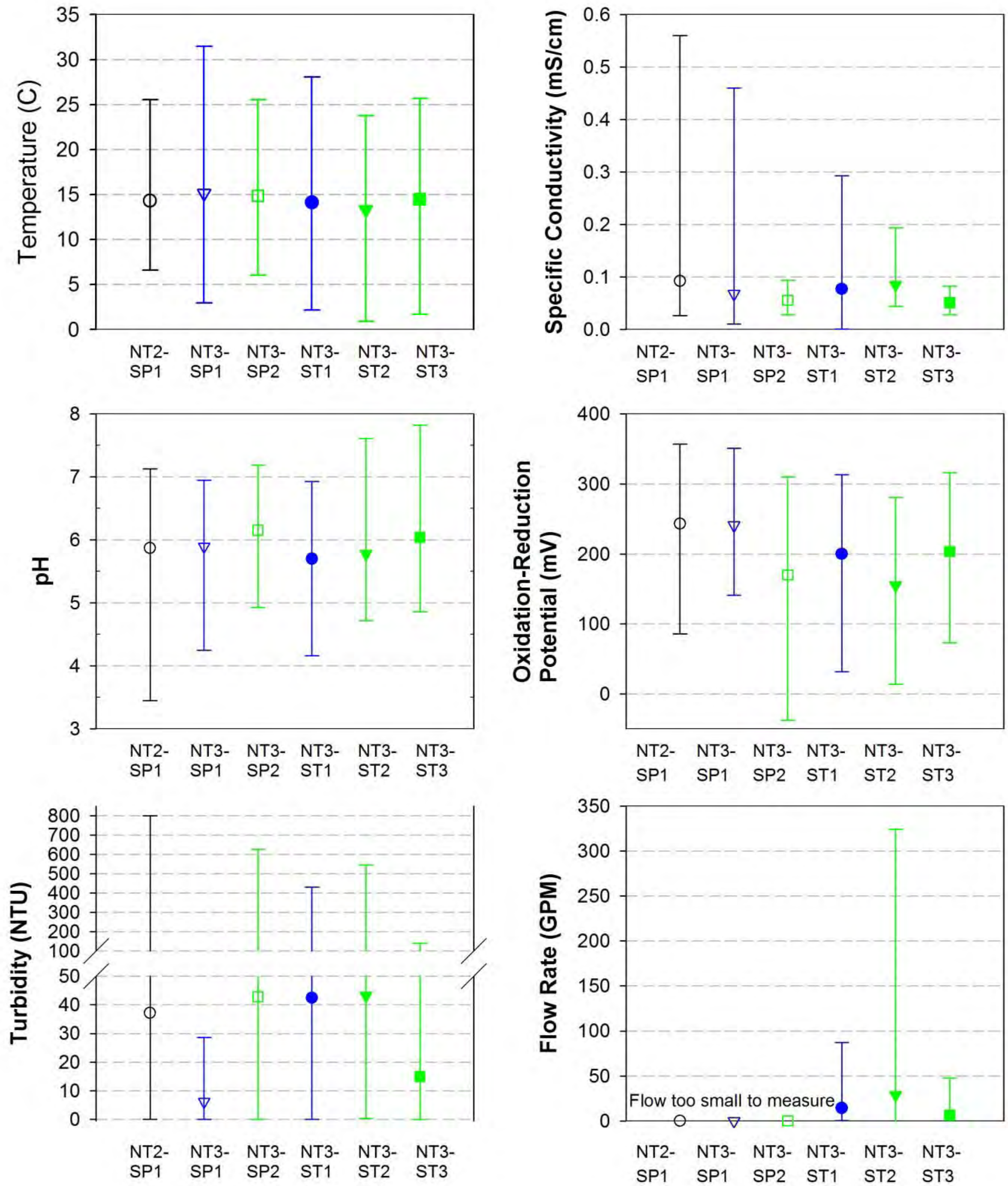
Table 2. Flow Statistics for NT-3 Tributary Locations between Headwater Springs/seeps and SWG Locations

Weekly Surface Water Monitoring Location	Statistics	Flow (gpm)
EMDNT3-ST1	Average	14.3
	Maximum	87.3
	Minimum	0.16
EMDNT3-ST2	Average	29
	Maximum	342
	Minimum	0
EMDNT3-ST3	Average	6.45
	Maximum	47.6
	Minimum	0

3.1.4 Surface Water Quality

Continuous monitoring of water temperature, pH, specific conductivity (SpC), and oxidation-reduction potential (ORP) at the three surface water gaging stations, along with weekly observational monitoring of these parameters at the locations described in Section 33 provide a general characterization of surface water quality at the EMDF site during the reporting period. The continuous collection (generally at a 20 min interval) of data at the SWG sites is potentially valuable for understanding water quality over the full range of flow conditions that may occur. However, a variety of challenges including sensor malfunctions, calibration errors, cold weather impacts, and development of unrepresentative microenvironments in stagnant water surrounding sensors has limited the amount of data that is useful for site characterization purposes. Fortunately, the quasi-weekly field measurements at stream sites upstream of SWG-1 and SWG-3 are more consistent. Only results from the weekly field measurements at the six observational monitoring sites are presented here.

The average values and range of water quality parameters measured at the weekly monitoring sites was similar across the six sites (see Figure 7) The range of water temperatures measured at the three springs (EMDNT2-SP1, EMDNT3-SP1 and -SP2) and stream locations (EMDNT3-ST2 and –ST3) reflected seasonal variations in the difference beween surface water and ground water temperatures. Specific conductivity recorded at the weekly monitoring sites were generally less than 0.1 mS/cm, with occaisional higher readings. pH readings averaged about 6 units, with a range between 4 and 8 units. The spring at EMDNT2-SP1 had pH readings below 4 units on a few days during the dry season. ORP readings at all sites reflected oxidizing conditions with the exceptionof several summer time readings at EMDNT3-SP2, when flow was very low and reducing conditions developed in the nearly stagnant pool where the spring emerged. Turbidity readings were generally very low, except for cases where flow was higher or disturbed conditions produced unrepresentative, high readings (Figure 7).



Symbols represent average values over the reporting period; error bars indicate minimum and maximum observed values for each parameter.

Figure 7. Summary of Weekly Surface Water Quality Measurements Collected at the Six Observational Monitoring Sites

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4. GROUND WATER MONITORING AND HYDROLOGY

Instrumentation and monitoring requirements for ground water levels and water quality parameters in each of the monitoring wells were identical to those for the Phase I surface water gaging stations, with the following exceptions. Turbidity was excluded as a measured water quality parameter in ground water. In the absence of well pumping (which may dramatically increase turbidity levels), the relatively slow fluctuations in water levels and the natural filtration effects of subsurface formations and filter packs typically result in ground water with very low turbidity. The other exception was GW-977(S) which does not intersect the water table. Each of the shallow wells at the five well cluster locations was drilled through shallow soils and weathered bedrock (saprolite) to auger refusal, with screened intervals placed atop the auger refusal depth. GW-977(S) is the only shallow well that experienced dry conditions above the water table; therefore no instrumentation was installed (although periodic monitoring was conducted to evaluate the possible occurrence of any rise of the water table into the well).

The same In-Situ® Level TROLL 700 and YSI 600XLM multi-parameter data logging instruments used at the flumes were placed in each of the monitoring wells to document variations in ground water levels and water quality parameters at one hour increments. The requirements for weekly ground water monitoring and documentation were identical to those described in Attachment A to Appendix E for the gaging stations, except that inspections and cleaning requirements were limited because of the protected and more stable conditions offered by the inner casing and protective casings. In addition, photo documentation was also not warranted. Additional details of the ground water monitoring practices were defined in the Alliant standard operating procedure, *Groundwater and Surface Water Monitoring Procedure* (AC-4301-001-GSM). Attachment A to Appendix E provides a table identifying the instrument depth placements in each well relative to ground surface and the regolith/bedrock interface.

Records of Alliant weekly downloads, equipment checks, and periodic calibration events for the continuous ground water monitoring are provided in Exhibit B.1. This documentation includes weekly monitoring equipment status/data sheets and checklists, but does not include the raw or processed data files from the continuous monitoring equipment. The processed data are presented in subsequent sections of this report as plots of water level fluctuations and ground water quality data over the initial three month Phase I monitoring period. The raw instrument and processed data files are extensive and therefore are not included as attachments to the Phase I report or to the current Addendum. However, the data files will be provided to the Oak Ridge Environmental Information System (OREIS) database.

4.1 PHASE I GROUND WATER MONITORING RESULTS

Results from the drilling, testing, and monitoring of the five Phase I well pairs at Site 5 provide preliminary data on ground water conditions for the shallow water table and intermediate intervals at the EMDF. The well clusters were located to intercept portions of each of the geologic formations underlying the Site 5 waste footprint, ranging from north to south in the Pumpkin Valley Shale [GW-968(I)/GW-969(S) and GW-970(I)/GW-971(S)], the Friendship/Rutledge formation [GW-972(I)/GW-973(S)], the Rogersville Shale [GW-974(I)/GW-975(S)], and the Dismal Gap/Maryville formation [GW-976(I); GW-977(S) is a dry well completed at auger refusal depth above the water table].

Results associated with ground water are reviewed in the following subsections. Water level hydrographs for the well pairs define water level depths and fluctuations in response to precipitation events. The highest water levels in the shallow wells provide benchmarks for assessing relationships between basal landfill conceptual design features (i.e. – geobuffer/liner system elevations) and the highest ground water levels representative of those occurring each year during the winter/spring non-growing wet season. The water level hydrographs also indicate the range of fluctuations in the water table surface over several feet that occur over relatively shorter periods of several days or more in response to significant rainfall events, and the overall fluctuations in the water table of several feet that occur between the annual wet and dry seasons. Potentiometric surface contour maps for the water table interval define general flow directions and gradients across Site 5 and adjacent areas and demonstrate convergence of shallow ground water flow from topographically high recharge areas toward discharge zones along the NT-2/NT-3 tributaries. The water table across much of the footprint during the wet winter non-growing season occurs within the regolith, except for the area along the south edge of the footprint where the water table occurs at lower elevations down within bedrock. The contour maps and water levels among well pairs provide data for estimating variations in horizontal and vertical gradients. The results provide baseline data for further project planning and EMDF design.

4.1.1 Ground Water Level Data and Interpretations

Hydrographs illustrating fluctuations in water level elevations among the five Phase I well pairs are provided in Figures 8, 9, and 10. The figures illustrate the complete one year period of water level monitoring from late November 2014 through late November 2015. The equipment was removed from the wells in November 2015 pending final site selection among the EMDF candidate sites. The hydrographs show the surveyed elevations of the ground surface at each well so that the vadose zone interval is illustrated on the hydrographs. The hydrographs include hourly precipitation data from the Y-12 west tower meteorological station (Figure 3). The hydrographs also show the overall range in water level fluctuations (maximum/minimum elevations) along the left margin for the period of record shown and weekly manual measurements made using an electronic water level indicator. The manual measurements were used to accurately calibrate and adjust the downhole In-situ® Troll instruments used for recording continuous water level data at hourly intervals. Where the continuous monitoring data are at odds with the manual measurements, the manual measurements (shown by black triangles in the hydrographs) should be regarded as valid, as there is virtually no potential for instrument error and no instrument drift using electronic water level indicators. The highest and lowest water level elevations, depths relative to ground surface, and range of fluctuations in each of the Phase I wells over the entire year of monitoring are presented in Table 3.

4.1.1.1 Correlations between Ground Water Levels and Precipitation and Variations among Wells

The close correlation between precipitation events and changes in water levels are obvious for all well pairs except for GW-976(I) where the water level response to precipitation events is much more subdued and gradual. Upward gradients are indicated in Figure 15 for the well pairs GW-968(I)/GW-969(S) and GW-974(I)/GW-975(S), both of which show consistently higher total heads (i.e., water levels) for the deeper versus shallow wells. For the GW-968(I)/GW-969(S) well pair, the water levels in GW-968(I) range from around 1 to 2.5 ft higher than those in GW-969(S) during the recessional stages of the hydrograph curves. In the GW-974(I)/GW-975(S) well pair, water levels in GW-974(I) generally average around 1 to 2 ft higher than those in GW-975(S) during the recessional stages of the hydrograph curves. Exceptions occur when water levels rise in both wells in response to significant precipitation events. During those shorter periods of rising water levels the head differences are reduced and may even be coincident or overlap for short periods where the water levels rise much faster in the shallow wells with respect to the deeper well. This appears reasonable as the shallow well screen/filter pack intervals intersect with the water table surface and would be expected to respond more directly with pulses of recharge water added to the top of the water table with rainfall/recharge events.

Water level conditions in GW-970(I)/GW-971(S) differ in some respects from those in the GW-968(I)/GW-969(S) and GW-974(I)/GW-975(S) well pairs. A number of shifts between upward and downward gradients occur during December 2014 and February 2015 in GW-970(I)/GW-971(S). For the first 16 days of continuous monitoring upward gradients persist but then transition to downward gradients for about six days (between December 11 and 17, 2014) and then return again to upward gradients for

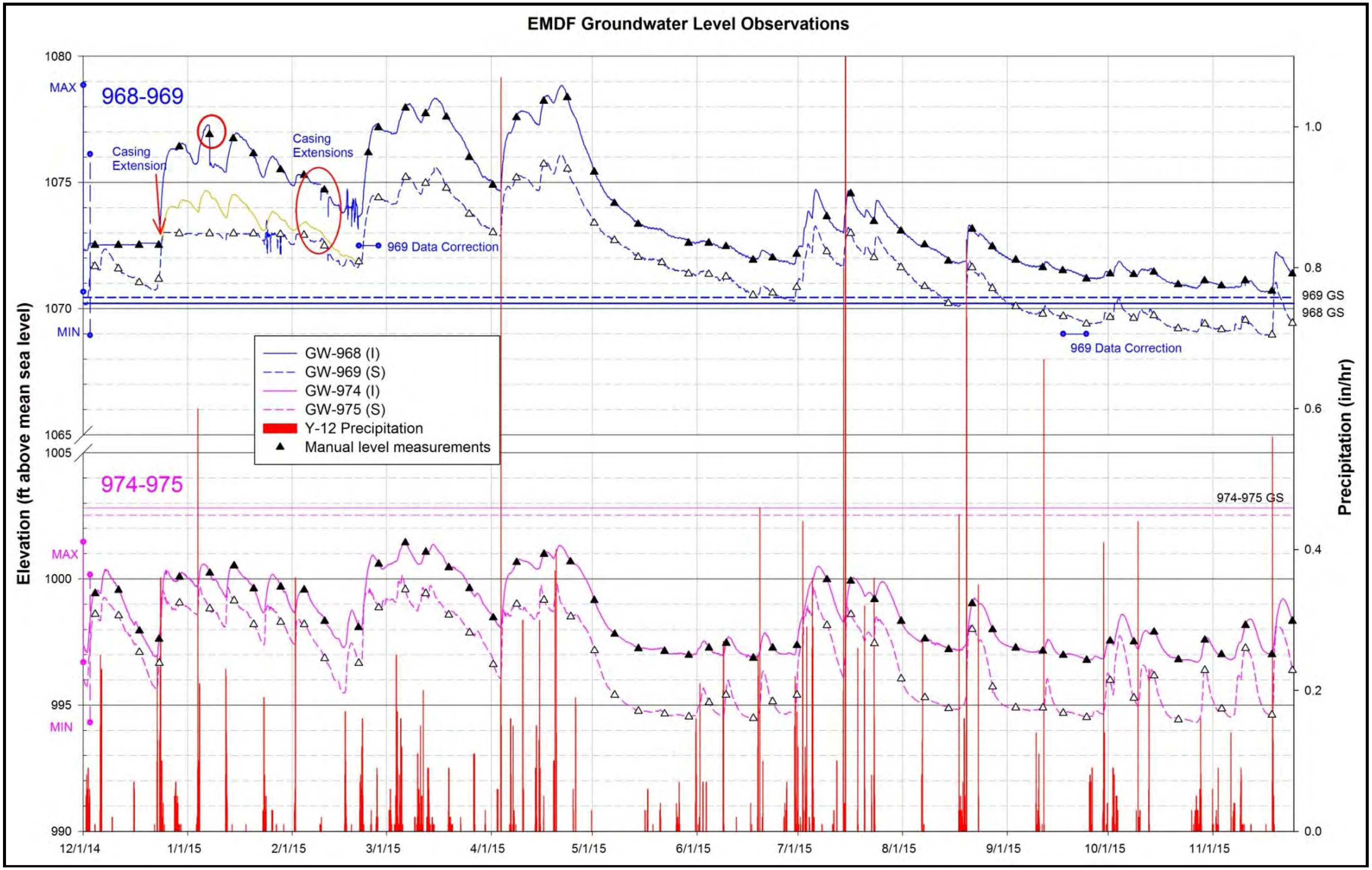

Figure 8. Water Level Hydrographs and Precipitation Data for Phase I Well Pairs

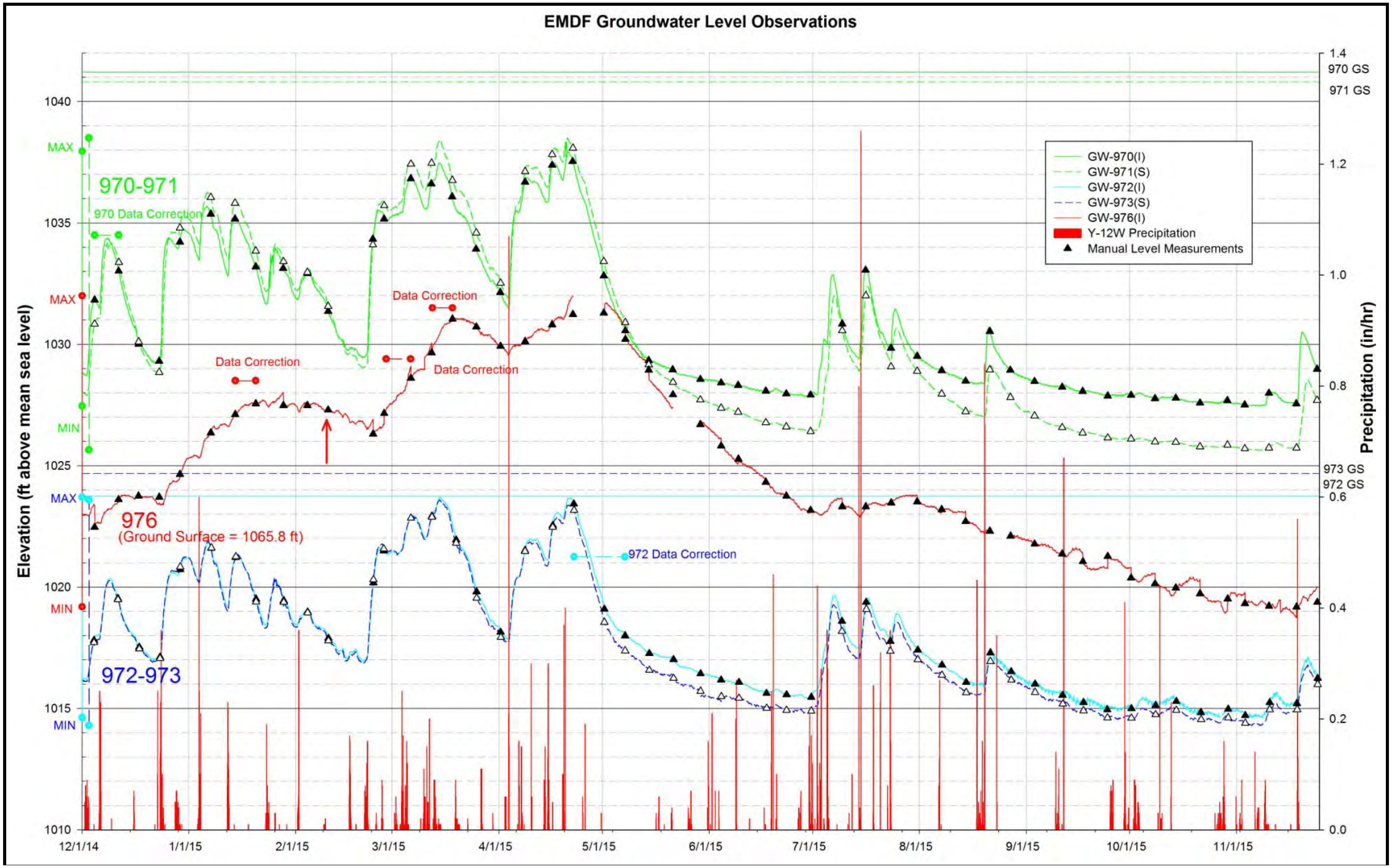

Figure 9. Water Level Hydrographs and Precipitation Data for Phase I Well Pairs

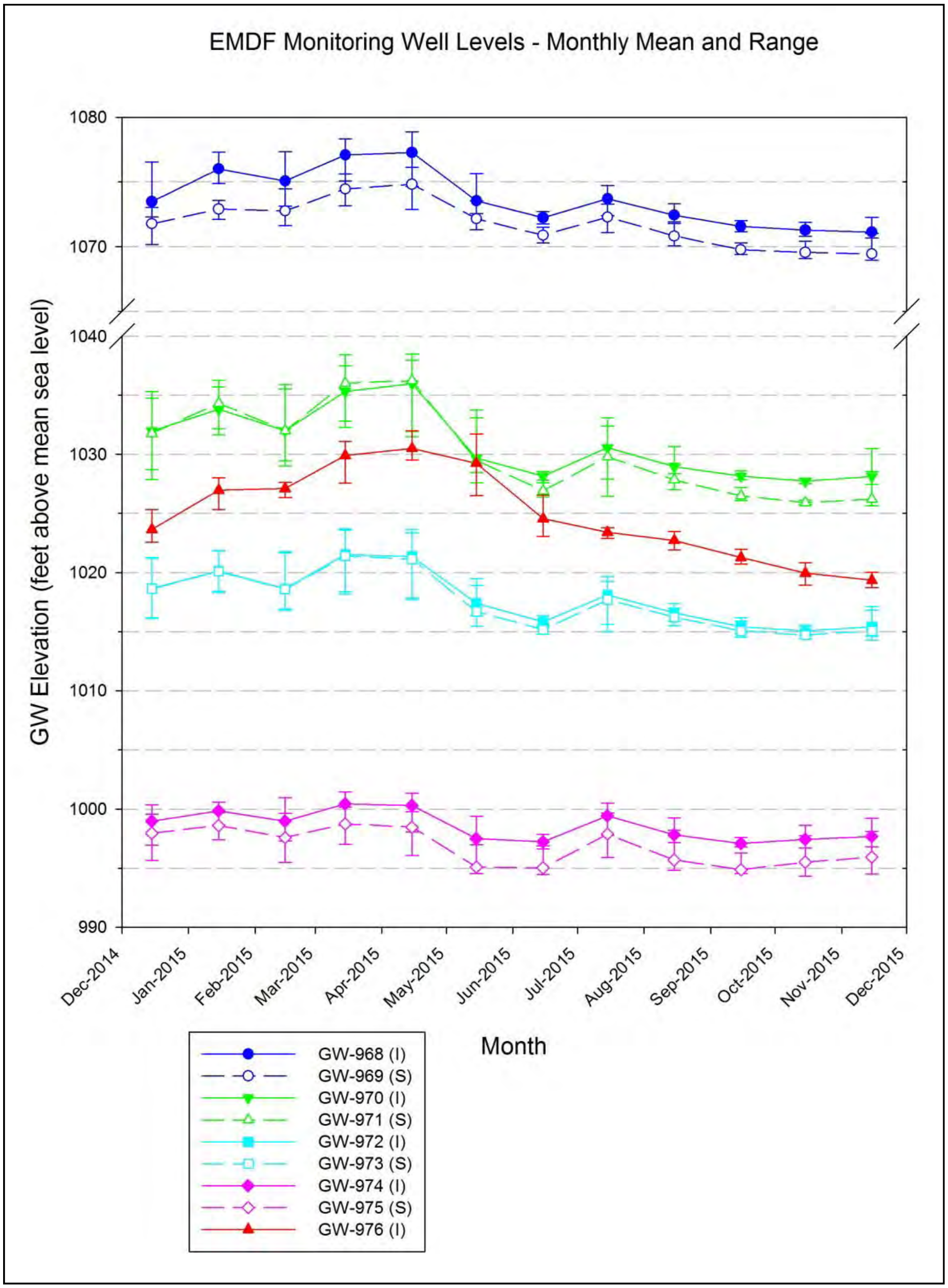

Figure 10. Monthly mean, maximum, and minimum ground water levels in Phase I wells at Site 5

Table 3. Highest and Lowest Water Level (Potentiometric Surface) Elevations in Phase I Wells

Well	Lowest Potentiometric Surface			Highest Potentiometric Surface			
	Elevation (ft AMSL)	Date	Depth (ft bgs)	Elevation (ft AMSL)	Date	Depth (ft bgs)	High/Low Difference (ft)
GW-968(I)	1070.67	11/16/2015	+0.5	1078.86	4/21/2015	+8.6	8.2
GW-969(S)	1068.95	11/16/2015	1.5	1076.12	4/21/2015	+5.7	7.2
GW-970(I)	1027.46	11/7/2015	13.5	1037.96	4/21/2015	3.0	10.5
GW-971(S)	1025.65	11/7/2015	15.0	1038.50	4/21/2015	2.2	12.8
GW-972(I)	1014.62	11/8/2015	8.9	1023.71	3/14/2015	+0.2	9.1
GW-973(S)	1014.30	11/5/2015	10.2	1023.60	3/14/2015	0.9	9.3
GW-974(I)	996.70	10/27/2015	6.1	1001.47	3/6/2015	1.3	4.8
GW-975(S)	994.32	10/27/2015	8.2	1000.17	3/5/2015	2.4	5.8
GW-976(I)	1019.19	11/18/2015	46.6	1032.00	4/22/2015	33.8	12.8

Notes and Abbreviations:

- Positive + signs indicate water level distances in feet above the ground surface at the well
- Results include the full year of continuous monitoring from late November 2014 to late November 2015.
- Note that GW-976(I) high and low elevations come from manual measurements; all others were obtained from continuous monitoring data
- Data come from hourly measurements using In-situ® Troll instruments with weekly manual calibration measurements made using an electronic water level indicator.

Ft AMSL - feet above mean sea level; ft bgs – feet below ground surface

about nine days (between December 17 and 26, 2014). Approximately four weeks into the monitoring period the upward gradients finally change relatively quickly again to downward gradients on December 26, 2014. Thereafter the downward gradients persist throughout much of the wet season monitoring period, but a transition occurs around early May after which upward gradients dominated across the summer and fall dry season, even during periods of recharge in July and August (see Figures 8 and 9).

Water level elevations in GW-972(I)/GW-973(S) during the winter/spring wet season (from December through mid April) track very closely over time with elevation differences that typically vary less than 0.15 ft. Relative to the other Phase I well pairs during the same time period these elevations appear close to identical and do not vary greatly during precipitation/recharge events or declining baseline periods as seen in the other three well pairs. Beginning around mid March water levels are very slightly higher in the deeper well GW-972(I) suggesting very slight upward gradients. This trend continues and increases around early May and across most of the dry season into early November with the most pronounced upward gradients evident during the long recessional stage across May and June when water levels in the deeper well GW-972(I) are about one foot higher than those in the adjacent shallow well GW-973(S). The closer tracking of water levels in this well pair may be related to the shorter distance between the isolation casing in GW-972(I) and the screen/filter pack interval in GW-973(S). The close tracking of water levels in the wells suggests that the water table interval intersected by the shallow well may be better connected to the uppermost part of GW-972(I) at and near the base of the 10 in. diameter isolation casing. In addition, the water level data suggest that the bedrock well has not intercepted fractures with high transmissivity under confined or semi-confined conditions that would exert substantial upward flow gradients (as indicated for other well pairs). The results of packer tests, borehole geophysical logs, and heat pulse flowmeter tests are also consistent with relatively low ground water flux and minimal upward gradients in GW-972(I).

Close examination of Figures 8 and 9 reveals that relatively low intensity and duration rainfall events during the dry summer/fall season often do not result in significant upward pulses in ground water levels, whereas comparable rainfall events during the wet winter/spring season generally do. For example, the precipitation events occurring in June 2015 after an extended period of little or no rainfall show little or no upticks in water levels where similar precipitation events in January 2015 result in pronounced upticks. These results appear to reflect differences in recharge rates based on seasonal variations in antecedent soil moisture conditions in the vadose zone. Soil moisture is often lowest during the summer and early fall when temperatures and evapotranspiration rates are higher. Conversely during the winter/spring non-growing season low temperatures and evapotranspiration result in higher soil moisture conditions conducive to more rapid infiltration and ground water recharge.

4.1.1.2 Unique Ground Water Conditions at GW-976(I) Below the Spur Ridge at Site 5

The water level changes in GW-976(I) differ greatly from those at any of the other four Phase I locations. The shallow well, GW-977(S), adjacent to GW-976(I) was completed at auger refusal depth and is dry. No data are therefore available at this location for evaluating vertical gradients by paired well water level elevation differences. However, the water table at the GW-976(I)/GW-977(S) cluster apparently occurs within the open hole interval of GW-976(I) well below the bottom of the isolation casing placed near auger refusal. Over the full year of monitoring, the top of the saturated zone (water table) or vadose zone thickness along the crest of the spur ridge at GW-976(I) has varied from 33.8 ft to 46.6 ft bgs between a highest water level in late April 2015 to a lowest level in mid November 2015, representing an overall vertical range of 12.8 ft. This depth range is equivalent to 9.4 to 22.2 ft below the top of competent bedrock, well below the base of the regolith at auger refusal. The water table at each of the other Phase I well clusters across Site 5 remained consistently above the top of bedrock within regolith materials throughout the entire year of monitoring.

Unique among the hydrographs of the Phase I wells shown in Figures 8 and 9, water levels in GW-976(I) do not show the dramatic fluctuations seen in response to precipitation events. With the exception of GW-976(I), the hydrographs in all the Phase I wells show prompt increases and steady declines in their potentiometric surfaces after precipitation events. In contrast, the hydrograph for GW-976(I) shows only very slight adjustments in water levels relative to precipitation events and gradual increases over the winter/spring wet season followed by a gradual prolonged decrease in water levels during the six months of the summer/fall dry season not seen in other well locations.

4.1.1.3 Relative Rates of Ground Water Flux at Site 5

The relatively rapid decline in water levels following precipitation events seen in all Phase I wells except for GW-976(I) indicates a greater rate of ground water flux, drainage, and discharge to the main NT-3 tributary valley relative to that from the ground water mound below the boot-shaped area of the spur ridge encompassing GW-976(I). The higher rate of flux north of the spur ridge may be influenced by the higher hydraulic heads below and more directly adjacent to Pine Ridge. In addition, the thicker vadose zone below the spur ridge crest probably results in a slower rate of recharge to the water table in that area. Ground water fracture flow paths and hydraulic gradients toward the northwest, north, and south of GW-976(I) may also be more restricted in a direction opposite to the northeast-southwest geologic strike and bedding plane dip direction toward the southeast. Tracer tests described in Appendix E demonstrate that tracers injected at the water table move more slowly and show greater lateral dispersion and diffusion in areas where hydraulic gradients are perpendicular to geologic strike.

4.1.1.4 Water Table Depths with Respect to Regolith and Bedrock

Among the five Phase I well cluster locations, the depth to bedrock varied from 10.0 to 24.4 ft bgs. The Phase I data summarized in Table 4 indicate that the water table surface consistently occurred above the regolith/bedrock interface (i.e. above auger refusal depths) for the entire year of monitoring across most of the EMDF footprint. The exception occurred in the area near GW-976(I) below the boot-shaped area of the spur ridge along the south side of the EMDF footprint, where the water table occurs well below the top of bedrock and where the vadose zone is much thicker.

Table 4. Relationships between water table depths and depths to the regolith/bedrock interface

Well	Overall range for depths to water table or vadose zone thickness (ft bgs)	Auger refusal depths or regolith thickness [i.e. Depth to Bedrock} (ft bgs)	Difference between highest and lowest water levels over one year monitoring period (ft)
GW-969(S)	1.5 to 5.7+	13.5	7.2
GW-971(S)	2.2 to 15.0	23.8	12.8
GW-973(S)	0.9 to 10.2	23.0	9.3
GW-975(S)	2.4 to 8.2	10.0	5.8
GW-976(I)	33.8 to 46.6	24.4	12.8

Notes and Abbreviations:

- Data in this table are based on the full year of Phase I continuous water level monitoring data for the period from late November 2014 through late November 2015
- The + sign next to 5.5+ indicates the maximum water level above ground surface on April 21, 2015. All other water table depths shown are below ground surface. The artesian conditions at the GW-969(S) well cluster are the result of lowering the original ground surface during site grading for access roads and drilling pads, and the well location within the lower portion of a natural ravine incised into the south lower flanks of Pine Ridge where ground water converges.

Ft bgs feet below ground surface

4.1.1.5 Annual and Seasonal Water Level Fluctuations

The overall annual differences between highest and lowest water level elevations are provided in Table 3 and illustrated in Figures 8 and 9. The greatest annual difference occurs at the locations with the greatest vadose zone thickness (i.e. – where the depth to the water table or potentiometric surface is greatest) – at GW-970(I)/GW-971(S) and at GW-976(I) where the annual difference is 10.5 and 12.8 ft for the shallow/deep wells, respectively. The location with the least annual difference in water table levels occurred at the GW-974(I)/GW-975(S) cluster where the annual difference was 4.8 and 5.8 ft, respectively.

Across the full year of monitoring, the greatest seasonal change is seen in GW-970(I)/GW-971(S) and at GW-976(I) where the winter and early spring high water levels contrast with the pronounced water level declines that occur across the summer and into the fall seasons (See hydrographs in Figures 8 and 9). The least seasaonal change is seen in the GW-974(I)/GW-975(S) cluster, with intermediate seasaonal declines in GW-968(I)/GW-969(S) and GW-972(I)/GW-973(S).

Water level hydrographs that illustrate seasonal cycles from 2000 to 2014 are available for many of the EMWMF monitoring wells and well clusters (see representative hydrographs in Attachment A Exhibit A.18). These hydrographs show seasonal high water levels that occur consistently in the winter and early spring when recharge and runoff tend to be higher, and evapotranspiration is lowest. The Phase I hydrographs shown in Figures 8 and 9 reflect these same annual seasonal cycles.

4.1.2 Potentiometric Surface Contour Maps

Figure 11 illustrates the potentiometric surface for the water table interval at Site 5 on April 21, 2015, representing the highest water level for the full year of monitoring. This map is representative of flow directions and gradients for the uppermost water bearing zone below the site during the wet non-growing season. Control points for the contours shown on Figure 10 are based on synoptic water levels in the *shallow* Phase I wells, except for GW-976(I) where the shallow well (GW-977[S]) is dry. Control points also include nine Phase I surveyed channel bottom elevations at monitoring locations along the NT-3 stream paths. In addition to those control points, the potentiometric surface (water table) is assumed to intersect with ground surface elevations along the NT-2 and NT-3 stream paths. Figures in Appendix E and H illustrate the model predicted potentiometric surface for the water table interval at Site 5 based on post-construction steady state conditions assuming various rates of infiltration. In comparison with Figure 10, the post-construction maps illustrate predicted declines in the water table surface assuming the low permeability landfill cap is in place significantly limiting recharge, the underdrain is functional, and natural recharge only occurs across a narrow swath of land along the upper south facing slopes of Pine Ridge above the Site 5 footprint. The most striking difference between the modeled water table surface and that in Figure 10 is the elimination of the existing ground water mound below the spur ridge along the south side of the Site 5 footprint. Elsewhere the water table is lowered and maintained through the combined effects of limited recharge and the underdrain system.

The vadose zone is believed to thin progressively toward the NT valley floors where the water table during the wet non-growing season seeps into the stream channels, springs, and seep and wetland areas providing baseflow for the NT streams. The water table contour map is a subdued version of surface topography with a flattening of the water table and thickening of the vadose zone below topographically high areas such as along the crest of Pine Ridge and the spur ridge where GW-976(I) is located. However, the actual water table surface may be more uneven on a local scale than shown, as shallow ground water occurs and migrates unevenly within macropores and fractures of saprolite and weathered bedrock that are not necessarily of a uniform or even configuration. The configuration of the potentiometric surface at greater depths within the intermediate and deep intervals of the saturated zone would be increasingly less uniform and uneven, according to the complexity of deeper interconnected fractures and depending upon which fractures are penetrated in any given monitoring well.

Relatively flat wetland areas with seeps and springs have been identified along the drainage paths of the NT-2 and NT-3 tributaries crossing and adjacent to Site 5 (see hatchured areas on Figure 11). These areas have been delineated using GPS field mapping as part of ecological/wetland surveys, and commonly occur at transitions between steeper and flatter slopes where the shallow water table intersects and discharges to the ground surface. These areas are key locations for the proposed underdrain system to capture and drain ground water underflowing the footprint and prevent upward migration of the water table into the geobuffer. The topographically low areas near seep locations EMDNT2-SE1, EMDNT2-SE2, and EMDNT2-SE3 along the southeast margins of Site 5 (see locations on Figure 10) were partially excavated and reworked during the Fall of 2014 as part of the UPF haul road construction. But these areas remain as significant discharge areas for shallow/intermediate level ground water emanating from the southeast quarter of the EMDF site. Similar areas occur along the southwest and western margins of the Site 5 footprint.

It is noteworthy that the three headwater springs, EMDNT2-SP1, EMDNT3-SP1, and EMDNT3-SP2, all occur consistently at elevations near the 1,050 ft surface elevation contour. These springs do not occur at or near the projected surface contact between the Rome Formation and Pumpkin Valley Shale (see locations and outcrop belts on other RI/FS figures and Plates). This suggests that the location of these springs is influenced primarily by the intersection of the water table with the ground surface within regolith soils/saprolite, and not in relation to springs or seeps that have been conjectured to occur along contacts between geologic formations.

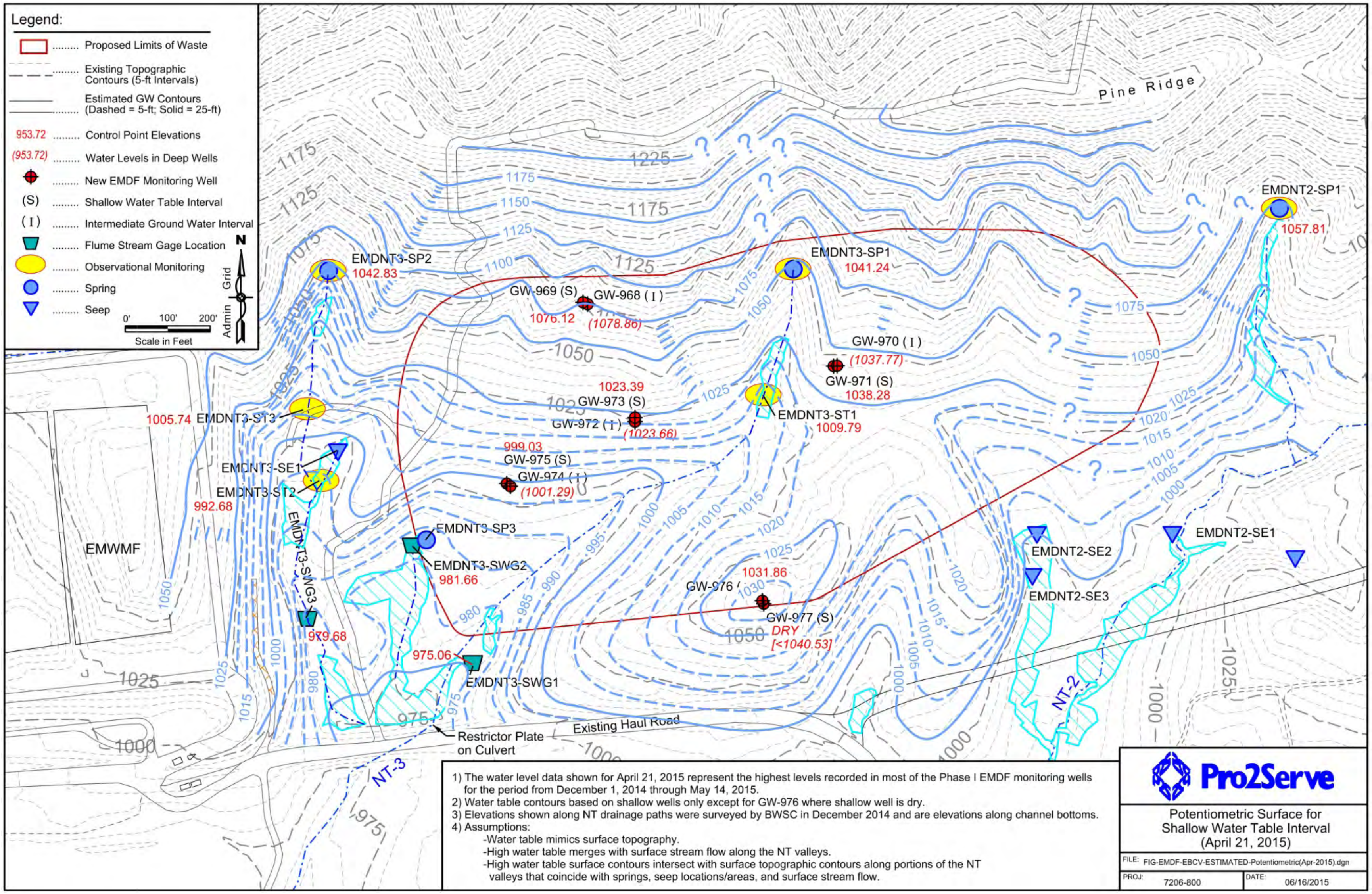

Figure 11. Contour Map of the potentiometric surface at Site 5 representing the seasonal highest shallow water table interval on April 21, 2015

4.1.3 Horizontal and Vertical Ground Water Gradients

An assessment of horizontal and vertical gradients is presented in Section 7.2.3.3 of Attachment A and not repeated here, except to note that the determinations of horizontal gradients determined in Section 7.2.3.3 would not differ appreciably from those illustrated in Figure 18. As described in Section 7.2.3.3 of Attachment A, vertical gradients can vary significantly over relatively short time frames depending primarily on the relationships between precipitation events and pulses of water table recharge. Vertical gradients tend to stabilize during the more prolonged declining phases of the hydrograph curves between storm events when lateral ground water flow and gravity drainage occurs toward base flow discharge zones along the nearest NT stream valleys.

4.1.4 Site Cross Sections and Cut/Fill Thickness Drawings

The attached Plates 5 and 6 (on DVD in pocket) provide north-south and east-west hydrogeological cross sections across the Site 5 footprint through the Phase I well clusters. The sections provide the primary lithological sequence defined by analysis of the rock core data in GW-972(I) and GW-976(I). The sections also illustrate the results of hydraulic conductivity tests in each well and results of the heat pulse flow meter testing conducted in the open boreholes of the deeper wells in each cluster. The sections illustrate the April 21, 2015 water table surface and regolith thickness (i.e. – top of bedrock) in relation to the main conceptual design elevations for the proposed landfill (i.e. – the geobuffer/liner and waste cell elevations, etc.). The sections are meant to be printed as E sized drawings. A figure is also provided illustrating the cut/fill thickness in feet based on the conceptual design, representing the difference between the existing ground surface elevations and the bottom of the proposed geobuffer elevations.

4.1.5 Ground Water Quality Parameter Data

Hourly monitoring of temperature, pH, SpC, and ORP collected from the nine ground water monitoring wells during the December 2014 through November 2015 period suggest some persistent differences between the shallow wells (water table interval) and the deeper wells (intermediate bedrock interval). Variations in water quality associated with changes in ground water levels in response to precipitation are also evident in the monitoring data, but patterns over time and differences among wells are more difficult to generalize because of data quality problems affecting much of the record. These problems include sensor malfunctions and calibration errors due to a variety of operational and environmental factors, and make it difficult to identify reliable portions of the record with confidence.

In general, for temperature, pH, and SpC, inter-well differences are large enough relative to variations over time due to environmental changes, instrument calibration, or other causes to differentiate among wells. Temperature records from the ground water monitoring wells are perhaps the most reliable data available, and reflect differences among wells as well as seasonal trends and the impact of precipitation events (see Figure 12). For each of the four well pairs for which data are available[1], the deep wells exhibit less water temperature variation than the paired shallow wells. The deep well ground water temperatures vary less than the shallow well temperatures, and are generally warm relative to the paired shallow well during the winter and cooler than the shallow wells during the summer.An exception to this pattern occurs for the GW-970, -971 pair, for which the shallow GW-971 well remains cooler than GW-970 throughout the period of record (Figure 12).

[1] Monitoring well GW-977(S) was dry throughout the reporting period.

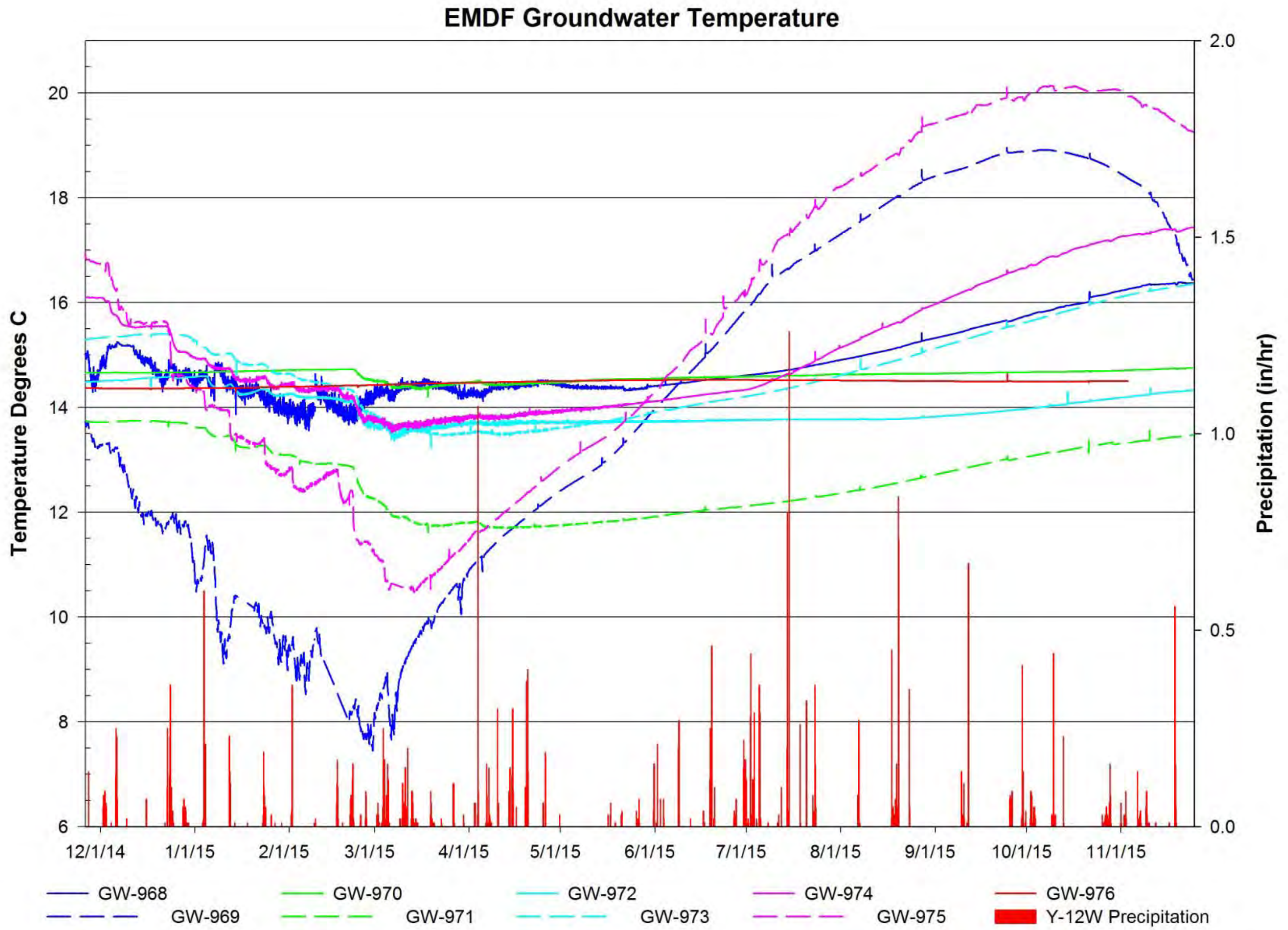

Figure 12. Ground Water Temperatures Recorded during the December 2014 through November 2015 Reporting Period

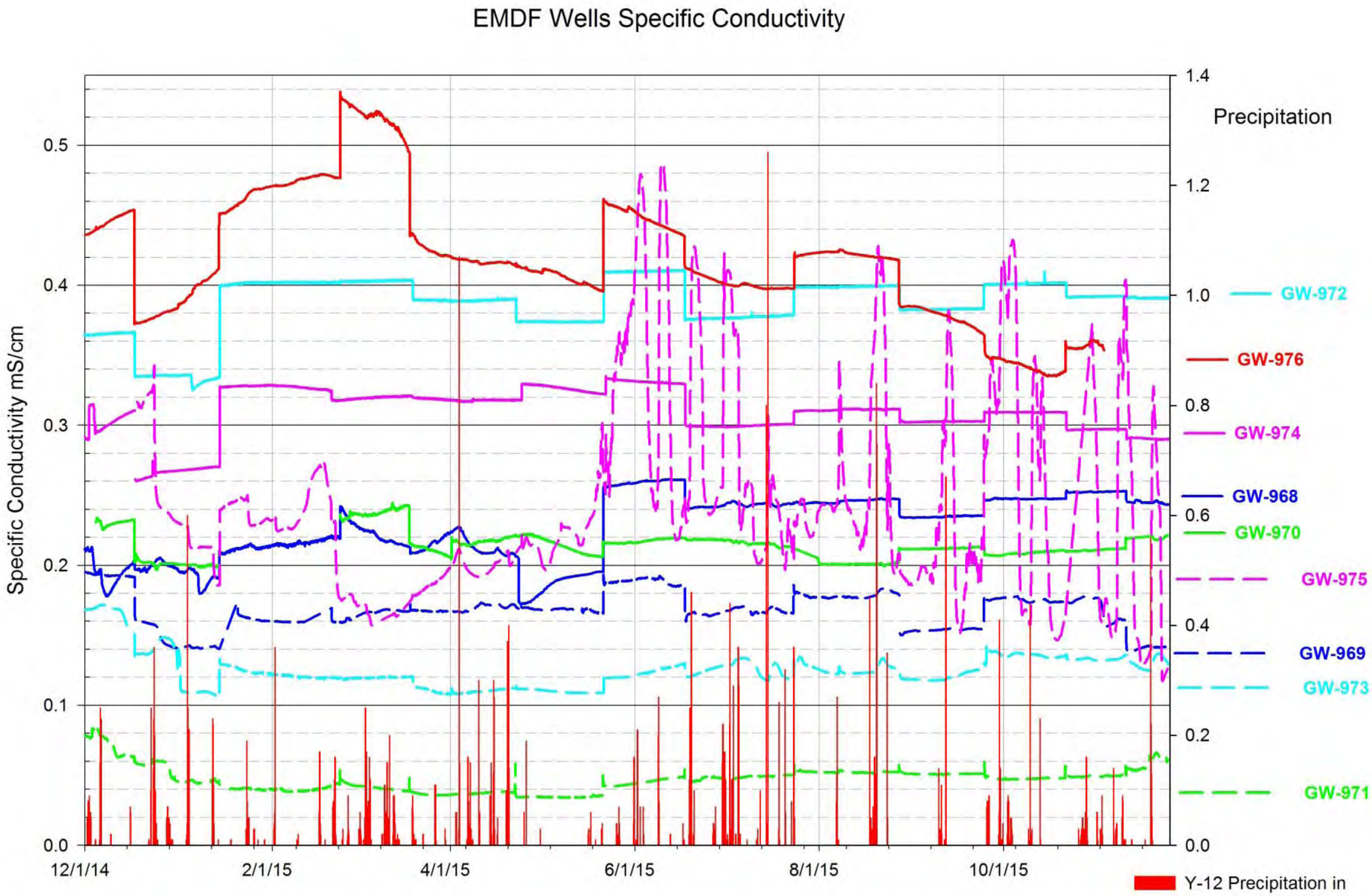

Figure 13. Ground Water Specific Conductivity Recorded during the December 2014 through November 2015 Reporting Period

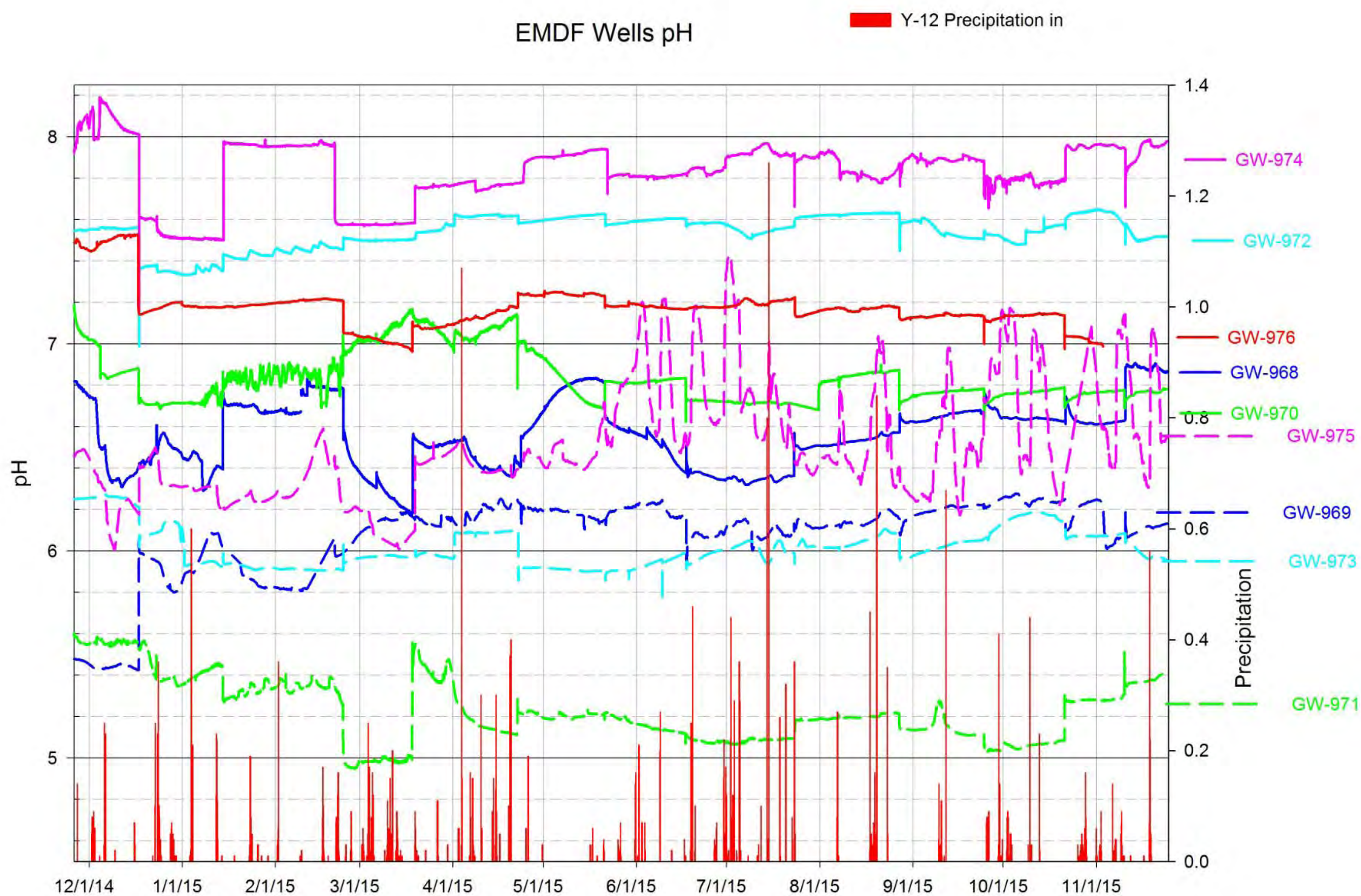

Figure 14. Ground Water pH Recorded during the December 2014 through November 2015 Reporting Period

Despite some relatively large calibration uncertainties, and some SpC data that were clearly erroneous and thus eliminated from further analysis, inter-well differences in mean values of pH and SpC clearly illustrate general water quality differences between the deep and shallow wells and reflect the influence of hydrology and lithology on ground water geochemistry.

The four shallow (water table interval) wells exhibited lower SpC and pH than the corresponding four paired deep wells and the GW-976deep well (see Figure 13 and 14). For the five deep wells, SpC was generally 0.20 mS/cm or greater, whereas for the four shallow wells, SpC remained below 0.25 mS/cm. Similarly, the five deep wells tended to have pH in the range from 6 to 8 units, while the four shallow wells, pH ranged between 5 and 7 units. For each of the four monitoring well pairs, there was little to no overlap in the range of pH and SpC values measured during the monitoring period. These distinctions in the range of observed pH and SpC among monitoring wells are fairly pronounced, even though for the deep wells much of the observed range is due to large changes in values upon instrument calibration. One basic hydrogeologic explanation for these water quality patterns is that pH and SpC in shallow ground water are strongly influenced by surface infiltration of relatively dilute, slightly acidic rainwater, whereas recharge to deeper ground water involves a longer period of geochemical evolution that is reflected in higher pH and SpC readings in the deep monitoring wells. Bedrock lithology is another factor that may affect differences among wells.

One anomaly in the generally stable ground water SpC and ph conditions observed over time was GW-975, for which the reading become highly variable beginning in late May 2015. This change was not related to instrument malfunction, and must represent either a change from wet season to dry season behavior or a more permanent change in the groundwater flow conditions in the vicinity of this particular well. Changes in pH and SpC in response to precipitation varied among wells and among rainfall events. With the exception of GW-968(I), the deeper (intermediate bedrock interval) wells exhibited few changes in pH or SpC that were clearly linked to precipitation events, whereas monitoring wells GW-968(I), GW-969(S), and especially GW-975(S) often exhibited pronounced decreases in pH and/or SpC associated with rising ground water elevations following precipitation. Decreasing pH and SpC in response to infiltration and ground water recharge reflects the input of meteoric water that is dilute and weakly acidic relative to ground water.

5. REFERENCES

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APPENDIX F:
ALTERNATIVES RISK ASSESSMENT
AND
FUGITIVE EMISSION MODELING

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CONTENTS

FIGURES

TABLES

ACRONYMS

ABC	articulated bulk containers
ANL	Argonne National Laboratory
BCV	Bear Creek Valley
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
DOE	U.S. Department of Energy
EMDF	Environmental Management Disposal Facility
EMWMF	Environmental Management Waste Management Facility
EPA	U.S. Environmental Protection Agency
ETSZ	East Tennessee Seismic Zone
ETTP	East Tennessee Technology Park
FEMA	Federal Emergency Management Agency
ILCR	Incremental Lifetime Cancer Risk
LLW	low-level waste
M	moment magnitude
MEI	maximally exposed individual
MMI	Modified Mercalli Intensity
NAAQS	National Ambient Air Quality Standard
NNSS	Nevada National Security Site
NOAA	National Oceanic and Atmospheric Administration
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
PGA	peak ground acceleration
PM	particulate matter
RCRA	Resource Conservation and Recovery Act of 1976
RI/FS	Remedial Investigation/Feasibility Study
SOF	sum of fraction
TEDE	total effective dose equivalent
TSCA	Toxic Substances Control Act of 1976
U.S.	United States
USGS	U.S. Geological Survey
WAC	waste acceptance criteria
Y-12	Y-12 National Security Complex

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1. INTRODUCTION

This Appendix presents the methodology and results of risk assessments for the on-site and off-site disposal of waste expected to be generated by future Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) actions on the United States (U.S.) Department of Energy (DOE) Oak Ridge Reservation (ORR) after Environmental Management Waste Management Facility (EMWMF) capacity is reached. Risks were estimated based on transportation of wastes assumed to occur in the On-site and Off-site Disposal Alternatives, and based on natural phenomena and fugitive dust emissions associated with the On-site Disposal Alternative. Risk assessments were completed using computer codes developed at Argonne and Sandia National Laboratories: RADTRAN, RESRAD, and RISKIND.

RADTRAN code was developed at Sandia National Laboratories. RADTRAN combines user-determined demographic, routing, transportation, packaging, and materials data with meteorological data (partly user-determined) and health physics data to calculate expected radiological consequences of incident-free radioactive materials transportation and associated accident risks (Sandia 2009).

RESRAD is a family of codes developed at Argonne National Laboratory (ANL) for evaluating human health risk at sites contaminated with radioactive residues. RESRAD is a pathway analysis computer code that calculates radiation doses and cancer risks to a specified population group (ANL 2001).

RISKIND was developed at ANL for analyzing the potential radiological health consequences to individuals or specific population subgroups exposed to radiation materials through routine and accident transportation scenarios (ANL 1995).

Combining the use of RISKIND and RADTRAN models allowed a thorough assessment of the risk due to transporting the waste (on-site and off-site). This analysis is presented in Chapter 2 below. Chapter 3 presents the assessment of risk associated with natural phenomena scenarios (for the On-site Disposal Alternative) using the RESRAD code, while Chapter 4 presents an assessment of the fugitive dust exposures expected during construction of an on-site facility.

Risk due to seismicity were evaluated using U.S. Geological Survey probability and spectral acceleration calculators available at the following publicly accessible websites:

- https://geohazards.usgs.gov/
- http://eqint.cr.usgs.gov/deaggint/2008/index.php

As noted in Section 3.2.2, a more detailed seismic evaluation will be carried out as part of the design process.

2. TRANSPORTATION OF WASTE

The assessment of risk posed by transportation of CERCLA waste (on-site and off-site) was completed based on guidance given in *A Resource Handbook on DOE Transportation Risk Assessment* (DOE 2002). As noted in this guidance, the primary end point for typical transportation risk assessments is the potential human health effect from exposure to low doses of radiation (cancer) or exposure to chemicals (toxic effects and cancer). As described in Chapter 2 of the Remedial Investigation/Feasibility Study (RI/FS), chemical contaminants for future waste streams to be disposed in the Environmental Management Disposal Facility (EMDF) are assumed to be similar to those of waste disposed at the EMWMF and contribute relatively minimal transportation risk. Because the risks to human health due to transportation are primarily from radioactive constituents in waste expected to be generated by future CERCLA actions, this assessment is limited to scenarios based on radioactive waste characterizations.

The risk assessment process for transportation is developed in Section 2.1 through Section 2.3. Section 2.4 presents the results of the assessment.

2.1 SCENARIO DEVELOPMENT

Transportation risk is associated with both the On-site and Off-site Disposal Alternatives. The Hybrid Disposal Alternative is a combination of the on- and off-site transportation risks. As such, it is not individually discussed throughout this analysis, but is determined as a portion of the on-site and off-site results. Parameters for evaluating transportation risk for on-site transportation and off-site transportation are discussed in the following sections. These include parameters associated with the alternatives: waste transported, routes traveled, vehicles used, and receptors (public and individuals) along the route. These parameters are the inputs to computer models used to ultimately determine the risks associated with transporting the waste.

2.1.1 On-Site Disposal Alternative

Several site Options are evaluated in the On-site Disposal Alternative. All are located within Bear Creek Valley (BCV). Cleanup actions at all three ORR sites, Oak Ridge National Laboratory (ORNL), Y-12 National Security Site (Y-12), and the East Tennessee Technology Park (ETTP) will generate CERCLA waste which will be transported to an on-site disposal facility. A single route was modeled that represented on-site transport for the On-site Disposal Alternative site Options (all locations) and Off-site Disposal Alternative, with the Hybrid Disposal Alternative a combination of the two. Although there will be shorter and longer routes during the life of the project, a distance of 11 miles was assumed to be a representative distance for risk modeling from any of the three plant sites to any of the EMDF site Options for the On-site Disposal Alternative or from any of the three plant sites to the ETTP rail yard for the Off-site Disposal Alternative. This distance was selected after examining various travel distances from locations within ORNL, Y-12, and ETTP to the new BCV sites and various travel distances to the ETTP rail yard from locations within ORNL, Y-12, and ETTP. All wastes were considered (total number of shipments, all types of waste) to travel this route by truck for on-site transport risk analyses.

2.1.2 Off-Site Disposal Alternative

The scenario involving transportation of waste to an off-site disposal facility must first be analyzed according to the type of waste generated, in order to evaluate the routes the waste must travel. For purposes of mapping routes, the waste may be broken into three categories. Classified waste travels from the site of origin to the Nevada Nuclear Security Site (NNSS) for disposal. Low-level waste (LLW) and waste with LLW and Toxic Substances Control Act of 1976 (TSCA) components (LLW/TSCA) will travel by truck from the site of origin to ETTP rail yard, be transferred to rail where it will travel to Kingman, Arizona[1], be unloaded and then trucked from there to the NNSS disposal facility outside of Las Vegas, Nevada. The third route will be followed for waste with LLW and Resource Conservation and Recovery Act of 1980 (RCRA) hazardous components (LLW/RCRA) and will involve transfer by truck from the site of origin to ETTP, where it will be transferred to rail and transported directly to Clive, Utah, for disposal at Energy*Solutions* disposal facility.

[1] The transfer from rail to truck, for the final leg of transport to NNSS for disposal now occurs in Parker, Arizona. The route difference total is about 30 miles, so no changes have been made to this analysis as any modifications would not result in measurable risk changes. The document continues to refer to a transloading station in Kingman, Arizona.

2.1.3 Scenario Routes

To summarize, there are essentially six full or partial routes to be traveled for the on-site and off-site scenarios:

- Truck from waste origin to disposal at EMDF (transported on-site to any of the possible site Options).
- Truck from waste origin to ETTP rail yard (transported on-site, but initial leg of off-site routes involving rail transport).
- Rail from ETTP rail yard to Kingman, Arizona, rail yard (off-site).
- Truck from Kingman, Arizona, rail yard to disposal at NNSS (off-site).
- Rail from ETTP rail yard to disposal at Energy*Solutions* site in Clive, Utah (off-site).
- Truck from waste origin to disposal at NNSS in Nevada (off-site).

The two on-site scenario routes listed above (waste origin to EMDF and waste origin to ETTP rail yard) were condensed into a single route "input" for modeling purposes, since the distance traveled is very similar and the mode of transport is the same. Combinations of partial routes make up the total off-site routes.

Figure F-1 is a schematic of all transportation routes used in modeling the risk.

Routes assumed to be followed in transporting the waste off-site were determined, and then input into the TRAGIS model developed at ORNL (ORNL 2000). Where possible, this model was used to determine population densities along the routes, miles traveled by state, and number of stops and locations, all of which provides input into dose calculation models RADTRAN and RISKIND. Additionally, TRAGIS output data were used in determining vehicle-related risks associated with transportation.

2.1.4 Waste Parameters

Waste parameters are required in order to model the dose rates needed to ultimately determine the risk in transporting the waste for both on- and off-site disposal scenarios. The waste characterization data used were developed in Chapter 2 and Appendix A of this RI/FS; the mass-weighted average concentrations of nuclides are used in the models RISKIND and RADTRAN. Predicted waste generation rates and volumes are provided in Chapter 2 and Appendix A of this RI/FS. Chapter 6 of this RI/FS provides information about packaging and number of shipments which were determined for each of the routes described in Section 2.1.3 of this Appendix. Intermodal containers are assumed to be used, both for trucking and rail transport. These data also provide input to the dose calculation models. Section 2.3 contains a summary of inputs and assumptions to the models.

2.1.5 Receptors

Receptors are the collective groups or individuals exposed to the radioactive waste during transport. Dose models calculate exposures for multiple receptors under specific scenarios; the user must identify the receptors. For purposes of on-site transportation, the receptors were identified as the driver and a resident along the route. These individuals are referred to as maximally exposed individuals (MEIs). A collective population was evaluated as well, and in the case of on-site travel, the collective population includes the crew (only the driver in this case), off-link (resident along the route) populations, and handlers. For trucks traveling off-site individual receptors or MEIs identified for the truck routes in this assessment include the truck driver(s), a passenger in a car sharing the road, a person living or working along the transport route, a truck inspector at a weigh station, and a person at a service station. Collective populations evaluated include the crew (driver and passenger), on-link (i.e., persons sharing the road), and off-link (i.e., persons living/working on the route).

Rail transport MEIs included a resident along the route, rail inspector at the rail yard, rail yard crew member, person stuck in traffic near a rail line, and a resident near a rail stop. Collective populations evaluated for rail transport included: crew (engineer, conductor, brakeman), on-link, and off-link populations.

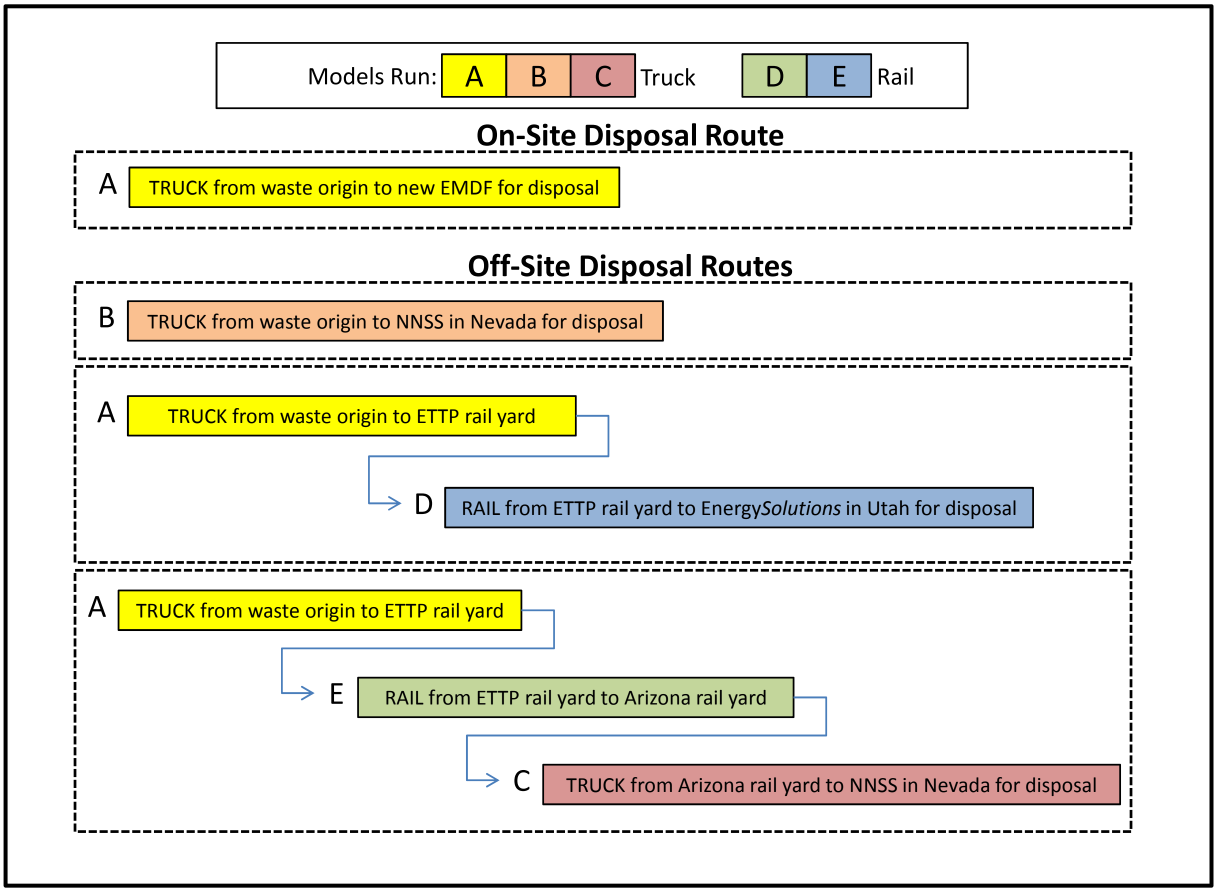

Figure F-1. Transportation Routes Assessed in On-site and Off-site Disposal Alternatives

2.2 TRANSPORTATION RISK MODELING

Assessing risk encountered through the transportation of waste involves multiple pathways and multiple receptors. Figure F-2 illustrates transportation risk exposure through two primary modes – "cargo-related" (radiological risk), having to do with the waste itself and "vehicle-related" risk, risk independent of the cargo and having to do with the emissions, rate of speed, vehicle, and route/route-related parameters.

2.2.1 Radiological Risk

Radiological risk, presented by the cargo itself, is the primary concern when assessing transportation risk. Estimates of exposure to low levels of ionizing radiation during transportation are made through the use of computer models which estimate the dose levels received by various receptors. This exposure occurs in one of two ways (see Figure F-2), through routine travel or through accidents. In both cases, receptors of concern include the general public and individuals, MEIs. *A Resource Handbook on DOE Transportation Risk Assessment* recommends using two separate codes to estimate the doses that could potentially occur to various people or groups of people along the transportation routes in order to perform a uniform and comprehensive assessment. The handbook suggests that the RADTRAN code be used to evaluate doses to collective populations and the RISKIND code be used to predict the doses for MEIs. This assessment follows these recommendations and uses the inputs as described in Sections 2.1 and 2.3 and Figure F-2 to obtain estimated doses (in rem or person-rem) for various individuals or groups. In order to translate these doses to a unit of risk, the dose rates were converted into expected cancer incidents based on conversion factors derived from decades of studying radiation exposed populations (DOE 2003).

2.2.1.1 RADTRAN Code

The RADTRAN code was used to predict radiological exposures as total effective dose equivalent (TEDE) in person-rem to collective populations in routine and accident transportation scenarios. These exposures are converted to terms reported for risk assessments (i.e., morbidity and mortality rates), using health risk conversion factors. For this RI/FS, RADTRAN was run for the five different routes (A through E) as shown in Figure F-1. For those routes that are made up of several partial routes, summing the output from the model is necessary to obtain information for the whole route.

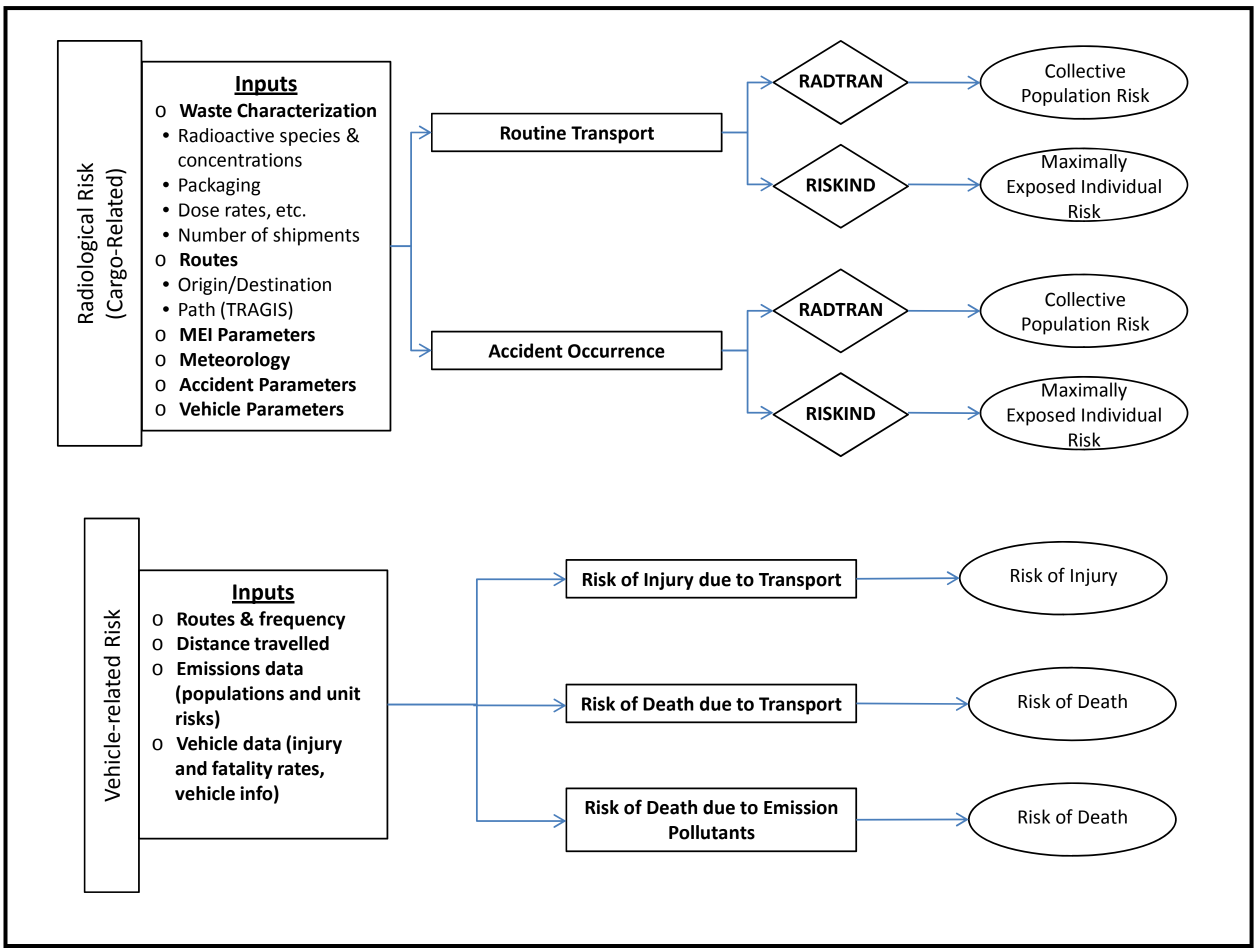

Figure F-2. Approach to Determining Transportation Risk

2.2.1.2 RISKIND Code

Like RADTRAN, RISKIND calculates exposures as TEDE during transportation of radioactive materials under routine and accident scenarios. RISKIND, however, was used to calculate the exposures to MEIs. RISKIND determines the dose rates that MEIs are exposed to independent of the route traveled. Therefore, it was only necessary to run the model for three scenarios which were dependent on the identified MEIs:

- Truck travel from waste origin to the proposed EMDF (drivers, resident along route).
- Truck travel from waste origin to NNSS or from Kingman, Arizona to NNSS (drivers, person in traffic, resident along route, truck inspector, and person at service station).
- Rail travel from ETTP rail to either Clive, Utah, or Kingman, Arizona (resident along the route, rail inspector at the rail yard, rail yard crew member, person stuck in traffic near a rail line, and a resident near a rail stop).

For those routes made up of more than one partial route, summing the output from the model is necessary to obtain information for the whole route. Exposure to individuals during routine travel is modeled as in-transit and stationary (e.g., traveling and stopped). For example, a truck may stop at a rest stop/restaurant for a short period of time, or stop overnight. Model inputs may be tailored to take into account all these situations. Again, summing the results for the different situations is required for a complete picture.

2.2.2 Vehicle-Related Risk

Vehicle-related risk is associated with travel; vehicle accidents occur, sometimes causing injuries and fatalities. In addition, risk due to emissions from vehicles must be considered, since extended exposure to fumes can cause illness and fatalities. These risk factors are functions of the inputs shown in Figure F-2: routes and frequencies traveled (related to amount of waste transported), routes dictate population densities and distances that must be accounted for; and vehicle data (truck and type of truck versus railcars) corresponds to tabulated injury and fatality rates. The processes followed and truck/rail injury and fatality rates used to calculate non-radiological (vehicle-related) risks were taken from *The DOE Risk Assessment Handbook* (DOE 2002).

2.3 ASSUMPTIONS AND INPUTS

The development of transportation risk scenarios and input to the modeling codes required multiple assumptions and minor calculations. The following assumptions and calculated inputs were assembled to complete the risk analysis.

On-Site Disposal Alternative Assumptions and Inputs

- All waste generated is considered to be disposed at the on-site facility. As described in Chapter 2 of the RI/FS, the small percentage of waste that does not meet the disposal facility waste acceptance criteria (WAC) or is shipped off-site due to other project-specific factors is not a differentiator in the alternatives and is not included in the RI/FS waste volume estimate.
- A single route is used for all on-site travel to the proposed EMDF, and this is sufficiently representative whether the waste is generated at ORNL, ETTP, or Y-12.
- It is estimated that 162,380 shipments of waste will be made.
- The MEIs include the driver of the truck and a worker within the defined radial contamination range that the program evaluates. Travel is assumed to occur on a non-public road, and; therefore, the MEIs exposure analysis does not include a typical MEI in traffic with vehicle.

- Collective population considered includes the crew (essentially the driver), the off-link population (on route [i.e., resident/worker within the defined radial contamination range]), and handlers. On-link population specifically refers to a location on the road with the truck. Because the Haul Road is a private DOE road, no population is considered to be traveling with the vehicle on the road; therefore, no on-link population is considered for the collective population evaluation.
- Truck is considered to be a Class VIIIA, 16 ½ tons.
- Shielding is assumed to be provided for higher activity waste; therefore, a shielding factor of 0.5 is assumed.
- Shipping container is assumed to be an intermodal cask with dimensions 6 ft × 8 ft × 20 ft. The shipping container is assumed to hold 12 yd^3 of waste. Waste is assumed to have a density of 1.5 g/cm^3.
- Waste characterization is as determined in Appendix A of this RI/FS. Radionuclide mass-weighted average concentrations were converted from pCi/g to Ci/waste package and are summarized in Table F-1.
- Dose rate is assumed to be 1 mrem/hr at 1 m after verification of dose rate based on MICROSHIELD software calculations using the waste data discussed above in Section 2.1.4 and given in Table F-1. Gamma radiation is assumed.
- Dose measurement offset is 0 (i.e., edge of the intermodal container is the edge of the truck).
- During an accident scenario, MEIs will shelter in a nearby structure at a distance of 30 m.
- Minor accidents do not result in a release of material. Severe accidents do result in a release of material. A breathing rate of 9,200 m^3/year is assumed. This is the average breathing rate based on the default breathing rate of 8,000 m^3/year (2.9×10^{-4} m^3/sec) for RISKIND and the 3.3×10^4 m^3/sec default rate for RADTRAN.
- Automobile shielding is assumed for driver; house shielding for resident/worker.
- A summary of some pertinent input values for RADTRAN is given in Table F-2.
- Routine and accident scenarios are evaluated for MEIs and collective populations.

Off-Site Disposal Alternative Assumptions and Inputs

- See routes as defined in Figure F-1.
- Mixed waste (LLW/RCRA) is transferred to Energy*Solutions* in Clive, Utah for disposal in both Options 1 and 2.
- LLW and LLW/TSCA waste is transferred to NNSS for disposal in Option 1.
- Classified waste is trucked to NNSS for disposal in Options 1 and 2.
- Rail cars used are articulated bulk container (ABC) flat cars that hold eight intermodals for NNSS shipments in Option 1. Weight limit is 354,000 lb maximum, allowing 36,000 lb per intermodal.
- Gondolas (weight limited to 100 tons each) are used in rail transfer to Clive, Utah in Option 2.
- For the off-site routes defined in which waste is *trucked*, the number of shipments made were calculated:
  - On-site transport (intermodals) to ETTP rail yard (and further transporting to Kingman, Arizona or Clive, Utah): 106,016
  - On-site transport (intermodals) to ETTP rail yard (and further transporting to Clive, Utah) for mixed waste: 8,302
  - Off-site transport (transload from rail to truck, 1 intermodal = 1 shipment or same as on-site transport of intermodals to rail yard) from Kingman, Arizona, to NNSS for Option 1: 106,016

- Off-site transport of classified waste (intermodals) from ETTP to NNSS: 1,898 (both Options 1 and 2)

- For the off-site routes defined in which waste is transferred by *rail*, the number of shipments made were calculated as follows:
  - Off-site rail transport (eight intermodals per rail car) from ETTP rail yard to Clive, Utah for mixed waste: 1,037
  - Off-site rail transport (eight intermodals per rail car) from ETTP rail yard to Kingman, Arizona (Opton 1): 13,252 shipments
  - Off-site transport by gondola (100 ton/gondola) from ETTP rail yard to Clive, Utah for LLW/TSCA waste (Option 2): 17,271 shipments
- An ABC rail car is assumed to hold eight intermodals, stacked two high. This makes the rail car dimension 12 ft × 8 ft × 80 ft long.
- Waste characterization is as determined in Appendix A of this RI/FS. Radionuclide mass-weighted average concentrations were converted from pCi/g to Ci/waste package. The values (pCi/g) are given in Table F-1.
- The MEIs for off-site trucking included two drivers, a person in traffic, a resident/worker along the route, a truck inspector, and a person at a service station.
- Shielding is assumed to be provided for higher activity waste for off-site truck transport; therefore, a shielding factor of 0.5 is assumed.
- The MEIs for off-site rail transport included a person living/working along rail route, rail inspector at a rail yard, rail yard crew members, person stuck in traffic near a rail line, and a resident near a rail stop.
- The collective population considered included the crew, on-link population (on road with truck/rail), off-link population (living/working on route), and handlers.
- All stops along the routes were as determined by TRAGIS model, plus one additional stop to account for traffic jams.
- A portion of the route for trucking waste from the ETTP rail yard to Palo Verde (the portion through Arizona only) was estimated because of the unavailability of the TRAGIS model.
- Population densities for travel along truck and rail routes were obtained from TRAGIS modeling. These population densities were based on 2000 census data. Census data from 2010 were obtained, and a weighted average increase from 2000–2010 was calculated to escalate the population densities input to the RADTRAN model.
- Numbers of persons during stops were assumed as: 10 (5–20 m) at rest/refuel stops, 10 (5–100 m) in traffic jams, and 1 (1–5 m) at inspections.
- Waste handled is soil-like, with a deposition rate of 3 m/sec.
- TRAGIS output was used for applicable routes, stops, and population densities.
- Vehicle speeds, accident rates, and fatality/injury rates were taken from a DOE Handbook (DOE 2002).
- Vehicle densities were taken from RADTRAN user manual (Sandia 2009).
- Accident probability was assumed to be 90% minor accidents, 10% severe accidents for trucking; and 98% minor accidents, 2% severe accidents for rail transport.
- Minor accidents do not result in a release of material. Severe accidents do result in a release of material.

- Dose rate is assumed to be 1 mrem/hr at 1 meter for an intermodal. Gamma radiation is assumed. Rail transport exposures involving multiple intermodals are taken into account by the models.
- Dose measurement offset is 0 (i.e., edge of the intermodal container is the edge of the truck).
- During an accident scenario, MEIs will shelter in a nearby structure at a distance of 30 m.
- A breathing rate of 2.9×10^{-4} m^3/sec is assumed.
- For truck transport, automobile shielding is assumed for driver; house shielding for resident/worker.
- For non-radiological incidents, travel by truck was assumed to be round-trip distances. Travel by rail was assumed to be one-way; return trips would be made with other cargo.
- For rail transport, crew is assumed to not be exposed during transit. Driver is considered a crew member during stops. Rail inspectors are assumed to be unshielded.
- For MEI exposures, routine stops are assumed to produce a 10 to 15-minute exposure duration; short-term accidents a 2-hour exposure duration; and long-term accidents result in an assumed 50-year exposure duration due to contamination of land and therefore food sources.
- A summary of selected pertinent input values is given in Table F-2.
- Routine and accident scenarios are evaluated for MEIs and collective populations.

Hybrid Disposal Alternative Assumptions and Inputs

As a combination of both the On-site and Off-site Disposal Alternatives, the risk for this hybrid alternative was determined as a percentage of each of these alternatives' results.

- 36% of waste is disposed in the on-site disposal facility (includes volume reduction).
- 64% of waste is disposed off-site (of which 3% [or 1.92% of the total]) is classified waste.
- Off-site disposal is the same scenario as Option 2; that is, waste is sent to Clive, Utah for disposal unless it is classified waste, which is sent to NNSS for disposal.

Table F-1. Mass-weighted, Average Radionuclide Concentrations Used in Risk Assessment Modeling

Radionuclide	Average Concentration (pCi/g)	Radionuclide	Average Concentration (pCi/g)	Radionuclide	Average Concentration (pCi/g)
Ag-110m	4.76E-01	Fe-59	1.49E+00	Pu-244	3.22E-02
Am-241	9.18E+00	H-3	1.91E+02	Ra-226	9.10E-01
Am-243	5.77E-01	I-129	1.79E+00	Ra-228	7.95E-01
C-14	2.91E+01	K-40	4.21E+00	Ru-106	6.27E+04
Cm-242	1.63E-01	Kr-85	1.04E+02	Sr-90	9.73E+03
Cm-243	6.69E+00	Mn-54	8.47E-01	Tc-99	3.67E+01
Cm-244	1.14E+04	Nb-94	7.93E-02	Th-228	4.27E-01
Cm-245	1.39E-01	Ni-59	4.04E+01	Th-229	4.00E-03
Cm-246	5.41E+00	Ni-63	1.05E+02	Th-230	1.55E+00
Cm-247	9.55E-03	Np-237	2.91E-01	Th-232	1.69E+00
Co-57	1.48E-01	Pb-210	2.50E+00	U-232	1.65E+00
Co-60	5.05E+02	Pm-147	1.00E+01	U-233	8.13E+01
Cs-134	2.48E+04	Pu-238	5.69E+01	U-234	2.69E+02
Cs-137	5.83E+03	Pu-239	1.17E+01	U-235	1.63E+01
Eu-152	6.43E+03	Pu-240	1.74E+02	U-236	1.14E+01
Eu-154	4.85E+03	Pu-241	2.01E+02	U-238	1.60E+02
Eu-155	1.41E+03	Pu-242	3.79E-01	Zn-65	1.46E+00

Table F-2. Summary of Selected Input Parameters for RADTRAN

Parameter	Units	Truck Transport	Rail Transport
Dose at 1m from container	mrem/hr	1.0	1.0
Traveling speed	km/hr	89 Rural 41 Suburban	64.4 Rural 40.2 Suburban 24.2 Urban
Population density	people/km^2	Varies by location on route (per TRAGIS)	Varies by location on route (per TRAGIS)
Persons per vehicle	Number of people	1.5	3
Accident exposure duration	hr or yr	Short-term 2 hour Long-term 50 year	Short-term 2 hour Long-term 50 year
Ratio minor accidents to major accidents	NA	9:1	9.8:0.2
Release fraction	(fraction of material released from package)	0.1	0.1
Aerosol fraction	(fraction of *release fraction* aerosolized)	0.05	0.05
Respirable fraction	(fraction of *aerosolized fraction* inhaled)	0.1	0.1

2.4 RISK RESULTS

The risk models require inputs as described in the sections above. Results from the models are typically given as dose rates, TEDEs, in units of person-rems. These values must then be multiplied by dose-to-risk conversion factors, also called health risk conversion factors, to result in the risk factors typically reported in assessments. For comparative purposes, such as this RI/FS, the DOE recommends using 6×10^{-4} fatal cancers/TEDE and 8×10^{-4} cancer illnesses/TEDE to convert to mortality and morbidity rates, respectively, for both collective populations and MEIs (DOE 2003). Table F-3 summarizes the results for this assessment, radiological risk per shipment for the two alternatives: on-site and off-site disposal of CERCLA waste. Results are given for MEIs and collective populations, for both routine and accident situations. These numbers are reported for single shipments (see Table F-3) and multiplied by the number of shipments to calculate risk based on all shipments of waste for each given alternative for the project lifecycle and, therefore, account for cumulative exposures over thousands of shipments (see Table F-4 – routine travel exposures only for off-link populations and resident MEIs). As expected, on-site transport of waste carries a significantly lower risk of cancer illnesses and fatalities than off-site transport of waste. Off-site Option 1 (majority of waste traveling to NNSS for disposal) and Option 2 where the majority of waste is disposed at Energy*Solutions* are both presented. The hybrid alternative radiological risk, also presented, is bounded by the on- and off-site alternatives.

Table F-5 summarizes the risk rates for injuries and fatalities expected from vehicular operation due to exposure to emissions and expected traffic accidents for all alternatives. Again, as expected, travel required for on-site disposal results in far fewer fatalities and injuries due to vehicle-related incidents than does off-site travel and transport to disposal sites. Logically, this is because of the much reduced travel time/miles and avoidance of public roadways in the case of on-site transportation. As can be interpreted in Table F-5, for the off-site disposal, if all waste (with the exception of classified waste) were to be shipped to Energy*Solutions* in Clive Utah (Option 2), the risks of injuries and fatalities would decrease by about a factor of 3 compared to the Off-site Disposal Alternative Option 1 (shipment to NNSS). However, the risks would still remain several orders of magnitude above the On-site Disposal Alternative risks. As expected, the hybrid alternative risk, as a combination of both on-site and off-site risks and quantified based on percentages of waste going to each location, is bounded on either end by on- and off-site results.

Table F-3. Transportation Risk Assessment, Cancer Risk Due to Radiological Exposures for Single Shipment for Given Route

Receptor/Scenario	On-site Disposal Alternative		Off-site Disposal Alternative					
	Truck to EMDF		Truck to NNSS		Truck to ETTP Rail to Kingman Truck Kingman to NNSS		Truck to ETTP Rail to Clive, UT	
	Fatal	Non-fatal	Fatal	Non-fatal	Fatal	Non-fatal	Fatal	Non-fatal
MEIs								
Routine Travel								
Driver (Truck) or Crew Member (Rail)	4.99E-08	6.65E-08	9.00E-06	1.20E-05	4.49E-07	5.99E-07	5.34E-08	7.12E-08
Resident on Route (off-site) Worker on Route (on-site)	2.40E-08	3.20E-08	2.40E-08	3.20E-08	7.20E-08	9.60E-08	4.80E-08	6.40E-08
Accidents								
Driver (Truck) or Crew Member (Rail)	7.68E-09	1.02E-08	7.68E-09	1.02E-08	2.17E-08	2.90E-08	1.40E-08	1.87E-08
Resident on Route (off-site) Worker on Route (on-site)	3.06E-09	4.08E-09	3.06E-09	4.08E-09	1.28E-08	1.70E-08	9.72E-09	1.30E-08
Collective Population								
Routine Travel								
Crew	4.25E-08	5.66E-08	1.91E-05	2.54E-05	1.43E-07	1.91E-07	4.25E-08	5.66E-08
On-Link	a	a	1.06E-05	1.42E-05	8.79E-07	1.17E-06	3.27E-07	4.36E-07
Off-Link	3.91E-10	5.22E-10	7.74E-07	1.03E-06	4.66E-06	6.21E-06	3.61E-06	4.81E-06
Handlers	5.90E-07	7.87E-07	5.90E-07	7.87E-07	3.30E-06	4.40E-06	2.71E-06	3.61E-06
Accidents								
Societal Accident Exposure	1.60E-13	2.13E-13	2.03E-09	2.71E-09	4.11E-09	5.48E-09	1.11E-09	1.48E-09

[a] No on-link analysis for on-site; all travel is on non-public road.

Table F-4. Transportation Risk Assessment, Cancer Risk Due to Radiological Exposures during Routine Travel for Multiple (All) Shipments

Receptor/Scenario	On-site Disposal Alternative		Off-site Disposal Alternative (Option 1) (see assumptions Section 2.3 for explanation of number of shipments)						Off-site Disposal Alternative (Option 2)		Hybrid Alternative (On-site and Off-site)					
	Truck to EMDF		Truck to NNSS (Classified waste)		Truck to ETTP Rail to Kingman, AZ Truck Kingman to NNSS		Truck to ETTP Rail to Clive, UT		Truck to ETTP Rail to Clive, UT (Truck to NNSS for classified, same)		On-site Portion Truck to EMDF		Truck to NNSS (Classified waste)		Off-site Portion Truck to ETTP Rail to Clive, UT	
	Number of shipments = 162,380		Number of shipments = 1,898		Number of shipments = 106,016 (to ETTP rail) 13,252 (rail to Kingman) 106,016 (Kingman to NNSS)		Number of shipments = 8,302 (to ETTP rail) 1,037 (rail to Clive)		Number of shipments = 114,318 (to ETTP rail) 17,271 (rail to Clive)		Number of shipments = 59,195		Number of shipments = 659		Number of shipments = 70,969 (to ETTP rail) 12,326 (rail to Clive)	
	Fatal	Non-fatal	Fatal	Non-fatal	Fatal	Non-fatal	Fatal	Non-fatal	Fatal	Non-fatal	Fatal	Non-fatal	Fatal	Non-fatal	Fatal	Non-fatal
MEIs																
Driver (Truck) or Crew Member (Rail) [a]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Resident on Route (off-site) Worker on Route (on-site) [a]	NA [a]	NA [a]	4.56E-05	6.07E-05	5.41E-03	7.21E-03	2.24E-04	2.99E-04	8.29E-04	1.11E-03	NA [a]	NA [a]	1.58E-05	2.11E-05	5.92E-04	7.89E-04
Collective Population																
Crew [a]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
On-Link [b]	NA [c]	NA [c]	NA	NA	NA	NA	NA	NA	NA	NA	NA [c]	NA [c]	NA	NA	NA	NA
Off-Link	6.35E-05	8.47E-05	1.47E-03	1.96E-03	6.84E-02	9.13E-02	3.74E-03	4.99E-03	6.23E-02	8.31E-02	2.31E-05	3.09E-05	5.10E-04	6.79E-04	4.45E-02	5.93E-02
Handlers [a]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

[a] No multiple shipments applied to workers. Workers assumed to be under radiation protection programs and cumulative exposure would be tracked and controlled.
[b] On-link (on route with shipments) during routine travel not cumulative (e.g., not applied to all shipments).
[c] No on-link analysis for on-site; all travel is on non-public road.

Table F-5. Transportation Risk Assessment, Injury and Fatality Risk from Vehicle-related Incidents

Scenario	Emissions	Vehicle Travel	
	Fatal	Fatal	Non-Fatal
On-site Disposal Alternative			
Truck to EMDF	**1.02E-02**	**2.29E-02**	**7.94E-01**
Off-site Disposal Alternative (Option 1)			
Truck to NNSS (classified waste)	4.65E-01	1.28E-01	2.22E+00
Truck to ETTP; Rail to Clive, UT	9.13E-02	4.36E-02	1.43E-01
Truck to ETTP; Rail to Kingman, AZ; Truck to NNSS	6.91E+00	1.07E+00	1.27E+01
Off-site Disposal Alternative (Option 1) TOTAL	**7.47E+00**	**1.24E+00**	**1.51E+01**
Off-site Disposal Alternative (Option 2)			
Truck to NNSS (classified waste)	4.65E-01	1.28E-01	2.22E+00
Truck to ETTP; Rail to Clive, UT	1.26E+00	6.02E-01	1.97E+00
Off-site Disposal Alternative (Option 2) TOTAL	**1.73E+00**	**7.3E-01**	**4.19E+00**
Hybrid Disposal Alternative			
On-site disposal (Truck to EMDF)	3.70E-03	8.36E-03	2.89E-01
Off-site disposal (Option 2)	7.91E-01	3.76E-01	1.22E+00
Hybrid Disposal Alternative TOTAL	**7.91E-01**	**3.76E-01**	**1.55E+00**

2.5 RAIL VERSUS TRUCK COMPARISON

A comparison using only the NNSS disposal site destination was performed to analyze the risk posed by transporting all waste by truck to the western disposal sites, as opposed to a majority of the waste being transported to these sites by rail. LLW and LLW/TSCA waste transported by truck to the ETTP rail yard, then by rail from the ETTP rail yard to Kingman, Arizona, and finally by truck from Kingman to the NNSS site for disposal was analyzed as part of the off-site disposal option. Additionally, classified waste transport by truck only from the ORR to NNSS was analyzed. Thus, this same truck route (ORR to NNSS) was modified to include the increased shipments of the LLW and LLW/TSCA waste streams in order to make a side-by-side comparison of truck versus rail transport. Outputs from RADTRAN runs, for the collective population risk, and RISKIND runs, for the MEI risk, for single shipments, were used and number of shipments modified to allow this comparison.

Table F-6 summarizes the comparison of radiological risk for the original shipment route using rail transportation (all shipments) versus the truck route to NNSS, for the same number of shipments. There is actually little difference in terms of radiological exposure (as would be expected since it is entirely dependent on exposure to a radiological source), which is the same for either case.

Table F-7 summarizes the same comparison, in terms of vehicular risk. As expected, vehicle-related risks are significantly higher when all the waste is trucked (e.g., the No Action Alternative) versus when rail transport is used where possible.

Table F-6. Comparison of Radiological Risk for Trucking Waste versus Trucking and Rail Transport of Waste to Destination NNSS for All Shipments

Receptor/Scenario	Truck Transport Only		Truck and Rail Transport	
	Truck to NNSS		Truck to ETTP; Rail to Kingman, AZ; Truck to NNSS	
	Fatal	Non-Fatal	Fatal	Non-Fatal
MEIs				
Routine Travel				
Resident Along Route	2.54E-03	3.39E-03	5.41E-03	7.21E-03
Collective Population				
Off-Link	8.21E-02	1.09E-01	6.84E-02	9.13E-02

Table F-7. Comparison of Vehicle-related Risk for Trucking Waste versus Trucking and Rail Transport of Waste to Destination NNSS

Scenario	Emissions	Vehicle Travel	
	Fatal	Fatal	Non-Fatal
Truck Transport Only			
Truck to NNSS	2.60E+01	7.15E+00	1.24E+02
Truck and Rail Transport			
Truck to ETTP; Rail to Kingman, AZ; Truck to NNSS	6.91E+00	1.07E+00	1.27E+01

3. NATURAL PHENOMENA HAZARDS

Two natural hazards, tornados and earthquakes, are considered in this evaluation, since these are the most likely potential natural phenomena that could affect the EMDF. Floods were not considered because no portion of the EMDF or its support areas/facilities will be located within either the 100-year or 500-year floodplains of Bear Creek. Mass wasting phenomena, such as landslides or rock fall, in this region tend to be small and localized. The potential for mass wasting, and the means to prevent such events, is addressed as part of the design process, and is not considered here.

3.1 TORNADO RISKS

Potential risk to human health via exposure to contamination from on-site disposal facilities was assumed to occur through three natural phenomena mechanisms: earthquake activity, sinkhole development, and tornado activity. This assessment only analyzes risk posed by the occurrence of a tornado for the following reasons: the potential for release of contamination resulting from an earthquake is assumed to be addressed by the design of the disposal facility, and site-selection criteria preclude building the disposal facility at a location underlain by the karst geology, which is most likely to cause a sinkhole to develop. In the east Tennessee area, the probability of a tornado strike is estimated as 4.26×10^{-5}/year (FEMA 2009, NOAA 2011). Although a low probability is associated with this natural phenomenon, the consequences of such an event could be high. An estimate of the human health risk posed by a tornado striking the on-site disposal facility and releasing contamination was made using the RESRAD computer code, and is presented here. Note that this risk assessment, as with the transportation risk assessment, considers the risk posed by release of radioactively contaminated waste as far exceeding the risk posed to the public by any contained chemical hazards; therefore, only the radioactive portion of the waste is considered in the assessment.

3.1.1 Model Inputs and Assumptions

Two RESRAD models were considered for use in evaluating the risk to the public presented by an on-site disposal facility, RESRAD and RESRAD OFFSITE. RESRAD OFFSITE was not used in this evaluation. It was determined that RESRAD OFFSITE is more suited for risk of the landfill liner or cover system failing and affecting nearby residents. Such a risk would be evaluated when the design for a liner is being engineered. The model that was used in this evaluation is RESRAD. It was used to evaluate the human health risk presented assuming a scenario whereby a tornado hits the open face of the cell and disperses contaminated debris. Inputs required to evaluate this scenario include: radioactive species and concentrations; extent of contamination (area and depth); local environmental parameters (air, geology, hydrology inputs); human parameters (inhalation rates, population, etc.); and a specified time period for evaluation.

Based on the EMWMF safety basis and current operating procedures at EMWMF, the assumption was made that the maximum open face of the disposal cell is 15 acres (BJC 2009).

Additionally, as specified in the previous *EMWMF Remedial Investigation/Feasibility Study* (DOE 1998), the tornado is assumed to spread contaminated debris across a 10 square mile area (assumed circular – corresponds to a radius of approximately 1 ¾ miles). In reference to the open, exposed face (using the maximum open face of the cell, 15 acres) of the cell, a scour depth of 6 inches is assumed.

Mass-weighted averages were used as input to the RESRAD model and are given in Table F-1. Average radionuclide concentrations used in the model were determined from waste lots in waste disposed to date at EMWMF (see Chapter 2 and Appendix A of this RI/FS). These radionuclide concentrations were then assumed to be present in waste evaluated for natural phenomenon risk due to tornado strike. Radionuclide concentration data for waste lots that had an EMWMF WAC sum of fractions (SOFs) exceeding 0.05

were not excluded from the analysis. This approach is conservative because, in practice at EMWMF, the facility authorization basis and operational controls require adjustments to normal operating practices be made prior to disposal of waste lots with an audible safety analysis-derived WAC SOF that exceeds 0.05. These adjustments, such as containerizing waste or further limiting the open cell face area, would prevent release of the waste.

Site geology and hydrology parameters were input to the model based on several hydrologic reports conducted for ORNL (ORNL 1988, 1989, 1992, 2006). The specific values used in the model are listed below:

- Saturated zone porosity: 0.4
- Saturated zone hydraulic gradient: 0.05
- Well pump intake (meters below water table): 20 m
- Overburden (unsaturated zone thickness): 12 m

Model inputs for ingestion, occupancy, and dose remained as model default values.

3.1.2 Tornado Probability

Tornado probabilities are estimated based on frequency of occurrence (either based on historical data or contour maps developed from historical data), and parameters defining the severity of the tornadoes. The method used to calculate the probability is presented in the *Federal Emergency Management Agency* (*FEMA*) *Benefit-Cost Analysis Reengineering (BCAR) Version 4.5* (FEMA 2009). Historical data for the two counties in which the ORR resides (Anderson and Roane Counties) were obtained from the National Oceanic and Atmospheric Administration (NOAA) National Weather Service Weather Forecast Office records (NOAA 2011). A probability of 4.26×10^{-5} was estimated based on these two reference sources.

3.1.3 Modeling Results

Two RESRAD runs were made, with all input variables held constant with the exception of the duration. Long term effects were examined out to 100,000 years, which registered the highest risk within the first six years. Therefore, a second run was made with a six-year duration to focus on the highest risk data/output. The model was used to calculate the estimated Incremental Lifetime Cancer Risk (ILCR) resulting from the assumed activity (in this case tornado) based on conservative exposure pathways. Contamination pathways examined included incidental ingestion of soil, inhalation of contaminated dust, external exposure to gamma radiation, ingestion of contaminated food products (fish, milk, meat, vegetables), and exposure to contaminated ground water and surface water.

The ILCR as calculated by RESRAD from radiation exposure resulting from tornado-dispersed contamination is 2.90×10^{-4} at the peak risk (immediately following dispersion). Applying the probability of tornado occurrence (4.26×10^{-5}) and a 30-year operating window (which is somewhat higher than the current assumed life-cycle of 23 years) for the disposal facility results in a maximum total aggregate risk of 3.71×10^{-7}.

3.2 SEISMIC RISKS

DOE O 420.1A and Tennessee Department of Environment and Conservation Rule 0400-20-11-.16 (5) require that radiologic facilities be designed, constructed, and operated so that the public, employees, and environment are protected from the adverse impacts of natural phenomena hazards, including earthquakes. The ORR lies within the Eastern Tennessee Seismic Zone (ETSZ), a seismically active area that extends from central Alabama to southern West Virginia and is roughly coincident with the Valley and Ridge Physiographic Province. Although there are a number of inactive faults formed during the late Paleozoic Era passing through the ORR, there are no known or suspected seismically capable faults[2]. A recent paleoseismic investigation (Vaughn et al., 2010) found preliminary evidence of surficial faulting near Dandridge, Tennessee, located approximately 75 km to the east of the ORR. The focal depths of most earthquakes in ETSZ range from 5–22 km (Vlahovic et al., 1998; Chapman et al., 2002).

3.2.1 Historical Seismicity

Numerous historical earthquakes have affected Eastern Tennessee. The series of three large earthquakes in 1811–1812 in the New Madrid Seismic Zone are believed to have resulted in a Modified Mercalli Intensity (MMI) of V to VI in Knoxville, Tennessee (Hough et al., 2000). Other smaller, nearby historical earthquakes in 1844, 1913, 1928, and 1956 produced epicentral MMI values between VI and VII (Stover and Coffman, 1993). See Figure F-3 for a description of the MMI scale.

Intensity	Shaking	Description/Damage
I	Not felt	Not felt except by a very few under especially favorable conditions.
II	Weak	Felto nly by a few persons at rest,especially on upper floors of buildings.
III	Weak	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
IV	Light	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V	Moderate	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Strong	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII	Very strong	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
VIII	Severe	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX	Violent	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X	Extreme	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.

Figure F-3. Modified Mercalli Intensity Scale (from U.S. Geological Survey)

Since 1970, there have been 68 recorded earthquakes with moment magnitudes (Ms) of 3.0 or greater within 200 km of the ORR (USGS 2014). The largest of these are the 1973 M4.7 Maryville, Tennessee, and the 1987 M4.3 Vonore, Tennessee earthquakes. However, Vaughn et al. (2010) found preliminary, paleoseismic evidence of one or more “strong” earthquakes during the late Quaternary period that suggest the potential for earthquakes larger than those recorded to date. Accordingly, recent values of the weighted average maximum earthquake magnitude associated with the ETSZ for seismic hazard mapping range from M6.6 to M6.8 (EPRI, 2008; 2012).

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[2] As defined in 10 CFR 100, Appendix A, a seismically capable fault is one that has had movement at or near the ground surface at least once within the past 35,000 years, or recurrent movement within the past 500,000 years.

3.2.2 Future Seismicity

A site-specific seismic hazard study has not been performed to date, but a preliminary estimate of the future seismic hazard may be obtained from the U.S. Geological Survey (USGS) (Petersen et al., 2008). Figure F-4 shows the uniform hazard response spectrum for a reference firm rock site condition (Site Class B) for a 90% probability of non-exceedance during a 250-year period, which is the hazard level specified by the Tennessee Department of Solid Waste Management (1993) and corresponds to an annual frequency of exceedance of 4.2×10^{-4} or a return period of 2,373 years (i.e., one event in 2,373 years). The peak ground acceleration (PGA) is approximately 0.22 g, and the maximum spectral acceleration (S_a) of approximately 0.49 g occurs at a period (T) of 0.1 sec.

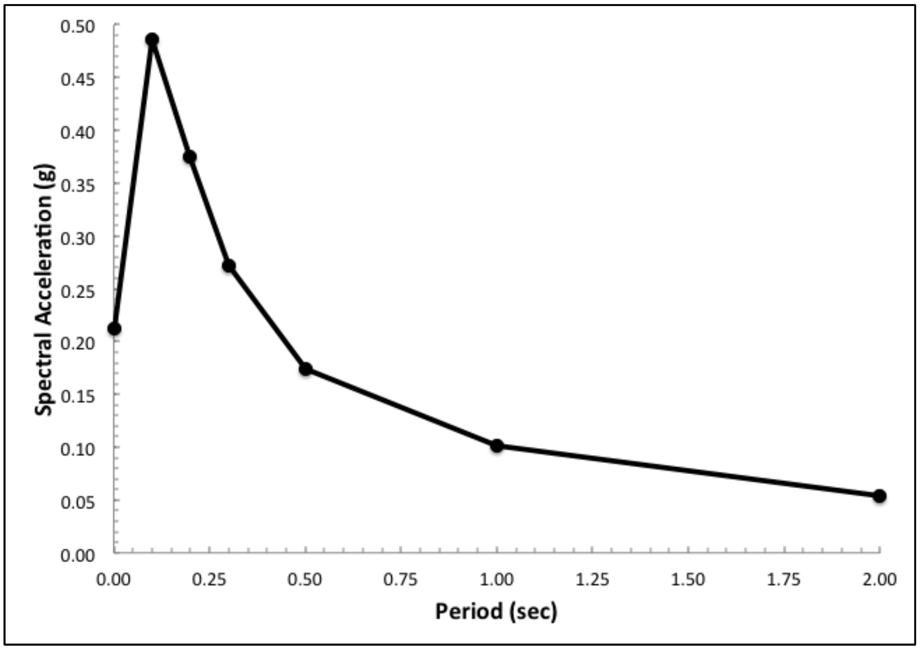

Figure F-4. Uniform Hazard Response Spectrum for 90% Probability of Non-Exceedance in 250 years

(Return Period = 2,373 years) for B/C Site Conditions Based on 2008 U.S. Geological Survey Seismic Hazard Maps

The dominant sources of the seismic hazard obtained via de-aggregation of the probabilistic seismic hazard are approximately M4.8 and R = 14.3 km for short-period spectral accelerations (PGA and S_a at T = 0.2 sec) and M7.7 and R = 448 km for long-period spectral accelerations (S_a at T = 1.0 sec). These sources are consistent with the historical seismicity at ORR described previously.

Site-specific seismic hazard analyses and design calculations will be prepared for the EMDF following the methods given by the Tennessee Department of Solid Waste Management (TDSWM 1993) or other appropriate methodology. The EMDF will be designed to meet applicable seismic hazard design requirements.

4. FUGITIVE DUST EMISSIONS

For the On-site Disposal Alternative, estimates of fugitive dust emissions generated and transported during construction activities were determined and compared to National Ambient Air Quality Standards (NAAQS) limits for particulate emissions. U.S. Environmental Protection Agency (EPA) research has shown that particulate emissions from open sources such as unpaved roads, borrow areas, spoil areas, general grubbing, and disposal cell construction can contribute significantly to ambient air particulate matter (PM) concentrations. Regarding activities considered in the construction of an on-site disposal facility, the NAAQS PM limit of interest is PM_{10} (particles with a mean aerodynamic diameter greater than 2.5 µm and less than or equal to 10 µm). The nearest residence to the construction site for all Options placed the location of interest at approximately 1,170 m horizontally distant from the proposed EMDF Site 7a in BCV (e.g., site 7a is the shortest distance to the nearest resident). Other distances between the nearest resident and Site Options 5, 14, and 6b were longer, thus the most conservative short distance was assumed. The estimation of fugitive dust emission for this RI/FS follows guidance contained in the EPA's *Compilation of Air Pollutant Emission Factors* (AP-42, EPA 1995).

4.1 METHOD

Estimates of PM concentrations are based on activities assumed to take place throughout the life of the construction project. Four main activities were defined for on-site construction of a disposal facility, consisting of more specific, daily elements as follows:

Activity 1 – Clearing and Grubbing

- Bulldozing
- Material hauling
- Material loading and unloading
- Spoils handling/spreading

Activity 2 – Topsoil Removal

- Topsoil removal by scrapers
- Material hauling
- Material unloading
- Spoils handling/spreading

Activity 3 – Excavation Earthwork

- Dozers excavating
- Material loading and unloading
- Material hauling
- Spoils handling/spreading

Activity 4 – Fill/Borrow Earthwork

- Hauling on-site (only haul from State Route 95 to stockpile was considered)
- Unloading at stockpile
- Loading to go to cell
- Hauling to cell from stockpile
- Unloading at cell
- Grading with dozers at cell
- Compacting with rollers at cell

Table F-8. Summary of Inputs for Calculation of Emission Rates

Parameters Used in Calculations of Emission Rates for Construction Activities (Non-site Specific):
• Average 120 days of rain annually • 250 work days per year • Wind speed 4.1 mph • Mean vehicle speed of 7.1 mph (applicable only to grading operations) • Silt content of the gravel haul roads of 6%
Assumptions:
• Only one of the four main activities will occur at one time. • All off-site areas (such as aggregate facility or borrow area) will be managed by the operator and would not need to be assessed in this evaluation. • Vehicle emissions would be negligible in comparison to the dust generated by the construction activities (consequences of vehicle emissions are examined and discussed as part of the Transportation Risk – see Section 2.2.2). • Salt is used on roads for ice control, not sand/gravel and; therefore, are removed from calculations. • Unpaved roads travelled are considered as industrial (not public). • The different materials handled during the various activities would have varying moisture and silt contents. • The different materials handled during the various activities would result in varying mean vehicle weights.

The main activities were assumed to take place in sequence, that is, only one main activity occurred at one time, with all daily elements occurring simultaneously. Particle emission rates (mass/time) were calculated for each daily element in the main activities. These emission rates are calculated based on several parameters and assumptions that are summarized in Table F-8. Methods used for calculating emission rates were those presented in AP-42 (EPA 1995).

Emission rates may be reduced by implementing controls to reduce the dust generation/transport. Controls include spraying water to reduce dust generation, limiting speeds, using enclosures, sweeping, using coverings such as straw, revegetation, etc. For this study, emission rates for hauling activities/elements (on the existing gravel Haul Road) were adjusted by a 74% control efficiency for water and additionally, by a 44% control efficiency for setting a speed limit of 25 mph. These efficiency rates are based on documentation provided by the Western Regional Air Partnership's Fugitive Dust Handbook. Natural dust suppression caused by regional precipitation is already factored into the uncontrolled emission rate by the equation provided in the AP-42 document. Unloading topsoil from scrapers and spreading topsoil was modified by a 74% control efficiency for the application of water sprayed by water trucks, as was excavating operations involving dozing, loading, and unloading spoils. These credits reduced the emission rates significantly for the specified elements.

Emission rates were converted to per-unit-area rates based on footprints that were estimated for each sub-activity/element. Each element within a main activity has an assumed footprint. For example within activity 3 (excavation earthwork) a footprint for bulldozer excavations is specified, which is different from the dump truck hauling footprint, which is also different from the spoils handling/spreading footprint. The area-based emission rates are input to the EPA code SCREEN3 (EPA 1995), along with other site-specific data such as distance to the location of interest (resident), to generate PM_{10} concentrations. The resultant PM_{10} concentrations are peak hourly concentrations that must be averaged over a 24-hour period (based on an eight hour work day) to obtain the PM_{10} values for the nearest resident location. This 24 hour averaged PM_{10} value is then compared to the EPA NAAQS PM_{10} limit of 150 µg/m^3.

4.2 RESULTS

The column on the far right of Table F-9 lists the final 24-hour PM_{10} total concentrations for each main activity. The values are obtained by summing the SCREEN3 output PM_{10} concentrations for all elements in a given activity. As seen in the table, the PM_{10} values for the site, with respect to the nearest resident location (e.g., along a straight line from Site 7a in Bear Creek Valley to the nearest resident), fall within the PM_{10} limit of 150 µg/m^3 specified in the NAAQS.

Table F-9. Bear Creek Valley (Site 7a) Particulate Matter Calculations Summary

Activity (1-4) and Corresponding Elements, Grouped by Footprint			Emissions Rate (lb/hr)	Combined Emissions Rate for Application to Footprint		SCREEN3 Inputs			SCREEN3 Output	24-hr PM_{10} for Each Activity at Residence ($\mu g/m^3$)
				(lb/hr)	(g/s)	Footprint, Larger Side (m)	Footprint, Smaller Side (m)	Emission Rate (g/s-m^2)	PM_{10} ($\mu g/m^3$)	
Activity 1- Site Clearing & Grubbing	Clearing Footprint	Clearing/Grubbing by Dozer	1.34	1.34	0.17	63.7	63.7	4.16E-05	13.83	113
		Loading Veg into Dump Truck	0.0024							
	Haul	Hauling to Spoils	13.4	13.4	1.69	1563.6	157.0	6.88E-06	84.90	
	Spoils Footprint	Unloading Dump Truck	0.0024	1.34	0.17	45.1	45.1	8.30E-05	14.44	
		Spreading Spoils	1.34							
Activity 2- Topsoil Removal	Clearing Footprint	Topsoil Removal	6.29	6.29	0.79	98.8	98.8	8.13E-05	26.1	137
	Haul	Hauling to Spoils	9.43 *	9.43 *	1.19	1563.6	157.0	4.84E-06	59.73	
	Spoils Footprint	Unloading Scraper	3.33 *	4.78 *	0.60	49.4	49.4	2.47E-04	51.07	
		Spreading Topsoil with Dozer	1.45 *							
Activity 3- Excavating Operations	Excavation Footprint	Dozer Excavating	5.58	5.59	0.70	31.4	31.4	7.15E-04	27.77	106
		Loading into Dump Truck	0.0088							
	Haul	Hauling to Spoils	8.05 *	8.05 *	1.01	1563.6	157.0	4.13E-06	51.07	
	Spoils Footprint	Unloading Dump Truck	5.58	5.59	0.70	40.2	40.2	4.35E-04	27.33	
		Spreading Spoils	0.0088							
Activity 4- Fill Placement	Haul Stock	Soil Hauling to Stockpile	6.49 *	6.49 *	0.82	823.0	83.8	1.19E-05	62.17	150
	Stockpile Footprint	Unloading at Stockpile	0.029	0.044	0.01	38.7	38.7	3.70E-06	0.48	
		Loading at Stockpile	0.015							
	Haul	Hauling from Stockpile to Cell	1.66	1.66	0.21	61.0	7.3	4.69E-04	18.7	
	Fill Footprint	Unloading at Cell	4.43	6.66	0.84	61.6	61.6	2.21E-04	69.13	
		Compacting at Cell	2.21							
		Grading at Cell	0.015							

* Value has been modified to take credit for dust controls by multiplying the original emissions rate by an appropriate control efficiency.

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APPENDIX G:
APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

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CONTENTS

TABLES

FIGURES

ACRONYMS

ACM	asbestos-containing material
AEA	Atomic Energy Act of 1954
ALARA	as low as reasonably achievable
ANOVA	analysis of variance
ARAP	Aquatic Resource Alteration Permit
ARAR	applicable or relevant and appropriate requirement
ARPA	Archaeological Resources Protection Act of 1979
AWQC	ambient water quality criteria
BCV	Bear Creek Valley
BMP	best management practice
CAA	Clean Air Act of 1970
CCC	criterion continuous concentration
CFR	*Code of Federal Regulations*
CMBST	combustion
CMC	criterion maximum concentration
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
COC	contaminant of concern
CWA	Clean Water Act of 1972
DEACT	deactivation
DOE	U.S. Department of Energy
DOE M	DOE Manual
DOE O	DOE Order
DOT	U.S. Department of Transportation
EBCV	East Bear Creek Valley
EIS	Environmental Impact Statement
EMDF	Environmental Management Disposal Facility
EMWMF	Environmental Management Waste Management Facility
EP	extraction procedure
EPA	U.S. Environmental Protection Agency
F&AL	fish and aquatic life
FEMA	U.S. Federal Emergency Management Agency
FFA	Federal Facility Agreement
FFCA	Federal Facility Compliance Agreement
FFS	Focused Feasibility Study
FR	Federal Register
FML	flexible membrane liner
GCL	geosynthetic clay liner
HMR	Hazardous Materials Regulations
HMTA	Hazardous Materials Transportation Act of 1975

ID	identification number
IRR	irrigation
LDR	land disposal restriction
LDS	leak detection system
LLW	low-level [radioactive] waste
LWTS	landfill wastewater treatment system
LWW	livestock watering and wildlife
MOU	memorandum of understanding
NAAQS	National Ambient Air Quality Standard
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NESHAP	National Emission Standards for Hazardous Air Pollutants
NRC	Nuclear Regulatory Commission
NT	Northern Tributary (to Bear Creek)
ORR	Oak Ridge Reservation
OSHA	Occupational Safety and Health Administration
PCB	polychlorinated biphenyl
POLYM	polymerization
PPE	personal protective equipment
PQL	practical quantitation limit
RCRA	Resource Conservation and Recovery Act of 1976
REC	recreation
RORG	recovery of organics
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
RRL	required reporting limit
SDWA	Safe Drinking Water Act of 1974
SHPO	State Historic Preservation Officer
SLB	shallow land burial
TBC	to be considered [guidance]
TC	toxicity characteristic
TCA	*Tennessee Code Annotated*
TDEC	Tennessee Department of Environment and Conservation
THPO	Tennessee Historic Preservation Officer
TSCA	Toxic Substances Control Act of 1976
TSD	treatment, storage and disposal
TWRA	Tennessee Wildlife Resources Agency
TWRCP	Tennessee Wildlife Resources Council Proclamation
U.S.	United States
USC	*United States Code*
USGS	U.S. Geological Service
UTS	universal treatment standards

WAC	waste acceptance criteria
WWTU	wastewater treatment unit

1. INTRODUCTION

The purpose of this Appendix is to identify and describe applicable or relevant and appropriate requirements (ARARs) for the disposal alternatives considered in this Remedial Investigation/Feasibility Study (RI/FS). Development of ARARs is an iterative process. This list of ARARs and to be considered (TBC) guidance will be further evaluated and refined as more information becomes known about proposed remedies and a detailed design is developed for a preferred remedy concurrent with the Proposed Plan stage. The final list of enforceable ARARs and TBCs will be set when the Record of Decision (ROD) is finalized.

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) Section 121(d) (see United States [U.S.] Code Title 42, Chapter 103, Section 9621{d}), as amended, specifies that remedial actions for cleanup of hazardous substances must comply with requirements and standards under federal or more stringent state environmental laws and regulations that are applicable or relevant and appropriate to the hazardous substances or particular circumstances at a site, or obtain a waiver under 40 *Code of Federal Regulations* (CFR) 300.430 (f)(1)(i)(B) and (C). Inherent in the interpretation of ARARs is the assurance that protection of human health and the environment is ensured. This RI/FS evaluates waste disposition for the volume of CERCLA waste generated from cleanup actions on the U.S. Department of Energy (DOE) Oak Ridge Reservation (ORR) that exceeds the available capacity of the existing Environmental Management Waste Management Facility (EMWMF) in Bear Creek Valley on the ORR. The purpose of this appendix is to specify federal and state chemical-, location-, and action-specific ARARs for the On-site Disposal Alternative (all sites)[1] for construction and operation of an additional CERCLA waste disposal facility referred to as the Environmental Management Disposal Facility (EMDF), the Off-site Disposal Alternative for transport of CERCLA waste to an approved off-site facility, and the Hybrid Disposal Alternative (a combination of on-site and off-site disposal). For the Hybrid Disposal Alternative, ARARs include all ARARs for each of the other two alternatives.

ARARs include federal and state environmental or facility siting laws/regulations designed to protect the environment and the public; they do not include occupational safety or worker radiation protection requirements. The U.S. Environmental Protection Agency (EPA) requires compliance with the Occupational Safety and Health Administration (OSHA) standards under Section 300.150 of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) regulations at 40 CFR 300.150, independent of the ARARs process; therefore, the regulations promulgated by OSHA related to occupational safety are not addressed as ARARs. These regulations would appear in and be implemented by the appropriate health and safety plans for this action.

The following terms are used throughout this appendix:

- Applicable requirements are “those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. Only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be applicable.” (40 CFR 300.5).
- Relevant and appropriate requirements are “those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state

[1] Several sites are proposed as locations to be considered for an on-site disposal facility in the Remedial Investigation/Feasibility Study. They are considered as distinct and individual Alternatives; however, as ARARs apply equally to all Site Options regardless of the location, the singular “Alternative” is used throughout this appendix, as opposed to the plural “Alternatives”.

environmental or facility siting laws that, while not ‘‘applicable’’ to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site. Only those state standards that are identified in a timely manner and are more stringent than federal requirements may be relevant and appropriate.” (40 CFR 300.5).

- To be considered guidance is non-promulgated advisories or guidance issued by Federal or State governments, are not legally binding, and do not have the status of potential ARARs. The TBC category consists of advisories, criteria, or guidance developed by federal and state agencies that may be useful in developing CERCLA remedies per 40 CFR 300.400(g)(3). TBCs may be considered along with ARARs as part of the site risk assessment and may be used in determining the necessary level of cleanup for protection of health or the environment.

CERCLA on-site remedial response actions must comply only with the substantive requirements of a regulation related to federal, state, or local permits (CERCLA Section 121[e]). To ensure that CERCLA response actions proceed as rapidly as possible, EPA re-affirmed in the final NCP (59 Federal Register [FR] 47416, September 15, 1994) that on-site remedial response actions need only comply with substantive requirements. The term on-site means the real extent of contamination and all suitable areas in very close proximity to the contamination necessary for implementation of the response action. Substantive requirements pertain directly to actions or conditions at a site, while administrative requirements facilitate their implementation. EPA recognizes that certain of the administrative requirements (i.e., consultation with state agencies, reporting, etc.) are accomplished through the state involvement and public participation. These administrative requirements should also be observed if they are useful in determining cleanup standards at the site (59 FR 47416).

Federal Facility Agreement (FFA) (DOE 1992) participants have agreed that the DOE ORR CERCLA actions generating wastes and the disposal facility evaluated in that alternative are considered to be on the same site, with respect to addressing regulations that relate to transport of waste within a site or between sites. The basis for this determination is described in Chapter 2 of this Appendix.

In accordance with 40 CFR 300.400(g), ARARs and TBC guidance have been identified for the disposal alternatives evaluated in this RI/FS. In accordance with EPA guidance (EPA 1991), there are no ARARs/TBCs for the No Action Alternative. For the On-site Disposal Alternative (all sites) and Hybrid Disposal Alternative, Tables G-1 and G-2 list the chemical-specific ARARs/TBCs; Table G-3 lists the location-specific ARARs/TBCs; and Tables G-4 through G-10 list the action-specific ARARs/TBCs.

Table G-11 provides the action-specific ARARs/TBCs for the Off-Site Disposal Alternative; these ARARs would also apply to the Hybrid Disposal Alternative. Chemical-specific and location-specific requirements may apply at the generator site or at the off-site disposal facility, but they are not ARARs for this alternative.

The On-site Disposal Alternative (all sites) would comply with all ARARs. DOE is requesting that the EPA Regional Administrator determine that two applicable Toxic Substances Control Act of 1976 (TSCA) technical requirements be found to not be necessary. The evidence for requesting this waiver is given in Chapter 4 of this Appendix. Under TSCA 40 CFR 761.75(c)(4) *Waivers*, evidence may be submitted to the Regional Administrator that operation of the landfill will not present an unreasonable risk of injury to health or the environment from polychlorinated biphenyls (PCBs) when one or more of the requirements of paragraph (b) *Technical Requirements* of 40 CFR 761.75 are not met. On the basis of such evidence and any other available information, the Regional Administrator may in his discretion find that one or more of the requirements of paragraph (b) of 40 CFR 761.75 is not necessary to protect against such a risk and may waive the requirements in any approval for that landfill. Any waiver under this paragraph will be provided in writing or granted through approval of the ROD.

2. CERCLA ON-SITE CONSIDERATIONS

CERCLA Section 121(e) exempts on-site CERCLA activities from administrative permitting requirements. The NCP, at 40 CFR 300.5, defines "on-site" as *"the areal extent of contamination and all suitable areas in very close proximity to the contamination necessary for the implementation of the response action."* Disposal of waste in a newly constructed on-site disposal facility, proposed as the On-site Disposal Alternative in this RI/FS, would consolidate wastes from cleanup of the ORR into a new disposal facility on the ORR. CERCLA Section 104(d)(4), discretionary authority to treat noncontiguous facilities as one site, also supports considering consolidation of waste between the individual sites as an on-site action and allows the EPA to consider multiple facilities as one for the purpose of conducting response actions where two or more noncontiguous facilities are reasonably related on the basis of geography, or on the basis of the threat or potential threat to the public health or welfare or the environment. The preamble to the NCP (at 55 FR 8690 [March 8, 1990]) clarifies that Section 104(d)(4) can be used when noncontiguous facilities are reasonably close to one another and wastes at the sites are compatible for a selected treatment or disposal approach. For purposes of not requiring a permit for the EMDF and the identification of ARARs, it is assumed that consolidation of wastes into a centralized disposal cell would be considered an on-site action under the CERCLA definition of "on site" and CERCLA Section 104(d)(4), as well as within the context of the FFA (see FFA Section IV, paragraph A).

Treating all areas of contamination within ORR as "on-site" for the purposes of waste disposal determinations is consistent both with the statute and EPA policy and was acknowledged and documented in the signed EMWMF ROD (DOE, 1999) and reaffirmed in the East Tennessee Technology Park Zone 2 ROD (DOE, 2005). This agreement serves as the basis for designating waste treatment, storage and disposal (TSD) facilities on the ORR as "on-site" facilities not subject to the CERCLA Off-site Rule (40 CFR 300.440) when accepting wastes from CERCLA on-site response actions. An August 3, 1995, EPA memorandum from Stephen D. Luftig, Acting Director, EPA Office of Emergency and Remedial Response (EPA 1995) provides that, where federal facilities are listed on the National Priorities List, *"the CERCLA site consists of all contaminated areas within the area used to define the site."*

By virtue of its location within the contiguous geographical boundaries of ORR, a single disposal facility would constitute a "suitable area in very close proximity to the contamination" in the case of areas of contamination on the ORR. Accordingly, it would be appropriate to consider such a disposal facility as "on-site" for the purposes of evaluating potential on-site disposal alternatives. The disposal facility analyzed in the On-site Disposal Alternative would accept CERCLA wastes meeting the facility-specific waste acceptance criteria (WAC) from ORR sites and associated sites outside the ORR boundary but within the state of Tennessee that have been contaminated by the receipt or transport of material from past ORR operations conducted by DOE and its predecessors. No out of state waste would be accepted at the proposed disposal facility.

3. ROLE OF NUCLEAR REGULATORY COMMISSION REGULATIONS AND DOE ORDERS

DOE is legally exempt from any Nuclear Regulatory Commission (NRC) low-level radioactive waste regulations as ARARs at DOE environmental restoration sites, unless the particular facility is also an NRC-licensed facility. Under the Atomic Energy Act of 1954 (AEA), a single agency, the Atomic Energy Commission, had responsibility for the development and production of nuclear weapons and for both the development and the safe regulation of the civilian uses of nuclear materials. Under the Energy Reorganization Act of 1974, this function was split between two separate and unique agencies (NRC and DOE). DOE has responsibility for the development and production of nuclear weapons, promotion of nuclear power, and other energy-related work, as well as the regulation of defense nuclear facilities, and NRC has responsibility for the development and the safe regulation of civilian uses of nuclear materials.

NRC has promulgated its own regulations governing the facilities and activities it oversees and licenses. The regulations in 10 CFR 61 establish, for land disposal of radioactive waste, the procedures, criteria, and terms and conditions upon which the NRC issues licenses for the disposal of radioactive wastes containing byproduct, source and special nuclear material received from other persons. The regulations in 10 CFR 20 establish standards for protection against ionizing radiation resulting from activities conducted under licenses issued by the NRC. Note that both sets of regulations are legally applicable only to NRC-licensed facilities or activities.

Under its Agreement State program, NRC often relinquishes its regulatory authority over source, byproduct and special nuclear material to states, authorizing them to administer its program in their state over its NRC-licensed facilities. Tennessee is such an "NRC Agreement" state.

Similarly, DOE is legally responsible for the management of nuclear materials at its facilities and is responsible for developing its own set of orders in carrying out its statutory responsibilities under the AEA. DOE orders are not promulgated because they apply only to DOE facilities and operations, and do not apply to non-governmental entities, as NRC regulations do. Tennessee specifically exempts DOE and its contractors or subcontractors from its NRC-equivalent regulations in Tennessee Department of Environment and Conservation (TDEC) 0400-20-10-.06 and NRC exempts DOE from its definition of a "person" subject to its regulations in 10 CFR 20.1003. EPA's ARARs guidance (EPA 1989a) recognizes DOE's unique role, stating that *"most of DOE's operations are exempt from NRC's licensing and regulatory requirements"* and DOE's requirements for *"radioactive waste management are spelled out in a series of internal DOE Orders…issued under the Atomic Energy Act [that] have the same force for DOE facilities or 'within DOE' as does a regulation."* The manual further states that, *"Because DOE's Orders typically incorporate requirements promulgated by other Federal agencies, they should be consistent with existing regulations."* (pp. 5–17 to 5–18).

DOE Order (O) 435.1-1, *Radioactive Waste Management*, is generally consistent with and typically includes equivalent 10 CFR 61 requirements that are appropriate or "well-suited" to DOE sites and waste management operations. That is, 10 CFR 61 requirements incorporated into DOE O 435.1-1 meet the "appropriateness" criteria of the term "relevant and appropriate." Conversely, 10 CFR 61 requirements that are not incorporated into DOE O 435.1-1 do not meet the "appropriateness" criteria and, as such, are not regarded as "relevant and appropriate" for DOE environmental restoration sites.

After a lengthy review and discussion by the FFA parties, all agreed that certain of these NRC standards and DOE order requirements would be considered relevant and appropriate requirements and TBC guidance, respectively, for this CERCLA response action. These agreed upon requirements are included in the ARARs tables.

4. TSCA TECHNICAL REQUIREMENTS ARARS WAIVER REQUEST

As a result of the engineering construction, site conditions, and anticipated type of waste planned for disposal in a proposed EMDF, DOE is seeking a waiver for two TSCA technical requirements. Although the requirements would still be considered ARARs, by agreeing that the requirements are not necessary to ensure protection of human health and the environment, the need to meet these requirements is waived.

4.1 TSCA 40 CFR 761.75(B)(3)

Technical requirements for chemical waste landfills used for the disposal of PCBs and PCB items include those relating to hydrologic conditions that require "*The bottom of the landfill shall be above the* *historical high ground water table as provided below. Floodplains, shorelands, and ground water recharge areas shall be avoided. <u>There shall be no hydraulic connection between the site and standing or flowing surface water.</u> The site shall have monitoring wells and leachate collection. <u>The bottom of the landfill liner system or natural in-place soil barrier shall be at least fifty feet from the historical high water table.</u>* " [40 CFR 761.75 (b) (3) – TSCA regulations]. As none of the proposed disposal sites in Bear Creek Valley (BCV) meet two parts of this requirement (those two parts are underlined), and because the facilities can be designed without meeting these requirements and still be protective of human health and the environment, a waiver is being requested. Under 40 CFR 761.75(c)(4) *Waivers.* "*An owner or operator of a chemical waste landfill may submit evidence to the Regional Administrator that operation of the landfill will not present an unreasonable risk of injury to health or the environment from PCBs when one or more of the requirements of paragraph (b) of this section are not met. On the basis of such evidence and any other available information, the Regional Administrator may in his discretion find that one or more of the requirements of paragraph (b) of this section is not necessary to protect against such a risk and may waive the requirements in any approval for that landfill.* Evidence and rationale in the following three categories is presented to support this waiver request:

1. PCB management and disposal practices on the ORR
2. Equivalent or superior effectiveness of site soils and engineered features of the EMDF
3. Results of risk assessment and related fate and transport modeling for PCBs

4.1.1 PCB management and disposal practices on the ORR

ORR facilities [East Tennessee Technology Park (ETTP), Y-12, and Oak Ridge National Laboratory) manage TSCA-regulated materials, including PCBs. Because of the age of many ORR facilities and the varied uses for PCBs in gaskets, grease, building materials, and equipment, DOE self-disclosed unauthorized use of PCBs to EPA in the late 1980s. As a result, DOE Oak Ridge Environmental Management and EPA Region 4 consummated a major compliance agreement known as the "Oak Ridge Reservation Polychlorinated Biphenyl Federal Facilities Compliance Agreement" (DOE 2012) (ORR PCB FFCA), which became effective December 16, 1996, and was last revised on May 23, 2012. The modification in 2012 incorporated institutional controls at the closed Toxic Substances Control Act Incinerator at the ETTP where limited areas of contamination remain in place at the facility after the facility closure actions were completed. The institutional controls will remain in place until future PCB cleanup actions, which will be addressed during CERCLA demolition actions, are complete.

The ORR PCB FFCA provides a mechanism to address legacy PCB-use issues across the ORR. The agreement specifically addresses the unauthorized use of PCBs [e.g. - in ventilation ducts and gaskets, lubricants, hydraulic systems, heat transfer systems (electrical equipment such as transformers and capacitors)], and other unauthorized uses; storage and disposal of PCB waste; cleanup and/or decontamination of PCBs and PCB items including PCBs mixed with radioactive materials; PCB research and development; and ORR records and reporting requirements. A major focus of the agreement is the disposal of PCB waste. The ORR PCB FFCA established specific requirements related to PCB disposal including a compliance strategy with four sequential, interdependent phases: 1) preparation of a PCB/radioactive waste inventory; 2) identification of treatment/disposal options for PCB wastes; 3) evaluation and selection of of preferred options for wastes; and 4) a PCB waste management plan and schedules (Attachment I to DOE 2012).

As a result of the compliance agreement, DOE and its contractor continue to notify EPA when additional unauthorized uses of PCBs, such as PCBs in paint, adhesives, electrical wiring, or floor tile, are identified. This notification process is routinely incorporated into the CERCLA documentation for demolition and remedial actions. EPA is updated annually on the status of DOE actions with regard to management and disposition of PCBs covered under the ORR PCB FFCA.

PCB waste generation, transportation, disposal, and storage at ETTP are regulated under EPA Identification Number (ID) TN0890090004. The removal of legacy PCB waste at Y-12 was completed in 2011 in accordance with the terms of the ORR PCB FFCA. PCB waste generation, transportation, and storage at ORNL are regulated under EPA ID TN1890090003.

The WAC for the EMWMF and proposed for EMDF do not (will not) allow for disposal of any liquids. ORR waste management practices dictate that inactive electrical equipment such as transformers and capacitors containing PCBs that are taken out of use are drained of PCB liquids and the drained liquids and carcasses are disposed of off-site through commercial vendors authorized by EPA for PCB disposal. Neither the liquids nor the electrical equipment are allowed for disposal in the EMWMF or proposed EMDF. In addition, other PCB containing equipment such as fluorescent light ballasts are systematically removed from buildings prior to demolition and disposed of through off-site commercial vendors. The ORR PCB FFCA addresses the requirements for management, removal, and disposal of PCB impregnated gaskets and ductwork contaminated with PCBs. The majority of PCB sources are systematically removed from buildings during pre-demolition decommissioning work when friable asbestos-containing materials (ACM) and universal wastes such as batteries and mercury-containing equipment and bulbs/lamps are removed. Project-specific waste management plans developed for building D&D and remedial actions under CERCLA include requirements to address PCB management and disposal that undergo review and approval by EPA and TDEC under the FFA for the ORR.

As a result of these in-place procedures on the ORR, disposal of PCB waste in the existing EMWMF has been limited to bulk PCB waste disposal (< 50 ppm), and has been confirmed in Waste Lot acceptance documents to date. It is expected that these procedures will continue in effect throughout operation of a future on-site disposal facility as well, thereby limiting all on-site disposal of PCB waste to < 50 ppm. This information is given as evidence that the proposed facility will not present an unreasonable risk of injury to health or the environment from PCBs when the requirements of 40 CFR 761.75(b)(3) are not met.

4.1.2 Equivalent or superior effectiveness of site soils and engineered features of the EMDF

The technical requirements for engineered features of chemical waste landfills defined in 40 CFR 761.75 (b) include two main components: 1) 4 ft of in place silt/clay soils or 3ft of compacted silt/clay soil liner thickness with a permeability ≤ 1x10-7 cm/sec, and 2) a leachate collection system that can be a simple (single), compound (double), or suction lysimeter system. A synthetic membrane liner is used "if in the judgment of the Regional Administrator", the hydrologic or geologic conditions require such a liner to provide a permeability equivalent to the soils noted above (i.e. ≤ 1x10-7 cm/sec).

The engineered features proposed for the EMDF include elements that exceed the requirements specified in 40 CFR 761.75 (b). These features are described and illustrated in detail in Section 6 of the RI/FS Report but in summary include: 1) a 5 ft thick liner system that includes two impermeable high density polyethylene (HDPE) liners, a geosynthetic clay liner, and two leachate collection drainage layers with a lower leak detection layer, 2) 10 ft of low permeability vadose zone geologic buffer material, 3) a variable thickness of low permeability structural fill material and relatively low permeability in-situ silty clay residuum/saprolite material, and 4) an underdrain system designed to maintain the water table well below the bottom of the geobuffer layer. The entire top to bottom vertical sequence below the waste layer includes (layers with greater thickness and low permeability are noted in parentheses):

- Protective material layer (1ft)
- Geotextile separator layer
- Leachate collection drainage layer (1ft)
- Geotextile cushion layer
- Primary geomembrane liner (Liner #1 – 60mil HDPE)

- Geosynthetic clay liner (≤ $1x10^{-9}$ cm/sec)
- Geocomposite drainage layer/leak detection layer
- Secondary geomembrane liner (Liner #2 – 60mil HDPE)
- Compacted clay liner (3 ft ≤ $1x10^{-7}$ cm/sec)
- Geologic buffer layer (10 ft ≤ $1x10^{-5}$ cm/sec)
- Structural fill layer (variable thickness ≤ $1x10^{-5}$ cm/sec)
- In-situ silty clay residuum soils and saprolite (variable thickness with relatively low permeability (10^{-4} to 10^{-7} cm/sec)
- Underdrain network designed to maintain the water table at depths ranging from 30-95 ft below the bottom of the waste

The final landfill cover (an 11 ft thick multilayer system with lateral drainage and low permeability layers) significantly reduces infiltration of water through the waste and along with the liner/geobuffer materials limits the potential for mobilization and exposure of PCBs and other waste constituents to the public and the environment. The sequence of engineered and in-situ materials proposed for the EMDF provides protection and redundancy well beyond the basic requirements for liners, leachate collection, and the 3-4 ft thick soil liner specifications defined for PCB disposal in chemical waste landfills stipulated in 40 CFR 761.75 (b). In addition, the underdrain network provides a viable system for lowering the pre-existing water table and maintaining a significant thickness of unsaturated zone below the waste, liner, and geobuffer materials. In conjunction with the limitations imposed on the quantities and volume of PCBs allowed for EMDF disposal, these features limit the possibility of PCB releases that would present an "unreasonable risk of injury to health or the environment".

4.1.3 Results of risk assessment and related fate and transport modeling for PCBs

Additional evidence supporting the TSCA waiver comes from fate and transport modeling of contaminants of concern (including PCBs and other organic compounds). Model simulations of potential PCB migration and exposure via ground water migration have been completed to estimate risk over longer timeframes assuming that current and future planned land use controls no longer exist. The modeling simulates contaminant migration via ground water pathways from the waste cells through the unsaturated zone below the site and then laterally downgradient through the saturated zone to a domestic well supplying drinking water to a hypothetical family of four. The simulations and risk assessment also calculate risks to a maximally exposed individual associated with contaminated surface water that is used for crop irrigation and livestock watering. The modeling and risk assessment employ two particular representative PCB Aroclors (Aroclor-1221 and -1232) to evaluate potential PCB migration and risks. Hazardous, non-radiological organic contaminants such as PCBs were not modeled past 1,000 years due to their expected natural degradation in the environment well within the 1,000 year timeframe. The modeling results indicated that these PCBs would not peak until well after the 1,000 year timeframe at the proposed receptor locations. Thus PCBs would not pose a risk to human health.

Consumption of PCB-contaminated foods is the most significant route of exposure to PCBs for the general human population (National Academy Press 2001). This exposure typically occurs as a result of bioaccumulation of PCBs through the food chain from contaminated sediments and accumulations of PCBs in macroinvertebrates that are carried up through the food chain through fish to humans and wildlife. The streams at and near the EMDF site are quite small and have intermittent and relatively low base flow characteristics, limiting the potential for PCBs to enter the food chain via surface water/sediment pathways and human exposure through fish consumption. The streams within an approximately 2000 ft radius of the site do not include water of sufficient size or volume to sustain any fish populations that could yield fish for human consumption. PCB dissolved phase aqueous migration from the waste cells (where PCBs occur in solid phase only and with relatively low bulk concentrations of

PCBs) through extensive layers of underlying fine grained low permeability soils with high sorptive capacity would inherently limit the potential for PCB migration to the nearest stream channels where flood plain sediments are limited in length and areal extent.

PCBs have relatively low water solubility and low vapor pressures and tend to readily partition to organic matter in soils and sediments. The relatively low mobility of PCBs in the subsurface environment and high adsorption of PCBs to soil particles and organic compounds in combination with significantly reduced infiltrations rates within the landfill footprint suggest that PCB migration in the subsurface would be limited. The risk of exposure to human health and the environment would therefore be limited.

4.2 TSCA 40 CFR 761.75(B)(5)

Technical requirements for chemical waste landfills used for the disposal of PCBs and PCB items include this siting requirement regarding topography, "*The landfill site shall be located in an area of low to moderate relief to minimize erosion and to help prevent landslides or slumping.*" [40 CFR 761.75(b)(5) – TSCA regulations]. The proposed disposal sites in BCV are all situated abutting the slopes of Pine Ridge but there is some question regarding whether the slopes of the EBCV Site (Figure G.1) meet the requirement as stated. The landfill in EBCV can be engineered to remain protective of human health and the environment, and will minimize erosion and help prevent landslides/slumping, thus a waiver is being requested. Under 40 CFR 761.75(c)(4) *Waivers.* "*An owner or operator of a chemical waste landfill may submit evidence to the Regional Administrator that operation of the landfill will not present an unreasonable risk of injury to health or the environment from PCBs when one or more of the requirements of paragraph (b) of this section are not met. On the basis of such evidence and any other available information, the Regional Administrator may in his discretion find that one or more of the requirements of paragraph (b) of this section is not necessary to protect against such a risk and may waive the requirements in any approval for that landfill.* Evidence regarding the low levels of PCBs expected to be disposed in this landfill (as with the technical requirement above) and equivalent or superior effectiveness of engineered features of the EMDF are presented to support the waiver request.

4.2.1 PCB management and disposal practices on the ORR

As a result of these in-place procedures on the ORR, as given in the previous waiver discussion and evidence section, disposal of PCB waste in the existing EMWMF has been limited to bulk PCB waste disposal (< 50 ppm), and has been confirmed in Waste Lot acceptance documents to date. It is expected that these procedures will continue in effect throughout operation of a future on-site disposal facility as well, thereby limiting all on-site disposal of PCB waste to < 50 ppm. This information is given as evidence that the proposed facility will not present an unreasonable risk of injury to health or the environment from PCBs when the requirements 40 CFR 761.75(b)(5) of this section is not met.

4.2.2 Equivalent or superior effectiveness of engineered features of the EMDF

The intent of the siting criteria is to ensure long-term stability of the landfill by avoiding terrain that is prone to slope failure and intense runoff that could cause damaging erosion, landslides, or slumping. What exactly constitutes low, moderate, and high relief is not explicitly stated in the regulation and additional research did not provide a standard definition. Some slopes in the vicinity of the proposed landfills are steep. The EMDF footprint in EBCV is proposed for an area of moderate to steep existing slopes within the BCV along the southern flank of Pine Ridge. Existing grades range from less than 25%, flatter than 4 horizontal (H) to 1 vertical (V), to approximately 50%, 2H to 1V. Based on the general site descriptions within the RI/FS, there are no unstable ground areas subject to previous sliding that were identified. Stability is not only a function of slope angles, but also the materials in place and their properties. Should on-site disposal be selected for implementation, additional field investigations would be planned to support the design phase that would verify existing observations and further evaluate historic slope stability. Extensive geotechnical characterization studies will be performed to provide data for final design and the calculations required to analyze static slope stability for the proposed EBCV facility.

The existing natural slopes of Pine Ridge along Bear Creek Valley have not shown any indications of past or future landslides or slumping. Characterization efforts such as test pits, boreholes, well drilling logs, and corresponding laboratory testing have occurred at various locations down the valley and demonstrate the stability of the existing terrain. Problems could arise if the existing slopes of Pine Ridge were excavated incorrectly, but this has been a design consideration in the conceptual designs of the RI/FS. Avoiding undercutting along Pine Ridge was a primary driver in the conceptual designs for two reasons: 1) to avoid creating potentially unstable slopes above excavated areas and 2) to avoid intercepting any potentially shallow ground water traveling down the ridge.

The relatively impermeable landfill features (cover system) will promote stability by reducing recharge in the area, as saturated soils are a primary cause of landslides and slumping. The landfill has been configured to improve overall landfill stability and associated existing slope stability through buttressing effects, control of ground water beneath the landfill, and reducing erosional flow paths for surface water. The majority of the footprint (about three-fourths of the footprint area) lies on existing slopes of about 30% steepness or less, while only about one-fourth of the footprint is developed on the steeper slopes of Pine Ridge. Based on cross-sections presented within the RI/FS, the landfills creates a buttress against the ridge for creation of the geologic buffer and bottom liner systems which are sloped at a proposed slope of 3H to 1V – flatter than some existing grades on the ridge. When filled, the completed landfill creates a buttress fill that flattens sections of the ridge and puts a large stabilizing mass at the toe of the steepest slopes above the proposed site area. Further, the EMDF configuration controls surface water and ground water through collection and rerouting drainage features that improve the overall stability of the landfill and associated existing slopes. Riprap armor and buttressing have been incorporated into the conceptual designs to further mitigate the potential for erosion and promote long-term stability. Diversion of upgradient surface water runoff is incorporated in the conceptual site design, to further reduce erosion at the site. As a final note, the EBCV Site upgradient north-side drainage area is a relatively small area totally only ten acres, with a quite narrow swath representing the path of storm water flow directed toward the landfill and requiring diversion (see Figure G-1), thus runoff that will be directed around the landfill using French and trench drains is limited in volume and velocity.

Any new slopes constructed as part of any landfill will use standard allowable slopes which will then be validated through modeling and calculations. All of the landfills considered in the RI/FS use similar proposed slopes for the various phases of landfill construction. Slope failure is always a key issue in the design of any large earth structure, regardless of existing terrain. Landfill design involves rigorous seismic analysis and slope stability calculations. Volume 3 of the Remedial Design Report for EMWMF provides examples of the types of slope stability modeling and calculations that will be performed to ensure long-term stability, while Volume 1 of the report provides the quality assurance plans that are used to ensure that the landfill is constructed to the standards required to ensure long-term stability. The new facility will undergo this process as well as considering new seismic standards that have been implemented in recent years.

TSCA regulations do not contain explicit seismic requirements; instead this topography siting requirement is given to promote the use of stable sites. However, explicit seismic requirements for the proposed landfill are derived from RCRA requirements (40 CFR 264.18(a)(1)) and NRC siting requirements (TDEC 0400-20-11-.17(1)(i)), and are included in the ARARs for this landfill; they will be met. Meeting these requirements further demonstrates the ability of this remedy to fulfill the intent of the TSCA regulation at 40 CFR 761.75(b)(5).

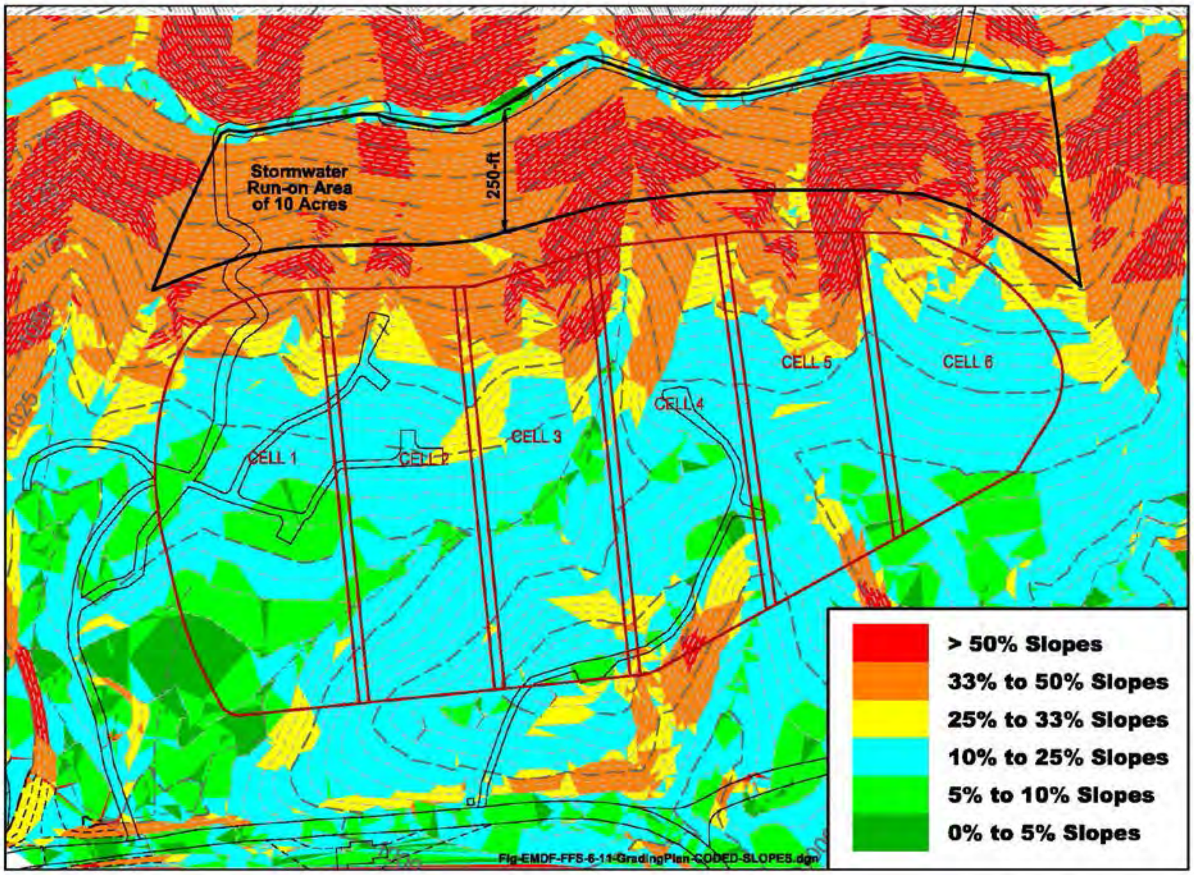

Figure G-1. EBCV Site Slopes

Slopes rated at 50% equates to 2H:1V slopes, 33% equates to 3H:1V, 25% equates to 4H:1V, and 10% equates to 10H:1V.

4.3 TDEC 0400-20-11-.17(1)(H)

This NRC low level waste (LLW) disposal siting criterion is based on a scenario of disposal that is vastly different from that proposed in this document. The NRC, over 30 years ago, promulgated 10 CFR 61, *Licensing Requirements for Land Disposal of Radioactive Waste*, based on the envisioned disposal of LLW as summarized in a draft Environmental Impact Statement (EIS) (NUREG-0782) and Final EIS (NUREG-0945). According to these documents, LLW "is disposed of by a method generally known as shallow land burial (SLB). This method of waste disposal consists of placing packaged waste into excavated trenches. The filled trenches are backfilled with soil, capped, and mounded to facilitate rainwater runoff."

In contrast to the trench method of SLB that excavates fully below the surface, the engineering design for each of the proposed EMDF sites results in most of the waste mass disposed at elevations above the existing ground surface and well above the local water table. This elevated form of construction is combined with underdrains to mitigate the effects of shallow ground water below and adjacent to the footprints, as well as a multi-layered 11-foot cap to drastically limit rainwater infiltration. The entire landfill is constructed to rigorous landfill design standards that meet RCRA Subtitle C requirements and enclose the wastes in an unsaturated state, control infiltration and runoff, prevent water table incursions, ensure stability, and minimize the potential for future releases to the environment. The elevated base of the waste cells combined with the design requirements for a minimum of 15 feet of unsaturated zone below the waste – which is composed of a very low permeability 10-foot geologic buffer and liner system that includes impermeable geosynthetics and 3 feet of extremely low permeability compacted clay – ensures that the hydrogeologic unit used for disposal will not discharge ground water to the surface within the disposal footprint.

Based on this analysis, the siting requirement appears to regulate a structure/facility that is vastly different from the proposed EMDF. As per U.S. Environmental Protection Agency Publication 9234.2-03/FS (EPA 1989b), a regulation may be relevant but not appropriate if a comparison of "the type and size of the structure or facility regulated and the type and size of the structure or facility affected by the release or contemplated by the CERCLA action" results in such a determination. In the case of the proposed EMDF, this NRC siting requirement, while it may be relevant in that it applies to LLW disposal, is not appropriate due to the differences in the types of facilities and, therefore, is not ARAR for this action.

5. CHEMICAL-SPECIFIC ARARs/TBCs

Chemical-specific ARARs and TBC guidance provide health- or risk-based concentration or discharge limitations in various environmental media (i.e., surface water, ground water, soil, and air) for specific hazardous substances, pollutants, or contaminants. There are chemical-specific ARARs for the remediation and discharge of landfill wastewater under the four proposed action alternatives in the Integrated Water Management Focused Feasibility Study (FFS). Those chemical-specific ARARs are incorporated into this RI/FS and listed in Tables G-1 and G-2 for the On-site Disposal Alternative. There are also chemical-specific ARARs limiting exposure to radioactivity identified for the On-site Disposal Alternative (see Table G-2) that are discussed below.

5.1 SURFACE WATER QUALITY STANDARDS

Surface water bodies in Tennessee are assigned use classifications by the Tennessee Water Quality Control Board. Those use classifications are not assigned based on surrounding land uses, and may have no relationship to how the surface water is currently being used. Tennessee surface water use classifications are listed in TDEC 0400-40-04. Bear Creek, near the EMWMF and the proposed EMDF, is classified by the state for Fish and Aquatic Life (FAL), Recreation (REC), Irrigation (IRR), and Livestock Watering and Wildlife (LWW) uses. All other named and unnamed surface waters in the Clinch River Basin, with the exception of wet weather conveyances, which have not been specifically named in the regulations, are classified for FAL, REC, LWW, and IRR uses per TDEC 0400-40-04-.09. Each of the use classifications has water quality standards set under TDEC 0400-40-03, although only the FAL and REC uses have specific numeric ambient water quality criteria (AWQC) set for particular compounds. The REC AWQC are human health criteria and the FAL criteria are set for the protection of aquatic life. Although all of these criteria, both numeric and narrative, are all potential ARARs for any effluent discharges to Bear Creek, the specific criteria that would be applied and enforced as final limits, should the selected remedy include an on-site water treatment facility at the EMWMF/EMDF, would be negotiated and set in the final decision document for this action and could include any subset of these criteria, as determined by the regulatory authorities.

A preliminary subset of key contaminants of concern in the leachate/contact water has been identified and agreed to by the FFA parties; this subset has been used during the development and screening of remedial alternatives in the FFS. AWQC for this subset of contaminants of concern are listed in Table G-1. Other narrative water quality standards are included in Table G-2 as potential chemical-specific ARARs.

Per TDEC 0400-40-05-.10(4), effluent discharges are required to meet the anti-degradation requirements of TDEC 0400-40-03-.06 to ensure that new or increased discharges do not would cause measurable degradation of any parameter that is "unavailable." Unavailable parameters exist where water quality is at, or fails to meet, the levels specified as water quality criteria in TDEC 0400-40-03-.03.

5.2 RADIATION PROTECTION

The radiation dose to members of the public must not exceed 100-mrem/year total effective dose equivalent from all sources excluding dose contributions from background radiation, medical exposures, or voluntary participation in medical/research programs and must be reduced below this limit as low as reasonably achievable (ALARA). This dose limit addresses exposure to radiation from all sources and activities as measured at the DOE facility boundary. In addition, DOE is required to use procedures to maintain the dose ALARA.

EPA Guidance Office of Solid Waste and Emergency Response Directive 9200.4-18 (EPA 1997) establishes cleanup levels for CERCLA sites with radioactive contamination. Responses to radionuclide releases will be consistent with this guidance, which establishes cleanup levels based on the NCP range of an excess upper bound lifetime cancer risk to an individual of between 10^{-4} to 10^{-6} (40 CFR 300.430[e][2)(i][A][2]).

6. LOCATION-SPECIFIC ARARS/TBCS

Location-specific requirements (see Table G-3) establish restrictions on siting or requirements for how activities will be conducted solely because they will take place in special locations (e.g., wetlands, floodplains, critical habitats, historic districts, streams, presence of threatened or endangered species). Additional location-specific ARARs place restrictions on certain site attributes, such as hydrogeology or seismicity, that could affect the performance of a remedy. The location-specific ARARs discussed here are based on the siting of the proposed EMDF in East Bear Creek Valley immediately east of EMWMF. The Off-site Disposal and No-Action Alternatives would not impact any special locations.

6.1 FLOODPLAINS/WETLANDS

Activities that affect wetlands are regulated under federal and state law. Impacts to wetlands from siting a new disposal facility would be avoided whenever possible. If impacts were unavoidable, they would be minimized through steps such as project design changes or the implementation of best management practices (BMPs), erosion and sedimentation controls, and site restoration.

As described in Appendix E of this RI/FS, several wetlands have been identified within or near the EMDF site. If the On-site Disposal Alternative is the selected remedy in the ROD, certain wetlands would be destroyed or adversely impacted and compensatory mitigation in the form of wetland restoration, creation, or enhancement would be carried out as required.

The conceptual design footprint of the EMDF, leachate storage tanks, contact water basins, access roads, and sediment basins are not within the 100-year or 500-year floodplain of Bear Creek for any of the proposed sites. However, if the final EMDF, including the wastewater treatment facility, is sited in an area away from the EMWMF requiring piping of wastewater to the water treatment facility, piping may need to be laid in a floodplain. Therefore, regulations regarding potential impacts on floodplains are included in Table G-3 for the On-site Disposal Alternative. Construction activities at the EMDF site would involve some disturbance of wetlands and aquatic resources and ARARs regarding those activities are included in Table G-3; mitigation activities are therefore assumed in the on-site cost estimate.

6.2 AQUATIC RESOURCES

The Fish and Wildlife Coordination Act of 1958 requires federal agencies to consider the effect of water-related projects on fish and wildlife resources and take action to prevent loss or damage to these resources. The provisions of the Act are not applicable to those projects or activities carried out in connection with land use and management programs carried out by federal agencies on federal lands under their jurisdiction; however, the provisions may be relevant and appropriate for such activities.

The TDEC Division of Water Pollution Control requires Aquatic Resource Alteration Permits (ARAPs) for alterations of waters of the state, including wetlands. Typical actions that trigger these requirements include the impoundment, diversion, stream location, or other control or modifications of any body of water or wetland. General permits are available for alteration of wet-weather conveyances, minor wetland alterations, minor road crossings, utility line crossings of streams, bank stabilization, sand and gravel dredging, debris removal, construction of a new intake and outfall structure, and stream and restoration habitat removal. Since this project would be implemented under CERCLA, proposed activities for development of an on-site disposal facility would be required to meet only the substantive requirements under the applicable General permit or individual ARAP process, including such elements as BMPs and erosion and sedimentation controls.

Implementation of the on-site EMDF would require substantial modification of NT-3 (i.e., construction over a portion of NT-3), site improvements, and potential construction of new bridges or culverts that would impact existing wetlands. Other direct impacts to aquatic resources are not expected to be required, based on the conceptual design. Actual design considerations will determine whether and to what extent aquatic impacts will occur.

6.3 ENDANGERED, THREATENED, OR RARE SPECIES

Tennessee lists state-specific threatened, endangered, and in-need-of-management animal species in Tennessee Wildlife Resource Conservation Proclamations (TWRCPs) 00-14 and 00-15, which supersede TWCRPs 94-16 and 94-17. The TDEC Division of Natural Areas Natural Heritage Program Rare Animal List (2009) was also consulted. The Tennessee endangered plant species are listed in Rule 0400-06-02-.04. The TDEC Division of Natural Areas Tennessee Natural Heritage Program Rare Plant List (2012) was also consulted for threatened and special status species.

As described in Appendix E, the East Bear Creek Valley (EBCV)site is not known to contain plants that are threatened or endangered, in need of management, or species of concern (Collins, et al, 2015; Baranski 2009). A biologic and wetlands survey was conducted of the EBCV site, and no rare or status plants or habitats were identified within the area. If such plants were later discovered in the area, they would be protected and preserved per the Tennessee Rare Plant Protection and Conservation Act of 1985. The Tennessee dace (*Phoxinus tennesseensis*), which is listed as a "species in need of management" by the state of Tennessee and known to occur in Bear Creek and several of its tributaries, was not found in NT-3 upstream of the Haul Road. Should any actions associated with the selected remedy impact any state-listed threatened or rare animal species or habitat, impacts would be considered and mitigated as appropriate in accordance with the Tennessee Nongame and Endangered or Threatened Wildlife Species Conservation Act.

Bald eagles, as well as the gray bat, the Indiana bat and the northern long-eared bat are known to inhabit the ORR. Although a biologic survey did not identify any in the EMWMF and the proposed EMDF project areas, there are trees in the area that could be potential nesting habitat for these species. The U.S. Fish and Wildlife Service (FWS) has established restrictions and guidance on tree cutting and felling which are designed to protect endangered and threatened animal species and their habitat. ORR land managers are required to comply with these restrictions, either by limiting tree removal to designated times of the year or by having the ORR Natural Resources Manager inspect and clear the trees for removal. Tree cutting should be carried out from November 15 to March 31 where possible to meet FWS bat conservation guidelines. Other tree cutting guidelines specific to the ORR are available from the ORR Natural Resources Manager.

DOE has signed a Memorandum of Understanding (MOU) with the FWS regarding implementation of Executive Order 13186 "Responsibilities of Federal Agencies to Protect Migratory Birds" (September 12, 2013). The MOU requires DOE to coordinate with the FWS prior to DOE operations and activities with significant adverse effects on migratory birds and their habitats, and to initiate appropriate actions to avoid or minimize the take of migratory birds. Although the MOU and the consultation it requires might be considered an administrative requirement under CERCLA, DOE will take appropriate actions, as necessary, to avoid or minimize the take of migratory birds as required by Executive Order 13186, which is listed as a TBC in Table G.3, should any migratory birds or their habitats be identified in the project area during implementation of the remedy.

6.4 CULTURAL RESOURCES

There are no known significant historical or archaeological resources within the EMDF proposed footprints, support facilities, or roadways (see Appendix E). No prehistoric sites are known to exist at the EMDF site and adjacent areas to be impacted by the proposed construction of support facilities and roadways. If such resources (e.g., Native American remains) are discovered during site grading and excavation activities, work will be suspended until applicable requirements are met. Several statutes and regulations protect cultural resources, such as Native American artifacts, that may be discovered. For the On-site Disposal Alternative, if such a discovery is made at any time during the project, it must be reasonably protected from disturbance and all activity in the discovery area must cease until the site and artifacts are properly evaluated.

7. ON-SITE DISPOSAL ALTERNATIVE – ACTION-SPECIFIC ARARs/TBCs

Under the On-site Disposal Alternative, most future-generated CERCLA waste in excess of the EMWMF capacity would be disposed of in a centralized, newly constructed engineered disposal facility on the ORR. This facility would be designed to manage radioactive low-level waste (LLW), RCRA characteristic waste, polychlorinated biphenyl (PCBs), and mixed waste consisting of combinations of these waste types. The anticipated small portion of CERCLA waste that does not meet the on-site disposal facility WAC (see Chapter 2, Section 2.1.3 of the main RI/FS document), including a minimal volume of disposal facility operations waste, would be shipped to an off-site commercial facility for disposal by the generating project and are not considered part of this analysis nor part of the On-site Disposal Alternative.

Performance, design, or other action-specific requirements set controls or restrictions on particular kinds of activities related to the management of hazardous waste under the selected remedy (55 FR 8741, March 8, 1990). No one set of regulations is tailored to the combination of wastes which will be disposed. Selection of action-specific ARARs for the On-site and Off-site Disposal Alternatives is based on the overriding priority to manage wastes in a manner protective of human health and the environment over both the short-term and long-term. As previously stated, there are no ARARs for the No Action Alternative.

Action-specific ARARs for the On-site Disposal Alternative (see Tables G-4 through G-10) address:

- Siting requirements (Table G-4)
- Design requirements (Table G-5)

- General landfill design
- Landfill liner system
- Storm water control for landfill
- RCRA tanks system and

- Construction requirements (Table G-6)
- Operations requirements (Table G-7)
  - Emissions and effluents (note that most ARARs under this subheading are currently incorporated in the FFS (see Section 7.4)
  - Secondary waste and waste acceptance criteria attainment
  - Construction and operation of an on-site volume reduction facility
  - Transportation
  - General operations
- Environmental monitoring requirements (Table G-8)
  - Pre-operations monitoring
  - Operations and closure/postclosure monitoring
- Closure and post-closure requirements (Table G-9)
- Operation of an on-site wastewater management facility (Table G-10)

A key assumption is that requirements for storage before transport, transportation requirements for moving wastes from individual response sites to the on-site disposal facility, and requirements for treatment of these wastes are not ARARs for the On-site Disposal Alternative because these requirements will be met by the individual waste generators prior to placement in the on-site facility. Some wastes (e.g., decontamination and decommissioning waste that exceeds WAC for the on-site disposal facility) may be managed at the generator site pending shipment to an off-site facility for treatment or disposal. In the event waste is determined to exceed WAC after receipt at the on-site disposal facility, the waste would be returned to the generator.

7.1 GENERAL CONSTRUCTION STANDARDS – SITE PREPARATION, EXCAVATION ACTIVITIES, AND CONSTRUCTION

Site preparation activities, such as excavation, earth-moving operations, and construction of support buildings would trigger requirements to prevent and minimize emission of radioactivity, fugitive dust, and storm-water runoff. These requirements, as listed in Table G-6, are ARARs for general construction activities under the On-site Disposal Alternative. Reasonable precautions include the use of BMPs for erosion prevention and sediment control to prevent runoff and application of water on denuded surfaces to prevent particulate matter from becoming airborne.

7.2 WASTE MANAGEMENT

Table G-7 lists ARARs and TBC guidance for characterization and management of different types of waste streams.

7.2.1 Characterization

All primary wastes (e.g., soil, scrap metal, and debris) delivered to the On-site EMDF and secondary wastes (e.g., contaminated personal protective equipment, dewatering fluids, decontamination wastewaters) generated during facility construction, operations, or closure will be appropriately characterized as either solid, hazardous, PCB-contaminated, radioactive, and/or mixed wastes and managed in accordance with appropriate RCRA, Clean Air Act of 1970 (CAA), TSCA, or DOE requirements for each waste stream. Requirements for characterization and management of waste are triggered in all phases of implementation of the On-site Disposal Alternative. Other projects generating waste to be disposed of at an on-site (or off-site) facility are responsible for characterizing waste per these requirements and to confirm that that the waste meets the disposal facility's WAC. These waste streams must be characterized and managed as RCRA waste, TSCA waste, LLW, or mixed waste as appropriate.

7.2.2 Storage

RCRA-hazardous waste may be accumulated and temporarily stored in containers on-site provided that the containers meet substantive RCRA requirements and are properly marked as hazardous waste. Containers may be stored on-site provided that container integrity is ensured and precautions to prevent release of the waste are taken.

Storage areas must be properly designed and operated such that containers are not in prolonged contact with liquid from precipitation, and the area will contain any spilled materials. PCBs and PCB items must be properly marked and stored in containers per TSCA requirements. PCB and PCB radioactive waste may be stored in a PCB storage facility, or in a RCRA compliant storage facility.

7.2.3 Waste Segregation

TSCA waste must be segregated from incompatible wastes during management and storage. LLW should be segregated from mixed waste. ARARs addressing this segregation [for example 40 CFR 761.75(b)(8)] would be implemented through operations plans and procedures for an on-site facility.

7.2.4 Waste Treatment and Disposal

RCRA waste may be land disposed only if it meets treatment standards or alternative treatment standards for hazardous waste (40 CFR 268) and requirements for ignitable, reactive, and incompatible waste. Hazardous waste may not be disposed of as free liquids and empty containers should be reduced in volume (e.g., shredded, compacted) prior to disposal. Treatment to meet LDRs will be accomplished.

Bulk PCB remediation waste, other PCB cleanup wastes, and PCB bulk product waste may be disposed of in a RCRA-compliant land disposal facility or a chemical waste landfill or by performance or risk-based options per 40 CFR 761.61(b)(2).

Potentially biodegradable LLW bearing uranium and thorium shall be conditioned to minimize the generation and escape of biogenic gases. LLW must have structural stability by processing or packaging of the waste; void spaces must be reduced to the extent practicable.

Secondary waste generation (e.g., landfill wastewaters) will be managed per requirements found at 40 CFR 761.75(b)(7), which would be implemented through operations plans and procedures for an on-site facility.

7.2.5 Construction and Operation of an On-site Volume Reduction Facility

A separate facility dedicated to mechanical size reduction of waste debris will be constructed and operated on site in the Hybrid Disposal Alternative. The facility will provide staging areas and equipment to conduct mechanical size reduction of debris. Because this facility will be handling debris likely contaminated with radioactive and possibly hazardous contaminants, the facility will be constructed and operated in accordance with RCRA requirements for a miscellaneous treatment facility. It is possible that there may be air pollutant emissions from this facility, although the amounts are not expected to be large enough to be considered a "major source" or to exceed emission thresholds and offset ratios allowed under CAA regulations. The air regulations and available exemptions will be reexamined as ARARs as facility design is further developed and refined.

7.3 DISPOSAL SITE SUITABILITY REQUIREMENTS

Siting and design requirements for land disposal facilities for RCRA-hazardous waste and LLW stipulate that facilities not be located in a 100-year floodplain or areas subject to seismic activity that could adversely affect the facility's stability or ability to meet performance standards. Performance standards for the facility include the requirement to achieve long-term stability of the disposal.

Location requirements for a chemical-waste landfill under TSCA are very similar to RCRA requirements for a hazardous waste landfill. However, the hydrologic requirements of TSCA specify that the bottom of the landfill liner system or natural in-place soil barrier must be located at least 50 ft above the historical high water table and prohibit any hydrologic connection between the site and any surface water. This depth requirement applies to all sites, regardless of underlying geology and soil type. The proposed EMDF locations would not meet the TSCA hydrologic requirement. As noted in Chapter 4 of this Appendix, two TSCA waivers to hydrologic and topographic requirements would be requested on the basis that the proposed facility at the locations examined will not present an unreasonable risk of injury to health or the environment from PCBs when the requirements at 40 CFR 761.75(b)(3) and 40 CFR 761.75(b)(5) are not met.

With the exceptions as noted above, implementation of the On-site Disposal Alternative (all sites) would meet all CERCLA ARARs. In addition, the risk assessment and preliminary WAC analyses (see Appendix F and Appendix H, respectively) indicate that there would be no risks above acceptable levels to human health or the environment as a result of constructing and operating an on-site disposal facility.

7.4 WASTEWATER COLLECTION AND DISCHARGE

Non-contact storm water generated during construction, operations, closure and post-closure will be collected in sedimentation basins to allow solids to settle out, and then released to surface streams.

At the request of TDEC and the EPA, a separate FFS that addresses leachate and contact water management for both the EMWMF and the EMDF has been prepared in parallel with this RI/FS. The FFS identifies several leachate/contact water management alternatives and provides appropriate ARARs. The preferred alternatives and ARARs from this RI/FS and the FFS will be merged into a single Proposed Plan. Therefore, ARARs identified in the FFS related to leachate/contact water management have been merged with the RI/FS ARARs and are included in this appendix.

7.5 DESIGN, CONSTRUCTION, AND OPERATION OF A MIXED (RCRA HAZARDOUS, TSCA CHEMICAL AND LOW-LEVEL RADIOACTIVE) WASTE LANDFILL

Tables G-4 through G-9 list RCRA and TSCA ARARs regarding design, construction and operation of a mixed waste landfill. RCRA and TSCA requirements regarding design and maintenance of a security system and access roads are applicable. TSCA requires pre-construction baseline sampling and sampling during operations of ground water and surface water. TSCA specifies leachate collection and liner design requirements for the landfill. If a synthetic liner is used, it must have a minimum thickness of 30 mils.

CERCLA differentiates between substantive and administrative requirements. Some requirements that would be considered administrative for most CERCLA response actions (and therefore would not be identified as ARARs) have nevertheless been identified as ARARs for the On-site Disposal Alternative because they are necessary to meet substantive requirements for an operating disposal facility. Operation of the on-site disposal facility will be in compliance with general facility requirements for security, inspection, training, construction quality assurance, contingency planning, preparedness and prevention, and inventory as identified in Table G-7.

RCRA regulations require that the landfill design must prevent leachate generation and release of hazardous constituents to ground water. Requirements stipulate that a disposal facility needs two or more liners, including a top liner and a bottom liner each with a leachate collection and removal system. The bottom liner will include a leak detection system. Facility design must also provide for run-on/runoff control systems and wind dispersion control systems. Construction and operation requirements include construction and post-construction inspections.

Mercury-contaminated wastes (i.e., those that fail the Toxicity Characteristic Leaching Procedure because of mercury) will be treated to meet land disposal restrictions (LDRs) as required in 40 CFR 268.

7.6 CLOSURE

After a disposal cell is filled to capacity, pursuant to RCRA, it must be covered with a final cover designed and constructed to provide long-term minimization of liquid migration through the capped area; function with minimum maintenance; promote drainage and minimize erosion or abrasion of the cover; and accommodate settling and subsidence so that the cover's integrity is maintained. Additionally, the cap must have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present to keep water and leachate from collecting in the waste.

Ground water detection monitoring will continue throughout closure and for the compliance period agreed upon by the FFA parties. Wells that are no longer needed for compliance monitoring must be permanently plugged and abandoned.

TSCA regulations do not specifically address capping individual cells or the chemical waste landfill, however, EPA guidance indicates that closure of a TSCA landfill should parallel closure requirements under RCRA.

7.7 POST-CLOSURE CARE

The owner of a RCRA landfill must have a post-closure plan and provide appropriate post-closure notices and surveys to the appropriate local authorities. Post-closure care must begin after closure and must continue for a period to be determined by the FFA parties. Property use must be restricted and the facility must be maintained to protect the integrity of the landfill cover and other components. General post-closure care includes site surveillance and maintenance, maintenance and operation of the leachate collection system as long as leachate is being generated, and environmental monitoring, including ground water detection monitoring.

7.8 ENVIRONMENTAL MONITORING DURING OPERATION, CLOSURE, AND POST-CLOSURE CARE

The owner of a RCRA landfill must conduct monitoring of leachate, surface water, and ground water during landfill operations, closure, and the post-closure care period. RCRA and TSCA provide requirements for construction of ground water monitoring wells, and RCRA further specifies ground water monitoring program, sample collection, and detection monitoring requirements.

The substantive requirements of RCRA detection and compliance monitoring at 40 CFR 264, Subpart F will be carried out, as applicable, during landfill operation, closure, and post-closure. An appropriate point of compliance and compliance period will be determined after discussions with regulators and recorded in appropriate FFA documents such as the Remedial Action Work Plan. Certain Subpart F ARARs relating to monitoring will be tailored to the specific wastes accepted by EMDF; tailoring of these ARARs are discussed further below and within Table G-8. Ground water detection monitoring is designed to detect a potential release from the landfill, and compliance monitoring is intended to be used to confirm a release and to assist with corrective actions in the event a leak is confirmed. In the event of a release, remedial actions would be planned and implemented under CERCLA, as applied by the FFA, and not RCRA.

RCRA and TSCA provide requirements for locating and constructing ground water monitoring wells. RCRA specifies ground water monitoring program requirements, sample collection, and analyses to be conducted at 40 CFR 264, Subpart F. DOE proposes to comply with substantive Subpart F requirements within the context of the CERCLA FFA process. Further, in recognition of the fact that the proposed EMDF is primarily a low-level radioactive waste landfill, DOE proposes certain modifications to Subpart F requirements that will make these requirements more suitable to a LLW landfill than a commercial hazardous waste landfill. Proposed modifications include:

- Subpart F requires that analyses conducted on ground water during detection and compliance monitoring are to include the constituents listed in 40 CFR 264, Appendix IX. This list is relevant but not appropriate since it (a) does not address radioactivity or radionuclides (primary contaminants of concern), and (b) includes a long list of organic compounds that are prohibited from disposal by the EMDF WAC. An appropriate analyte list will be provided in a monitoring plan to be prepared and approved by the FFA parties prior to waste receipt. It is noted that a constituent list that is appropriate for the EMDF should contain some radioactive parameters (alpha, beta) and certain radionuclides. These constituents are not subject to RCRA, but may be included as part of the expected CERCLA environmental monitoring program at the EMDF.

- The NCP (40 CFR 300.430[e][5][B] and [C]), requires that remedial actions conducted in surface or ground waters that are or may be used for drinking water must meet the Safe Drinking Water Act of 1974 (SDWA) maximum contaminant level goal, or if that is set to zero, the maximum contaminant level will apply. Therefore, because Tennessee classifies all ground water as potable water, unless otherwise classified, the Safe Drinking Water Act limits are applicable to ground water contaminants that may originate from the EMDF and, as such, the concentration limits set forth in 40 CFR 264.94 will be changed, per approval of the FFA parties and as allowed by 40 CFR 264.94(b), to the SDWA limits. The SDWA limits are not applicable or relevant and appropriate for surface waters, which are not classified for Domestic Water Supply.

- Detection monitoring required by 40 CFR 264.98 will use indicator parameters and a short list of laboratory analytes to statistically determine if a release to ground water is indicated. Detection monitoring will either follow the statistical procedures defined in the regulation, or will develop an alternative procedure for approval by the FFA parties.

- Compliance monitoring will be carried out in the event that a leak is thought to have been detected. If a leak is confirmed, compliance monitoring plans will be approved by the FFA parties. It is anticipated that compliance monitoring would incorporate certain 40 CFR 264.99 requirements.

- The corrective action requirements of 40 CFR 264.100, triggered by exceedances confirmed during compliance monitoring, will be met entirely through the CERCLA FFA process that is currently in place or as may be modified by future agreement among the FFA parties.

Reporting requirements of 40 CFR 264 Subpart F are administrative, and the FFA reporting requirements will be followed. The EMDF ROD, when approved, constitutes the necessary “permit” to operate a CERCLA landfill.

The effluent limitations contained in 40 CFR 445.1 are not ARARs because EMDF fits the definition of a captive landfill (40 CFR 445.1[e]) in that it is operated by and receives wastes from the industrial operation directly associated with the landfill (EPA 2000, see Sections 2.3a and 2.12 for discussion) and is therefore exempt from the landfill effluent limitations contained in 40 CFR 445.

7.9 CONSTRUCTION AND OPERATION OF AN ON-SITE LANDFILL WASTEWATER TREATMENT SYSTEM

Three of the proposed alternatives in the FFS include construction and operation of an on-site (on-ORR) landfill wastewater treatment system (LWTS). These alternatives are Alternative 3 – on-site treatment at EMWMF/EMDF (if necessary) in a constructed LWTS and discharge to Bear Creek (batch or continuous); Alternative 4 – truck or pipe water to the Outfall 200 (OF200) Water Treatment System at Y-12, an on-site (on-ORR) wastewater treatment facility for treatment and eventual discharge via a CWA authorized outfall (includes possible construction of pretreatment facility at EMWMF or OF200); and Alternative 5 – a combined Managed Discharge-Treat at EMWMF/EMDF (combination of Alternatives 2 and 3). ARARs specific to the construction and operation of an on-site LWTS are listed in Table G-10.

Although the EMWMF and the proposed EMDF are designed to accept RCRA Subtitle C hazardous waste, no RCRA listed hazardous waste has been disposed at EMWMF and all RCRA characteristic waste sent to the EMWMF has been treated to meet RCRA LDRs prior to transfer. Years of leachate and contact water sampling data indicate none of the water contains RCRA characteristic waste. No RCRA listed waste is expected to be disposed at the proposed EMDF. Estimates of future waste streams at the EMDF, however, indicate there may be enough mercury to cause leachate or contact waters to fail TCLP for hazardous characteristics, which would cause the wastewater stream to be characteristically hazardous.

On-site wastewater treatment units that are part of a wastewater treatment facility subject to regulation under Section 402 or Section 307(b) of the Clean Water Act of 1972 (CWA) are exempt from the requirements of RCRA Subtitle C for all tank systems, conveyance systems (whether piped or trucked), and ancillary equipment used to store or transport RCRA contaminated water. Therefore, RCRA requirements are not legally applicable to the wastewater treatment facility(ies), including any tanks, containers, trucks, pipelines, or surface impoundments. However, because the EMWMF and the proposed EMDF are designed to meet RCRA hazardous waste facility standards and the EMDF water may be characteristically hazardous, the situation is considered sufficiently similar and “well suited” to a RCRA site to consider certain of the RCRA standards “relevant and appropriate” requirements under the CERCLA ARARs process for this action [see 40 CFR 300.430(g)(2) for a discussion of the “relevant and appropriate” analysis process]. These include the design, construction, operation, and closure/post-closure standards for tanks and surface impoundments.

Although effluent from RCRA Subtitle C hazardous waste landfills is regulated under the CWA and subject to effluent limits set under 40 CFR 445.11, EPA notes that RCRA Subtitle C landfills that only receive wastes generated by the industrial operations directly associated with the landfill (i.e., “captive landfills”) are exempt from these CWA effluent standards for Subtitle C hazardous waste landfills [40 CFR §445.1(e); 65 FR 3008, January 19, 2000]. EMWMF and the proposed EMDF qualify for this exemption, and the proposed LWTS would be part of the landfill complex, thus the §445.11 limits are not triggered as action-specific ARARs for the water treatment alternatives.

The surface water quality standards discussed as chemical-specific ARARs in Section G.5 and listed as chemical-specific ARARs in Tables G.1 and G-2 will be implemented through the state’s action-specific effluent discharge requirements under the CWA. The state requires that point source discharges of wastewaters receive the degree of treatment or effluent reduction necessary to comply with water quality standards and, where appropriate, that such discharges comply with the “Standard of Performance” as required by TN Water Quality Control Act at TCA §§69-3-101, et seq. For industrial discharges without applicable National Pollutant Discharge Elimination System federal effluent guidelines for its particular category of industry, best professional judgment must be employed to determine appropriate effluent limitations and standards. As discussed in Section G.5.1, the specific effluent criteria and how and where they would be applied and enforced as final limits, should the selected remedy include an on-site LWTS, would be negotiated and set in the final decision document for this action and could include any subset of these criteria, as determined by the regulatory authorities.

It is possible that there may be air pollutant emissions from a constructed LWTS, although the amounts are not expected to be large enough to be considered a “major source” or to exceed emission thresholds and offset ratios allowed under CAA regulations. The National Ambient Air Quality Standards (NAAQS) are established as the criteria state and local governments must plan to achieve and thus are not directly enforceable in and of themselves. Under the CAA §110, states are required to promulgate regulations to achieve the NAAQS and these state regulations are then the potential ARARs. The CAA National Emission Standards for Hazardous Air Pollutants (NESHAPs) for various industrial sources that emit one of several pollutants are established in 40 CFR 61. Most of the NESHAPs are neither applicable nor relevant and appropriate to cleanup at CERCLA sites because they regulate particular types of sources that would not be expected to be found at a CERCLA site (EPA, 1989; EPA, 1990; EPA, 1992a). The 40 CFR 61.92 NESHAP, however, is applicable to DOE facilities and is included as a chemical-specific ARAR on Table G-2. The RCRA air emission control requirements of 40 CFR 264 Subpart CC [air emission standards for tanks]do not apply to a waste management unit(s) that is used solely for on-site treatment or storage of hazardous waste that is generated as the result of implementing remedial activities required under CERCLA authorities [40 CFR 264.1080(b)(5); TDEC 0400-12-01-.32(a)(2)(v)]. On-site remediation and treatment of contaminated water using air strippers is also an exempted air contaminant source under TDEC regulations provided the emissions are no more than 5 tons per year of any regulated pollutant that is not a hazardous air pollutant and less than 1000 pounds per year of each hazardous air pollutant [TDEC 1200-03-09-.04(4)(d)(24)]. If on-site water treatment is selected as part of an alternative, the air regulations and available exemptions will be reexamined as ARARs as facility design is further developed and refined.

Per EPA regulation and guidance, reporting and recordkeeping requirements, as well as requirements related to test procedures and sampling methods are considered administrative requirements, not substantive environmental protection standards, therefore are not ARARs [40 CFR 300.5; EPA, 1992b, pg. 2; Preamble to the Final NCP, 55 *FR* 8756, March 8, 1990; EPA, 1988, pg. 1-11]. Although these requirements will be met as mandated by internal DOE and company policy and procedures, and will be completed in accordance with those procedures and CERCLA requirements and guidance and documented in project files, they are not listed as ARARs on the ARAR tables.

7.10 OFF-SITE TRANSPORTATION AND DISPOSAL

ARARs for off-site transportation and disposal of hazardous waste, radioactive waste, LLW, and PCB waste are listed in Table G-11 and discussed below in Chapter 8.

8. OFF-SITE DISPOSAL ALTERNATIVE ACTION-SPECIFIC ARARs/TBCs

Table G-11 lists action-specific ARARs for the Off-site Disposal Alternative and for off-site transportation and disposal of waste under the On-site Disposal Alternative. Prior to sending the wastes off-site, debris will be size reduced at an on-site volume reduction facility at ETTP. ARARs for this facility are discussed in Section 7.2.5 and included in Table G-11. Any wastes that are transferred off-site or transported in commerce along public rights-of-way must meet the U.S. Department of Transportation (DOT) requirements summarized in Table G-11 for hazardous materials, as well as the specific requirements for the type of waste (e.g., RCRA, PCB, LLW, or mixed).

The DOT regulations for hazardous materials include requirements for marking labeling, placarding, and packaging. RCRA requires generators to ensure and document that the hazardous waste they generate is properly identified and transported to a treatment, storage, and disposal facility. Specific requirements are given for manifesting, packaging, labeling, marking, and placarding. In addition, there are record-keeping and reporting requirements. Pre-transport requirements reference the DOT regulations under 49 CFR 172, 173, 178, and 179.

CERCLA Section 121(d)(3) requires that the off-site transfer of any hazardous substance, pollutant, or contaminant generated during CERCLA response actions be to a facility that is in compliance with RCRA and applicable state laws. EPA has established the procedures and criteria for determining whether facilities are acceptable for the receipt of off-site waste at 40 CFR 300.440.

Any generator who relinquishes control of PCB wastes by transporting them to an off-site disposal facility must comply with the applicable provisions of TSCA (40 CFR 761.207 et seq.). Once wastes generated from a CERCLA response action are transferred off site, all administrative as well as substantive provisions of all applicable requirements must be met.

DOE’s policy is to treat, store, and in the case of LLW, dispose of waste at the site where it is generated, if practical, or at another DOE facility if on-site capabilities are not practical and cost effective. The use of non-DOE facilities for storage, treatment, and disposal of LLW may be approved by ensuring, at a minimum, that the facility complies with applicable federal, state, and local requirements and has the necessary permit(s), license(s), and approval(s) to accept the specific waste.

Table G-1. Numeric Ambient Water Quality Criteria (AWQC) that are Potential Chemical-Specific ARARs/TBCs for Key COCs in EMWMF/EMDF Landfill Wastewater[a]

Chemical	Fish and Aquatic Life [TDEC 0400-40-03-.03(3)]		Recreation[b] [TDEC 0400-40-03-.03(4)]	Required reporting level[c] [TDEC 0400-40-03-.05(8)]
	Criterion maximum concentration (CMC) (µg/L or ppb)	Criterion continuous concentration (CCC) (µg/L or ppb)	Organisms only (µg/L or ppb)	(RRL) (µg/L or ppb)
Aldrin (c)	3.0		0.00050	0.5
Arsenic (c)			10.0	1.0
Arsenic (III)	340[d]	150[d]		1.0
b-BHC (c)			0.17	
Cadmium	2.0[e]	0.25[e]		1.0
Chromium (III)	570[e]	74[e]		1.0
Chromium (VI)	16[d]	11[d]		10.0
Copper	13[e]	9.0[e]		1.0
Cyanide	22	5.2	140	5.0
4,4’-DDT (b)(c)	1.1	0.001	0.0022	0.1
4,4’-DDE (b)(c)			0.0022	0.1
4,4’-DDD (b)(c)			0.0031	0.1
Dieldrin (b)(c)	0.24	0.056	0.00054	0.05
Lead	65[e]	2.5[e]		1.0
Mercury (b)	1.4[d]	0.77[d]	0.051	0.2
Nickel	470[e]	52[e]	4600	10.0

(b) = bioaccumulative parameter
(c) = carcinogenic parameter

[a] http://www.tn.gov/sos/rules/0400/0400-40/0400-40-03.
[b] A 10^{-5} risk level is used for setting TDEC recreational criteria for all carcinogenic pollutants. Recreational criteria for noncarcinogenic chemicals are set using a 10^{-6} risk level. [*Note*: All federal recreational criteria are set at a 10^{-6} risk level].
[c] In cases in which the in-stream AWQC or effluent limits established for an outfall are less than current chemical technological capabilities for analytical detection, compliance with the AWQC or limits will be determined using the higher RRLs, per TDEC 0400-40-03-.05(8).
[d] Criteria are expressed as dissolved.
[e] Criteria are expressed as dissolved and are a function of total hardness (mg/L). Criteria displayed correspond to a total hardness of 100 mg/L.

ARARs = applicable or relevant and appropriate requirements
AWQC = ambient water quality criteria
CCC = criterion continuous concentration
CMC = criterion maximum concentration
COCs = contaminants of concern
EMDF = Environmental Management Disposal Facility
EMWMF = Environmental Management Waste Management Facility
RRL = required reporting level
TBC = to-be-considered [guidance]
TDEC = Tennessee Department of Environment and Conservation

Table G-2. Chemical-specific ARARs and TBC Guidance for CERCLA Waste Disposal, On-site Disposal Alternative

Media/Chemical	Requirements	Prerequisite	Citation
Radionuclide emissions	Emissions of radionuclides (other than radon) to the ambient air from Department of Energy facilities shall not exceed those amounts that would cause any member of the public to receive in any year an effective dose equivalent of 10 mrem/year.	Radionuclide emissions from point sources at a DOE facility—**applicable**	40 CFR 61.92 TDEC 1200-03-11-.08(6)
	Radionuclide emission measurements shall be made at all release points which have a potential to discharge radionuclides into the air in quantities which could cause an effective does equivalent in excess of 1 percent of the standard. All radionuclides which could contribute greater than 10 percent of the potential effective dose equivalent for a release point shall be measured. [*Note: DOE has an ORR-wide radionuclide emissions monitoring program in place to comply with these requirements under 40 CFR 61, Subpart H. Adherence to the ORR-wide NESHAPS monitoring program will constitute compliance with this ARAR requirement.*]		40 CFR 61.93(b)(4)(i) TDEC 1200-03-11-.08(6)
Releases of radionuclides to the environment	Shall use, to the extent practicable, procedures and engineering controls based upon sound radiation protection principles to achieve doses to members of the public that are ALARA.	Releases of radionuclides into the environment from an active NRC licensed operation—**relevant and appropriate**	TDEC 0400-20-05-.40(2)
Radon releases to environment	No source at a Department of Energy facility shall emit more than 20 picocuries per square meter per second (pCi/[m^2-sec]) (1.9 pCi/[ft^2-sec]) of radon-222 as an average for the entire source, into the air. This requirement will be part of any Federal Facilities Agreement reached between Environmental Protection Agency and Department of Energy.	Radon releases to the environment at a DOE facility—**applicable**	40 CFR 61.192 TDEC 1200-03-11-.17
Performance objectives for LLW disposal facility	Concentrations of radioactive material which may be released to the general environment in ground water, surface water, air, soil, plants or animals must not result in an annual dose exceeding an equivalent of 25 millirems to the whole body, 75 millirems to the thyroid and 25 millirems to any organ of any member of the public. Reasonable effort shall be made to maintain releases of radioactivity in effluents to the general environment as low as is reasonably achievable (ALARA).	Construction of a LLW disposal facility— **relevant and appropriate**	TDEC 0400-20-11-.16(2)
Instream water quality criteria for release of contact water and leachate into Bear Creek tributary	Dissolved oxygen shall not be less than 5.0 mg/l. Substantial or frequent variations in dissolved oxygen levels, including diurnal fluctuations, are undesirable if caused by man-induced conditions. Diurnal fluctuations shall not be substantially different than the fluctuations noted in reference streams in the region. There shall always be sufficient dissolved oxygen present to prevent odors of decomposition and other offensive conditions.	Release of wastewater or effluents into surface water—**applicable** as instream criteria beyond the mixing zone	TDEC 0400-40-03-.03(3)(a) TDEC 0400-40-03-.03(4)(a) TDEC 0400-40-03-.03(5)(a) TDEC 0400-40-03-.03(6)(a)

Table G-2. Chemical-specific ARARs and TBC Guidance for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)

Media/Chemical	Requirements	Prerequisite	Citation
	The pH value shall not fluctuate more than 1.0 unit over a period of 24 hours and shall not be outside the following ranges: 6.0-9.0.		TDEC 0400-40-03-.03(3)(b) TDEC 0400-40-03-.03(4)(b) TDEC 0400-40-03-.03(5)(b) TDEC 0400-40-03-.03(6)(b)
	The hardness of or the mineral compounds contained in the water shall not impair its use for irrigation or livestock watering and wildlife.		TDEC 0400-40-03-.03(5)(c) TDEC 0400-40-03-.03(6)(c)
	There shall be no distinctly visible solids, scum, foam, oily slick, or the formation of slimes, bottom deposits or sludge banks of such size or character that may be detrimental to fish and aquatic life or recreation or impair its use for irrigation or livestock watering and wildlife.		TDEC 0400-40-03-.03(3)(c) TDEC 0400-40-03-.03(4)(c) TDEC 0400-40-03-.03(5)(d) TDEC 0400-40-03-.03(6)(d)
	There shall be no turbidity, total suspended solids, or color in such amounts or of such character that will materially affect fish and aquatic life or result in any objectionable appearance to the water, considering the nature and location of the water.		TDEC 0400-40-03-.03(3)(d) TDEC 0400-40-03-.03(4)(d)
	The maximum water temperature shall not exceed 3 degrees C relative to an upstream control point. The temperature of the water shall not exceed 30.5 degrees C and the maximum rate of change shall be 2 degrees C per hour. There shall be no abnormal water temperature changes that may affect aquatic life unless caused by natural conditions. The temperature in flowing streams shall be measured at mid-depth. Temperature shall not interfere with its use for irrigation or livestock watering and wildlife purposes.		TDEC 0400-40-03-.03(3)(e) TDEC 0400-40-03-.03(4)(e) TDEC 0400-40-03-.03(5)(e) TDEC 0400-40-03-.03(6)(e)
	Waters shall not contain substances that will impart unpalatable flavor to fish or result in noticeable offensive odors in the vicinity of the water or otherwise interfere with fish or aquatic life.		TDEC 0400-40-03-.03(3)(f) TDEC 0400-40-03-.03(4)(g)
	Waters shall not contain substances or combination of substances including disease-causing agents which, by way of either direct exposure or indirect exposure through food chains, may cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunctions in reproduction), physical deformations, or restrict or impair growth in fish or aquatic life or their offspring. See Table D.2 for list of criteria for key contaminants of concern.		TDEC 0400-40-03-.03(3)(g)
	Water shall not contain toxic substances that will render the water unsafe or unsuitable for water contact activities including the capture and subsequent consumption of fish and shellfish, or will propose toxic conditions that will adversely affect man, animal, aquatic life, or wildlife. See Table D.2 for list of criteria for key contaminants of concern.		TDEC 0400-40-03-.03(4)(j)
	Water shall not contain other pollutants that will be detrimental to fish or aquatic life, or adversely affect the quality of the waters for recreation, irrigation, or livestock		TDEC 0400-40-03-.03(3)(h) TDEC 0400-40-03-.03(4)(k)

Table G-2. Chemical-specific ARARs and TBC Guidance for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)

Media/Chemical	Requirements	Prerequisite	Citation
	watering and wildlife.		TDEC 0400-40-03-.03(5)(f) and (g) TDEC 0400-40-03-.03(6)(f) and (g)
	Water shall not contain iron at concentrations that cause toxicity or in such amounts that interfere with habitat due to precipitation or bacteria growth.		TDEC 0400-40-03-.03(3)(i)
	The one-hour and thirty-day average concentrations of ammonia shall not exceed the acute criterion and chronic criteria calculated using the equations given in TDEC 0400-40-03-.03(3)(j).		TDEC 0400-40-03-.03(3)(j)
	Water shall not contain nutrients in concentrations that stimulate aquatic plant and/or algae growth to the extent that aquatic habitat is substantially reduced and/or biological integrity fails to meet regional goals or that the public's recreational uses of the water body or downstream waters are affected. Quality of downstream waters shall not be detrimentally affected. Interpretation of this provision may be made using the document Development of Regionally-based Interpretations of Tennessee's Narrative Nutrient Criterion and/or other scientifically defensible methods.		TDEC 0400-40-03-.03(3)(k) TDEC 0400-40-03-.03(4)(h)
	The concentration of the *e. coli* group shall not exceed 126 per 100 ml as a geometric mean based on a minimum of 5 samples collected as specified in the regulation. The concentration of *e. coli* group in any individual sample shall not exceed 1 per 100 ml.		TDEC 0400-40-03-.03(3)(l) TDEC 0400-40-03-.03(4)(f)
	Waters shall not be modified through the addition of pollutants or through physical alteration to the extent that diversity and/or productivity of aquatic biota within the receiving waters are substantially decreased or, in the case of wadeable streams, substantially different from conditions in reference streams in the same ecoregion. The parameters associated with this criterion are the aquatic biota measured. These are response variables.		TDEC 0400-40-03-.03(3)(m)
	Quality of stream habitat shall provide for development of a diverse aquatic community that meets regionally-based biological integrity goals. Types of habitat loss include channel and substrate alterations, rock and gravel removal, stream flow changes, silt accumulation, precipitation of metals, and removal of riparian vegetation. For wadeable streams, instream habitat within each sub ecoregion shall be generally similar to that found at reference streams. However, streams shall not be assessed as impacted by habitat loss if it has been demonstrated that the biological integrity goal has been met.		TDEC 0400-40-03-.03(3)(n)
	Stream flow shall support fish and aquatic life criteria and recreational use.		TDEC 0400-40-03-.03(3)(o) TDEC 0400-40-03-.03(4)(m)
Antidegradation requirements	Effluent limitations may be required to insure [sic] compliance with the Antidegradation Statement in TDEC 0400-40-03-.06.	Point source discharge(s) of pollutants into waters of the U.S. **—applicable**	TDEC 0400-40-05-.10(4)

Table G-2. Chemical-specific ARARs and TBC Guidance for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)

Media/Chemical	Requirements	Prerequisite	Citation
	New or increased discharges that would cause measurable degradation of the parameter that is unavailable shall not be authorized. Nor will discharges be authorized if they cause additional loadings of unavailable parameters that are bioaccumulative or that have criteria below current method detection levels.	Waters with "unavailable"[as defined in TDEC 0400-40-03-.06(2)] parameters—**applicable**	TDEC 0400-40-03-.06(2)(a)
	No new or expanded water withdrawals that will cause additional measurable degradation of the unavailable parameter shall be authorized.		TDEC 0400-40-03-.06(2)(b)
	Where one or more of the parameters comprising the habitat criterion are unavailable, activities that cause additional degradation of the unavailable parameter or parameters above the level of de minimis shall not be authorized.		TDEC 0400-40-03-.06(2)(c)

Table G-3. Location-specific ARARs and TBC Guidance for CERCLA Waste Disposal, On-site Disposal Alternative

Location Resource	Requirements	Prerequisite	Citation
	Wetlands		
Presence of wetlands as defined in 10 CFR 1022.4	Incorporate wetland protection considerations into its planning, regulatory, and decision-making processes, and, to the extent practicable, minimize the destruction, loss, or degradation of wetlands; and; preserve and enhance the natural and beneficial values of wetlands.	DOE actions that involve potential impacts to, or take place within wetlands—**applicable**	10 CFR 1022.3(a)(7) and (8)
	Undertake a careful evaluation of the potential effects of any proposed wetland action. Avoid, to the extent possible, the long- and short-term adverse impacts associated with the destruction of and occupancy and modification of wetlands. Avoid direct and indirect development in a wetland wherever there is a practicable alternative. Identify, evaluate, and, as appropriate, implement alternative actions that may avoid or mitigate adverse wetland impacts.		10 CFR 1022.3(b), (c), (d)
	Project Description. This section shall describe the proposed action and shall include a map showing its location with respect to the floodplain and/or wetland. For actions located in a floodplain, the nature and extent of the flood hazard shall be described, including the nature and extent of hazards associated with any high-hazard areas.		10 CFR 1022.13(a)(1)
	Floodplain or Wetland Impacts. This section shall discuss the positive and negative, direct and indirect, and long- and short-term effects of the proposed action on the floodplain and/or wetland. This section shall include impacts on the natural and beneficial floodplain and wetland values (§ 1022.4) appropriate to the location under evaluation. In addition, the effects of a proposed floodplain action on lives and property shall be evaluated. For an action proposed in a wetland, the effects on the survival, quality, and function of the wetland shall be evaluated.		10 CFR 1022.13(a)(2)
	Alternatives. Consider alternatives to the proposed action that avoid adverse impacts and incompatible development in a wetland area, including alternate sites, alternate actions, and no action. DOE shall evaluate measures that mitigate the adverse effects of actions in a wetland including, but not limited to, minimum grading requirements, runoff controls, design and construction constraints, and protection of ecologically-sensitive areas.		10 CFR 1022.13(a)(3)

Table G-3. Location-specific ARARs and TBC Guidance for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)

Location Resource	Requirements	Prerequisite	Citation
	If no practicable alternative to locating or conducting the action in the wetland is available, then before taking action design or modify the action in order to minimize potential harm to or within the wetland, consistent with the policies set forth in Executive Order 11990.		10 CFR 1022.14(a)
Presence of jurisdictional wetlands as defined in 40 CFR 230.3; 33 CFR 328.3(a), and 33 CFR 328.4	The discharge of dredged or fill material into waters of the United States, including jurisdictional wetlands, is prohibited if there is a practical alternative that would have less adverse impact. No discharge shall be permitted that results in violation of state water quality standards, violates any toxic effluent standard, and/or jeopardizes an endangered species or its critical habitat. No discharge will be permitted that will cause significant degradation of waters of the United States. No discharge is permitted unless mitigation measures have been taken in accordance with 40 CFR 230, Subpart H.	Actions that involve discharge of dredged or fill material into waters of United States, including jurisdictional wetlands**—applicable**	40 CFR 230.10(a), (b), (c) and (d) 40 CFR 230, Subpart H
Mitigation of state wetlands as defined under TDEC 0400-40-07-.03	If an applicant proposes an activity that would result in appreciable permanent loss of resource value of wetlands, the applicant must provide mitigation, which results in no overall net loss of resource value. Compensatory measures must be at a ratio of 2:1 for restoration, 4:1 for creation and enhancement, and 10:1 for preservation, or at a best professional judgment ratio agreed to by the state. For any mitigation involving the enhancement or preservation of existing wetlands, to the extent practicable, the applicant shall complete the mitigation before any impact occurs to the existing state waters. For any mitigation involving restoration or creation of a wetland, to the extent practicable, the mitigation shall occur either before or simultaneously with impacts to the existing state waters. Mitigation actions for impacts to wetlands are prioritized as listed in TDEC 0400-40-07-.04 (7)(b)(1)(i) – (viii).	Activity that would cause loss of wetlands as defined in TDEC 0400-40-07-.03—**applicable**	TDEC 0400-40-07-.04 (7)(b)
Presence of minor isolated wetlands of less than 0.25 acres – Minor alterations to wetlands	Alteration of up to 0.25 acre of wetlands that are degraded or of low functional capacity must meet certain requirements as follows: • The alteration shall not adversely affect the functions and classified use support of adjacent wetlands.	Alteration of minor isolated wetlands of less than 0.25 acres**—applicable**	*TCA* 69-3-108(l) TDEC 0400-40-07-.01 TDEC ARAP General Permit for Minor Alterations to Wetlands (effective July 1, 2010) (**TBC**)
	• Any material discharged into wetlands shall be free of contaminants, including toxic pollutants, hazardous substances, waste metals, or construction debris, or other wastes.		
	• Excavation and fill activities shall be kept to a minimum, and all excess material shall be hauled upland and properly stabilized or disposed of.		
	• Erosion and sediment controls shall be designed according to the size and slope of disturbed or drainage to detain runoff and trap sediment, and shall be properly selected, installed, and maintained in accordance with manufacturer's specifications and good engineering practices.		

Table G-3. Location-specific ARARs and TBC Guidance for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)

Location Resource	Requirements	Prerequisite	Citation
	• Erosion and sedimentation control shall be in place and functional before earthmoving operations begin and must be maintained throughout the construction period. Temporary measures may be removed at the beginning of the work day but shall be replaced at the end of the work day.		
	• Litter, construction debris, and construction chemicals exposed to stormwater shall be picked up prior to anticipated storm events or otherwise prevented from becoming a pollutant source for stormwater discharges.		
	• Clearing, grubbing, or other disturbance of areas immediately adjacent to waters of the state shall be limited to the minimum necessary to accomplish the proposed activity. Unnecessary vegetation removal is prohibited, and disturbed areas shall be stabilized and revegetated as soon as practicable.		
Floodplains			
Presence of floodplain as defined in 10 CFR 1022.4	Incorporate floodplain management goals into planning, regulatory, and decision-making processes, and, to the extent practicable, reduce the risk of flood loss; minimize the impact of floods on human safety, health, and welfare; restore and preserve natural and beneficial values served by floodplains; require the construction of DOE structures and facilities to be, at a minimum, in accordance with FEMA National Flood Insurance Program building standards; and promote public awareness of flood hazards by providing conspicuous delineations of past and probable flood heights on DOE property that is in an identified floodplain.	DOE actions that involve potential impacts to, or take place within, floodplains—**applicable**	10 CFR 1022.3(a)(1) through (6)
	Undertake a careful evaluation of the potential effects of any proposed floodplain action. Identify, evaluate, and, as appropriate, implement alternative actions that may avoid or mitigate adverse floodplain impacts.		10 CFR 1022.3(b) and (d)
	Avoid, to the extent possible, the long- and short-term adverse impacts associated with the occupancy and modification of floodplains. Avoid direct and indirect development in a floodplain wherever there is a practicable alternative.		10 CFR 1022.3(c)
	Consider alternatives to the proposed action that avoid adverse impacts and incompatible development in the floodplain, including alternate sites, alternate actions, and no action. DOE shall evaluate measures that mitigate the adverse effects of actions in a floodplain including, but not limited to, minimum grading requirements, runoff controls, design and construction constraints, and protection of ecologically-sensitive areas.		10 CFR 1022.13(a)(3)

Table G-3. Location-specific ARARs and TBC Guidance for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)

Location Resource	Requirements	Prerequisite	Citation
	If no practicable alternative to locating or conducting the action in the floodplain is available, then before taking action design or modify the action in order to minimize potential harm to or within the floodplain, consistent with the policies set forth in Executive Order 11988.		10 CFR 1022.14(a)
	Aquatic Resources		
Within an area potentially impacting "waters of the State" as defined in TCA 69-3-103(42) - General Permit conditions	Must comply with the [substantive] requirements of the ARAP for erosion and sediment control to prevent pollution of waters of the state. Pollution control requirements, as detailed in each particular General Permit, include but are not limited to, the following: • Activity must not result in discharge of waste or substances that may be harmful to humans or wildlife; • Material may not be placed in a location or manner so as to impair surface water flow into or out of any wetland area; • Work must be carried out in a manner that does not violate water quality criteria as stated in TDEC 0400-40-03-.03, including, but not limited to, prevention of discharges that cause a condition in which visible solids, bottom deposits, or turbidity impairs the usefulness of waters of the state for any of the designated uses for that water body by TDEC 0400-40-04; • Excavation and fill activities shall be kept to a minimum, and all excess material shall be hauled upland and properly stabilized or disposed of. • Sediment shall be prevented from entering waters of the state; erosion and sediment controls shall be designed according to the size and slope of disturbed or drainage to detain runoff and trap sediment, and shall be properly selected, installed, and maintained in accordance with manufacturer’s specifications and good engineering practices. • Erosion and sedimentation control shall be in place and functional before earthmoving operations begin and must be maintained throughout the construction period. Temporary measures may be removed at the beginning of the work day but shall be replaced at the end of the work day. • Litter, construction debris, and construction chemicals exposed to stormwater shall be picked up prior to anticipated storm events or otherwise prevented from becoming a pollutant source for stormwater discharges. • Clearing, grubbing, or other disturbance of areas immediately adjacent to waters of the state shall be limited to the minimum necessary to accomplish the proposed activity. Unnecessary vegetation removal is prohibited, and disturbed areas shall be stabilized and re-vegetated as soon as practicable. • Appropriate steps shall be taken to ensure petroleum products or other	Action potentially altering the properties of any "waters of the State"—**applicable**	TCA 69-3-108(1) TDEC 0400-40-07-.01 TDEC Aquatic Resource Alteration General Permit (ARAP) Program Requirements (**TBC**)

Table G-3. Location-specific ARARs and TBC Guidance for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)

Location Resource	Requirements	Prerequisite	Citation
	chemical pollutants are prevented from entering waters of the state, including ground water; • Adverse impacts to T&E species or cultural, historical, or archeological features or sites are prohibited.		
Waters of the state as defined in TCA 69-3-103(42) – Bank stabilization	Bank stabilization activities along state waters must be conducted in accordance with the requirements of the ARAP Program (Rules of the TDEC, Chap. 0400-40-07). The general permit requirements for stream bank stabilization include the following: • The erosion and sedimentation control practices indicated under the TDEC ARAP general conditions apply; in addition, • Stream beds must not be used as transport routes for construction equipment; • Temporary stream crossings shall be limited to one point in the construction area and erosion control measures shall be utilized where stream banks are disturbed; crossing shall be constructed so that stream flow is not obstructed; • Following construction, all materials used for the temporary crossing shall be removed and disturbed banks shall be restored and stabilized if needed; • Materials used in bank stabilization shall include clean rock, riprap, anchored trees or other non-erodible materials found in the natural environment; materials shall be free of contaminants including toxic pollutants, hazardous substances, waste metals, or construction debris, or other wastes; • Activity may not be conducted in a manner that would permanently disrupt the movement of fish and aquatic life; • Material may not be placed such that it impairs surface water flow into or out of any wetland area; • Except under certain conditions detailed in the permit, length of bank stabilization is limited to 300 linear ft.	Bank-stabilization activities affecting waters of the state—**applicable**	TCA 69-3-108(l) TDEC 0400-40-07-.01 TDEC ARAP General Permit for Bank Stabilization Activities (effective July 1, 2010) (**TBC**)
Waters of the state as defined in TCA 69-3-103(33) – Culvert maintenance activities	The maintenance of existing serviceable structures or fills along waters of the state must be conducted in accordance with the requirements of the ARAP Program (Rules of the TDEC, Chap. 0400-40-07). The general permit requirements for maintenance activities include the following: • The erosion and sedimentation control practices indicated under the TDEC ARAP general conditions apply; in addition, • Placement of material for scour protection or repair shall be limited to clean	Maintenance activities affecting waters of the state—**applicable**	TCA 69-3-108(l) TDEC 0400-40-07-.01 TDEC ARAP General Permit for Maintenance Activities (effective July 1, 2010) (**TBC**)

Table G-3. Location-specific ARARs and TBC Guidance for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)

Location Resource	Requirements	Prerequisite	Citation
	rock, riprap, rock-filled wire baskets or mattresses, or concrete contained by formwork for footing repair. Clean rock can be of various type and sizes depending on application. Clean rock shall not contain fines, soils, or other wastes or contaminants. • Materials used in maintenance activities shall be free of contaminants, including toxic pollutants, hazardous substances, waste metal, construction debris and other wastes as defined by TCA 69-3-103-(18). • Placement of material shall not impair flow or be conducted in a manner that would permanently disrupt the movement of fish or aquatic life. • Streambeds shall not be used as transportation routes for construction equipment. Temporary stream crossings shall be limited to one point in the construction area and erosion control measures shall be utilized where stream banks are disturbed. Stream crossings shall be constructed of clean rock and stream flow shall be conveyed in appropriately sized pipe. Crossing shall be constructed so that stream flow is not obstructed. Following construction, all materials used for temporary crossing shall be removed and disturbed stream banks restored and stabilized if needed. • Excavation and fill activities shall be kept to a minimum and shall be separated from flowing waters to the extent practicable and necessary. Activities shall be conducted in the dry to the maximum extent practicable by diverting flow utilizing cofferdams, berms, temporary channels, or pipes. Temporary diversion channels shall be protected by non-erodible material and lined to the expected high water level. • Excavated materials, removed vegetation, construction debris, and other wastes shall be removed to an upland location and properly stabilized or disposed of in such a manner as to prevent reentry into the waterway. • The placement of riprap shall be the minimum necessary to protect the structure or to ensure the safety of the structure. • Sediment shall be prevented from entering waters of the state. Erosion and sediment control measures shall be designed according to the size and slope of the disturbed or drainage areas to detain runoff and trap sediment and shall be properly selected, installed, and maintained in accordance with the manufacturer's specifications and good engineering practices. • Erosion and sediment controls must be in place and functional before earth moving operations begin, and shall be constructed and maintained throughout the construction period. Temporary measures may be removed at the beginning of the work day but replaced at the end of the work day. • Litter, construction debris, and construction chemicals exposed to storm		

Table G-3. Location-specific ARARs and TBC Guidance for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)

Location Resource	Requirements	Prerequisite	Citation
	water shall be picked up prior to anticipated storm events, or otherwise prevented from becoming a pollutant source for storm water discharges. After use, silt fences should be removed. • Clearing, grubbing, and other disturbance to riparian vegetation shall be kept to minimum necessary for slope construction and equipment operations. Unnecessary riparian vegetation removal, including trees, is prohibited. • Material may not be placed in a location or manner so as to impair surface water flow into or out of any wetland area. • Appropriate steps shall be taken to ensure that petroleum products or other chemical pollutants are prevented from entering waters of the state. All spills shall be reported to the appropriate emergency response agency and to TDEC and all measures taken immediately to prevent pollution of waters of the state, including ground water.		
Waters of the state as defined in TCA 69-3-103 (42) – Wet weather conveyances	Wet-weather conveyances may be altered provided the following conditions are met: • The activity must not result in the discharge of waste or other substances that may be harmful to humans or wildlife; • Material must not be placed in a location or manner so as to impair surface water flow into or out of any wetland area; and • Sediment shall be prevented from entering other waters of the state: – Erosion/sediment controls shall be designed according to size and slope of disturbed or drainage areas to detain runoff and trap sediment and shall be properly selected, installed, and maintained in accordance with manufacturer's specifications and good engineering practices. – Erosion/sediment control measures must be in place and functional before earthmoving operations begin, and must be constructed and maintained throughout the construction period. Temporary measures may be removed at the beginning of the work day, but shall be replaced at the end of the work day. – Check dams must be utilized where runoff is concentrated. Clean rock, log, sandbag or straw bale check dams shall be properly constructed to detain runoff and trap sediment. Check dams or other erosion control devices are not to be constructed in stream. Clean rock can be of various type and size depending on the application and must not contain fines or other wastes or contaminants. • Appropriate steps must be taken to ensure that petroleum products or other chemical pollutants are prevented from entering waters of the state. All	Activities that alter wet-weather conveyances—**applicable**	TDEC 0400-40-07-.04(10)(a) TDEC ARAP General Permit for Alteration of Wet Weather Conveyances (effective July 1, 2010) (**TBC**)

Table G-3. Location-specific ARARs and TBC Guidance for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)

Location Resource	Requirements	Prerequisite	Citation
	spills must be reported to the appropriate emergency management agency and TDEC. In event of spill, measures shall be taken immediately to prevent pollution of waters of the state, including ground water.		
Within area impacting stream or any other body of water -*and*- presence of wildlife resources (e.g., fish)	The effects of water-related projects on fish and wildlife resources and their habitat should be considered with a view to the conservation of fish and wildlife resources by preventing loss of and damage to such resources.	Action that impounds, modifies, diverts, or controls waters, including navigation and drainage activities—**relevant and appropriate**	Fish and Wildlife Coordination Act (16 *USC* 662(a))
Location encompassing aquatic ecosystem as defined as 40 CFR 230.3(c)	The discharge of dredged or fill material into waters of the United States is prohibited if there is a practical alternative that would have less adverse impact. No discharge shall be permitted that results in violation of state water quality standards, violates any toxic effluent standard, and/or jeopardizes an endangered species or its critical habitat. No discharge will be permitted that will cause significant degradation of waters of the United States. No discharge of dredged or fill material shall be permitted unless appropriate and practicable steps in accordance with 40 CFR 230.70 et seq. are taken that will minimize potential adverse impacts of the discharge on the aquatic ecosystem.	Action that involves the discharge of dredged or fill material into "waters of the U.S.", including jurisdictional wetlands—**applicable**	40 CFR 230.10(a), (b), (c) and (d) 40 CFR 230, Subpart H
Mitigation of state waters other than wetlands	Must provide mitigation that results in no overall net loss of resource values for any activity that would result in appreciable permanent loss of resource value of a state water. For any mitigation involving relocation or re-creation of a stream segment, to extent practicable must complete mitigation before any impact occurs to existing state waters. Mitigation measures include but are not limited to: restoration of degraded stream reaches and/or riparian zones; new (relocated) stream channels; removal of pollutants from and hydrologic buffering of stormwater runoff; and other measures which have a reasonable likelihood of increasing the resource value of a state water. Mitigation measures or actions should be prioritized in the following order: restoration, enhancement, re-creation, and protection.	Activity that would result in an appreciable permanent loss of resource value of a state water **—applicable**	TDEC 0400-40-07-.04(7)(a)
Cultural Resources			
Presence of historical resources on public land	Federal agencies must take into account the effects of their undertakings on historic properties.	Federal agency undertaking that may impact historical properties listed or eligible for inclusion on the National Register of Historic Places—**applicable**	36 CFR 800.1(a)
	Determine whether the proposed Federal action is an undertaking as defined in § 800.16(y) and, if so, whether it is a type of activity that has the potential to cause effects on historic properties.		36 CFR 800.3(a)
	Determine and document the area of potential effects, as defined in §800.16(d). Review existing information on historic properties within the area of potential		36 CFR 800.4(a)(1) – (2)

Table G-3. Location-specific ARARs and TBC Guidance for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)

Location Resource	Requirements	Prerequisite	Citation
	effects, including any data concerning possible historic properties not yet identified.		
	Take the steps necessary to identify historic properties within the area of potential effects.		36 CFR 800.4(b)
	Apply the National Register criteria (36 CFR 63) to properties identified within the area of potential effects that have not been previously evaluated for National Register eligibility. If the agency official determines any of the National Register criteria are met and the SHPO/THPO agrees, the property shall be considered eligible for the National Register for section 106 purposes.		36 CFR 800.4(c)(1) – (2)
	Shall apply the criteria of adverse effect to historic properties within the area of potential effects.		36 CFR 800.5(a)
	Shall ensure that a determination, finding, or agreement under the procedures in this subpart is supported by sufficient documentation to enable any reviewing parties to understand its basis.		36 CFR 800.11(a)
Presence of archaeological resources on public land	No person may excavate, remove, damage, or otherwise alter or deface, or attempt to excavate, remove, damage, or otherwise alter or deface any archaeological resource located on public lands or Indian lands unless such activity is pursuant to a permit issued under §7.8 or exempted by §7.5(b) of this part.	Action that would cause the irreparable loss or destruction of significant historic or archaeological resources or data on public land—**applicable**	43 CFR 7.4(a)
Presence of human remains, funerary objects, sacred objects, or objects of cultural patrimony	Intentional excavation of human remains, funerary objects, sacred objects, or objects of cultural patrimony from Federal or tribal lands may be conducted only if: • The objects are excavated or removed following the requirements of the Archaeological Resources Protection Act (ARPA) (16 *USC* 470aa et seq.) and its implementing regulations and • The disposition of the objects is consistent with their custody as described in §10.6.	Action involving alteration of terrain that might cause irreparable loss or destruction of any discovered significant scientific, prehistoric, historic, or archaeological resources—**applicable**	43 CFR 10.3(b)(1) and (3)
	Must take reasonable steps to determine whether a planned activity may result in the excavation of human remains, funerary objects, sacred objects, or objects of cultural patrimony from Federal lands.		43 CFR 10.3(c)

Table G-3. Location-specific ARARs and TBC Guidance for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)

Location Resource	Requirements	Prerequisite	Citation
	If inadvertent discovery occurred in connection with an on-going activity on Federal or tribal lands, in addition to providing the notice described above, must stop activities in the area of the inadvertent discovery and make a reasonable effort to protect the human remains, funerary objects, sacred objects, or objects of cultural patrimony discovered inadvertently.	Excavation activities that inadvertently discover such resources on federal lands or under federal control—**applicable**	43 CFR 10.4(c)
	Must take immediate steps, if necessary, to further secure and protect inadvertently discovered human remains, funerary objects, sacred objects, or objects of cultural patrimony, including, as appropriate, stabilization or covering.		43 CFR 10.4(d)(ii)
Presence of a cemetery	Intentional desecration of a place of burial without legal privilege or authority to do so is prohibited.	Action that would alter or destroy property in a cemetery—**applicable**	*TCA* 39-17-311(a)(1)
	Disinterment of a corpse that has been buried or otherwise interred, without legal privilege or authority to do so, is prohibited.		*TCA* 39-17-312(a)(2)
Endangered, Threatened or Rare Species			
Presence of Tennessee nongame species as defined in TCA 70-8-103 and listed in TWRA Proclamations 00-14 and 00-15	May not take (i.e., harass, hunt, capture, kill or attempt to kill), possess, transport, export, or process wildlife species. May not knowingly destroy the habitat of such species. Certain exceptions may be allowed for reasons such as education, science, etc., or where necessary to alleviate property damage or protect human health or safety. Upon good cause shown and where necessary to protect human health or safety, endangered or threatened species or "in need of management" species may be removed, captured, or destroyed.	Action impacting Tennessee nongame species, including wildlife species which are "in need of management" (as listed in TWRA Proclamations 00-14 and 00-15 as amended by 00-21) —**applicable**	TCA 70-8-104(b) and (c) TCA 70-8-106(e) TWRA Proclamations 00-14, Section II and 00-15, Section II, as amended by Proclamation 00-21 **(TBC)** See also the TN Natural Heritage Program Rare Animal List (2009)
Presence of Tennessee-listed endangered or rare plant species as listed in TDEC 0400-06-02-.04	May not knowingly uproot, dig, take, remove, damage or destroy, possess or otherwise disturb for any purposes any endangered species.	Action impacting rare plant species including but not limited to federally listed endangered species—**relevant and appropriate**	TCA 70-8-309(a) 16 USC 1531 et seq. TDEC 0400-06-02-.04 and Tennessee Natural Heritage Program Rare Plant List (2012)
Presence of federally endangered or threatened species, as designated in 50 CFR 17.11 and 17.12 or critical habitat of such species	Actions that jeopardize the existence of a listed species or results in the destruction or adverse modification of critical habitat must be avoided or reasonable and prudent mitigation measures taken.	Action that is likely to jeopardize fish, wildlife, or plant species or destroy or adversely modify critical habitat—**applicable**	16 U.S.C. 1531 et seq., Sect. 7(a)(2)
Presence of migratory birds as defined in 50 CFR 10.13,	Unlawful killing, possession, and sale of migratory bird species, as defined in 50 CFR 10.13, native to the U.S. or its territories is prohibited.	Action that is likely to impact migratory birds—**applicable**	16 USC 703-704

Table G-3. Location-specific ARARs and TBC Guidance for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)

Location Resource	Requirements	Prerequisite	Citation
and their habitats	Requirements are as follows: • avoid or minimize, to the extent practicable, adverse impacts on migratory bird resources when conducting agency action; • restore and enhance the habitats of migratory birds, as practicable; and • prevent or abate the pollution or detrimental alteration of the environment for the benefit of migratory birds, as practicable.	Federal agency action that is likely to impact migratory birds—**TBC**	Executive Order 13186

Table G-4. Action-specific ARARs and TBC Guidance (Siting Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative

Action	Requirements	Prerequisite	Citation
Siting of a RCRA landfill	A new facility where treatment, storage, or disposal of hazardous waste will be conducted must not be located within 200 ft of a fault which has had displacement in Holocene time.	Construction of a RCRA hazardous waste landfill—**applicable**	40 CFR 264.18(a)(1)
	A facility located in a 100 year floodplain (as defined in 40 CFR 264.18[b][2]) must be designed, constructed, operated and maintained to prevent washout of any hazardous waste, unless it can be demonstrated that procedures are in effect which will cause the waste to be removed safely, before flood waters can reach the facility		40 CFR 264.18(b)(1) TDEC 0400-12-01-.06(2)(i)
Siting of new commercial hazardous waste management facility	New land based units are prohibited if they cannot demonstrate the technical practicability of a corrective action program at the site, based on the availability of current or new and innovative technologies that could practicably achieve ground water remediation. The demonstration shall specify how a corrective action response will be effectively implemented to remediate a release to ground water within the facility property boundary and shall illustrate all the factors that are necessary to be in compliance with Rule 0400-12-01-,06(6) *[Note: The demonstration referred to here will be a description of how corrective action would be implemented.]*	Construction of a new commercial hazardous waste management facility – **relevant and appropriate**	TDEC 0400-12-02-.03(2)(e)(1)(i)(III)
Siting requirements for a TSCA Landfill	Shall be located in thick, relatively impermeable formations such as large area clay pans. Where this is not possible, the soil shall have a high clay and silt content with the following parameters: (i) In place soil thickness, 4-ft or compacted soil liner thickness, 3 ft; (ii) Permeability (cm/sec), equal to or less than 1 x 10-7; (iii) Percent soil passing No. 200 Sieve, >30; (iv) Liquid Limit, >30; and (v) Plasticity Index > 15.	Construction of a TSCA landfill—**applicable**	40 CFR 761.75(b)(1)
	The landfill must be located above the historical high ground water table. Floodplains, shorelands and ground water recharge areas shall be avoided. The site shall have monitoring wells and leachate collection.	Construction of a TSCA chemical waste landfill—**applicable**	40 CFR 761.75(b)(3)
	There shall be no hydraulic connection between the site and standing or flowing surface water.		
	The bottom of the landfill liner system or natural in-place soil barrier shall be at least 50 ft from the historical high water table. *[Note: A waiver under TSCA 40 CFR 761.75(c)(4) will be requested for this requirement.]*		

Table G-4. Action-specific ARARs and TBC Guidance (Siting Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation
	The landfill site shall be located in an area of low to moderate relief to minimize erosion and to help prevent landslides or slumping. *[Note: A waiver under TSCA 40 CFR 761.75(c)(4) will be requested for this requirement.]*		40 CFR 761.75(b)(5)
Siting of a Subtitle D landfill – buffer zones	Class I Disposal Facilities must be located, designed, constructed, operated, and maintained such that the fill areas are, at a minimum: • 100 feet from all property lines; • 500 feet from all residences, unless the owner of the residential property agrees in writing to a shorter distance; • 500 feet from all wells determined to be downgradient and used as a source of drinking water by humans or livestock; and • 200 feet from the normal boundaries of springs, streams, lakes, (except that this standard shall not apply to any wet weather conveyance nor to bodies of water constructed and designed to be a part of the facility); • A total site buffer with no constructed appurtenances within 50 feet of the property line.	Construction of a Class I solid waste disposal facility—**relevant and appropriate**	TDEC 0400-11-01-.04(3)(a)
	Class II Disposal Facilities must meet the same buffer zone standards for siting as Class I facilities (subparagraph (a) of this paragraph).	Construction of a Class II solid waste disposal facility—**relevant and appropriate**	TDEC 0400-11-01-.04(3)(b)
Siting requirements and performance objectives for LLW disposal facility	Land disposal facilities must be sited, designed, operated, closed and controlled after closure so that reasonable assurance exists that exposures to humans are within the limits established in the performance objectives. *[Note: Performance Objectives are those given at TDEC 0400-20-11-.16(1), (2), and (5).]*	Construction of a LLW disposal facility—**relevant and appropriate**	TDEC 0400-20-11-.16(1)
	Stability of the site after closure. The disposal facility must be sited, designed, used, operated and closed to achieve long-term stability of the disposal site and to eliminate to the extent practicable the need for ongoing active maintenance of the disposal site following closure so that only surveillance, monitoring or minor custodial care are required.		TDEC 0400-20-11-.16(5)
	Disposal site shall be capable of being characterized, modeled, analyzed and monitored.		TDEC 0400-20-11-.17(1)(b)
	Within the region where the facility is to be located, a disposal site should be selected so that projected population growth and future developments are not likely to affect the ability of the disposal facility to meet performance objectives. *[Note: Performance Objectives are those given at TDEC 0400-20-11-.16(1), (2), and (5).]*		TDEC 0400-20-11-.17(1)(c)

Table G-4. Action-specific ARARs and TBC Guidance (Siting Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation
	Areas must be avoided having known natural resources which, if exploited, would result in failure of the cell to meet performance objectives. *[Note: Performance Objectives are those given at TDEC 0400-20-11-.16(1), (2), and (5).]*		TDEC 0400-20-11-.17(1)(d)
	Disposal site must be generally well drained and free of areas of flooding and frequent ponding, and waste disposal shall not take place in a 100- year floodplain or wetland.		TDEC 0400-20-11-.17(1)(e)
	Upstream drainage area must be minimized to decrease the amount of runoff which could erode or inundate the disposal unit.		TDEC 0400-20-11-.17(1)(f)
	The disposal site must provide sufficient depth to the water table that ground water intrusion, perennial or otherwise, into the waste will not occur. If it can be conclusively shown that disposal site characteristics will result in molecular diffusion being the predominant means of radionuclide movement and the rate of movement will result in the performance objectives of Rules of the TDEC 0400-20-11-.16 being met, wastes may be disposed below the water table. In no case will waste disposal be permitted in the zone of fluctuation of the water table. *[Note: Performance Objectives are those given at TDEC 0400-20-11-.16(1), (2), and (5).]*		TDEC 0400-20-11-.17(1)(g)
	Areas must be avoided where tectonic processes such as faulting, folding, seismic activity may occur with such frequency to affect the ability of the site to meet the performance objectives. *[Note: Performance Objectives are those given at TDEC 0400-20-11-.16(1), (2), and (5).]*		TDEC 0400-20-11-.17(1)(i)
	Areas must be avoided where surface geologic processes such as mass wasting, erosion, slumping, landsliding or weathering may occur with such frequency and extent to affect the ability of the disposal site to meet performance objectives or preclude defensible modeling and prediction of long-term impacts. *[Note: Performance Objectives are those given at TDEC 0400-20-11-.16(1), (2), and (5).]*		TDEC 0400-20-11-.17(1)(j)
	The disposal site must not be located where nearby activities or facilities could impact the site's ability to meet performance objectives or mask environmental monitoring. *[Note: Performance Objectives are those given at TDEC 0400-20-11-.16(1), (2), and (5).]*		TDEC 0400-20-11-.17(1)(k)

Table G-5. Action-specific ARARs and TBC Guidance (Design Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative

Action	Requirements	Prerequisite	Citation
General Landfill Design			
Preparedness and prevention	Facilities must be designed, constructed, maintained, and operated to prevent any unplanned release of hazardous waste or hazardous waste constituents into the environment and minimize the possibility of fire or explosion. All facilities must be equipped with communication and fire suppression equipment and undertake additional measures as specified in 40 CFR 264.30 *et seq*.	Operation of a RCRA hazardous waste facility—**applicable**	40 CFR 264.30-264.37 TDEC 0400-12-01-.06(3)
Site design for a LLW disposal facility	Site design features must be directed toward long-term isolation and avoidance of the need for continuing active maintenance after site closure.	Design of a LLW disposal facility—**relevant and appropriate**	TDEC 0400-20-11-.17(2)(a)
	Disposal site design and operation must be compatible with the disposal site closure and stabilization plan and lead to disposal site closure that provides assurance that the performance objectives will be met. *[Note: Performance Objectives are those given at TDEC 0400-20-11-.16(1), (2), and (5).]*		TDEC 0400-20-11-.17(2)(b)
	Disposal site must be designed to complement and improve, where appropriate, the ability of the disposal site's natural characteristics to assure that the performance objectives will be met. *[Note: Performance Objectives are those given at TDEC 0400-20-11-.16(1), (2), and (5).]*		TDEC 0400-20-11-.17(2)(c)
	Covers must be designed to minimize to the extent practicable water infiltration, to direct percolating or surface water away from the disposed waste and to resist degradation by surface geologic processes and biotic activity.		TDEC 0400-20-11-.17(2)(d)
	Surface features must direct surface water drainage away from disposal units at velocities and gradients which will not result in erosion that will require ongoing active maintenance in the future.		TDEC 0400-20-11-.17(2)(e)
	Disposal site must be designed to minimize to the extent practicable the contact of water with waste during storage, the contact of standing water with waste during disposal and the contact of percolating or standing water with wastes after disposal.		TDEC 0400-20-11-.17(2)(f)
	A buffer zone of land must be maintained between any disposal unit and the disposal boundary and beneath the disposed waste. The buffer zone shall be of adequate dimensions to carry out environmental monitoring activities specified in paragraph (4) of this rule and take mitigative measures if needed.		TDEC 0400-20-11-.17(3)(h)

Table G-5. Action-specific ARARs and TBC Guidance (Design Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation
Landfill Liner System			
Liner design requirements for a TSCA landfill	Synthetic membrane liners shall be used when the hydrologic or geologic conditions at the landfill require such in order to achieve the permeability equivalent to the soils in paragraph (b)(1) of this section. Whenever a synthetic liner is used at a landfill site, special precautions shall be taken to insure that its integrity is maintained and that it is chemically compatible with PCBs. Adequate soil underlining and cover shall be provided to prevent excessive stress or rupture of the liner. The liner must have a minimum thickness of 30 mils.	Design of a TSCA chemical waste landfill—**applicable**	40 CFR 761.75(b)(2)
Liner and leachate collection design for a RCRA landfill	The owner or operator of a landfill unit on which construction commences after January 29, 1992 must install two or more liners and a leachate collection and removal system above and between such liners.	Design of a RCRA landfill—**applicable**	40 CFR 264.301(c) TDEC 0400-12-01-.06(14)(b)(3)
Liner system for RCRA landfill	(i) The liner system must include: A. A top liner, designed and constructed of materials (e.g., geomembrane) to prevent the migration of hazardous constituents into the liner during active life and the post closure period; and B. A composite bottom liner, consisting of at least two components. The upper component must be designed and constructed of materials (e.g., a geomembrane) to prevent the migration of hazardous constituents into this component during the active life and post-closure care period. The lower component must be designed and constructed of materials to minimize the migration of hazardous constituents if a breach in the upper component were to occur. The lower component must be constructed of at least 3 feet (91 cm) of compacted soil material with a hydraulic conductivity of no more than $1 \times 10{-7}$ cm/sec. (ii) Liners must comply with paragraphs (a)(1)(i), (ii), and (iii) of this section.		40 CFR 264.301(c)(1)

Table G-5. Action-specific ARARs and TBC Guidance (Design Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation
Liner for a RCRA landfill	A liner that is designed, constructed, and installed to prevent any migration of wastes out of the landfill to the adjacent subsurface soil or ground water or surface water at any time during the active life (including the closure period) of the landfill. The liner must be constructed of materials that prevent wastes from passing into the liner during the active life of the facility. The liner must be: (i) Constructed of materials that have appropriate chemical properties and sufficient strength and thickness to prevent failure due to pressure gradients, physical contact with the waste or leachate to which they are exposed, climatic conditions, or stress from installation or daily operation; (ii) Placed on a foundation or base capable of supporting the liner and resistance to the pressure gradients above and below the liner to prevent failure of the liner due to settlement, compression or uplift; and (iii) Installed to cover all surrounding earth likely to be in contact with waste or leachate.		40 CFR 264.301(a)(1) TDEC 0400-12-01-.06(14)(b)1(i)
Facility design, construction	Underlying the liners shall be a geologic buffer which shall have: (i) A maximum hydraulic conductivity of 1.0×10^{-5} cm/s and measures at least ten (10) feet from the bottom of the liner to the seasonal high water table of the uppermost unconfined aquifer or top of the formation of a confined aquifer, or (ii) Have a maximum hydraulic conductivity of 1.0×10^{-6} cm/s and measure not less than five (5) feet from the bottom of liner to the seasonal high water table of the uppermost unconfined aquifer or the top of the formation of a confined aquifer, or (iii) Other equivalent or superior protection as defined in subpart (ii) of this part.	Design and construction of a hazardous waste landfill—**relevant and appropriate**	TDEC 0400-11-01-.04(4)(a)(2)
Leachate collection and removal system	Must be designed, constructed, operated, and maintained to collect and remove leachate from the landfill during the active life and post closure period and ensure that the leachate depth over the liner does not exceed 30 cm. The leachate collection and removal system must comply with paragraphs (c)(3)(iii) and (iv) of this section.		40 CFR 264.301(c)(2) TDEC 0400-12-01-.06(14)(b)1(ii)
Leak detection system	The leachate collection and removal system between the liners, and immediately above the bottom composite liner in the case of multiple leachate collection and removal systems, is also a leak detection system. This leak detection system must be capable of detecting, collecting, and removing leaks of hazardous constituents at the earliest practicable time through all areas of the top liner likely to be exposed to waste or leachate during the active life and post-closure care period. The requirements for a leak detection system in this paragraph are satisfied by installation of a system that is, at a minimum: (i) Constructed with a bottom slope of one percent or more; (ii) Constructed of granular drainage materials with a hydraulic conductivity of		40 CFR 264.301(c)(3) TDEC 0400-12-01-.06(14)(b)3(iii)

Table G-5. Action-specific ARARs and TBC Guidance (Design Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation
	1×10^{-2} cm/sec or more and a thickness of 12 inches (30.5 cm) or more; or constructed of synthetic or geonet drainage materials with a transmissivity of 3×10^{-5} m2/sec or more; (iii) Constructed of materials that are chemically resistant to the waste managed in the landfill and the leachate expected to be generated, and of sufficient strength and thickness to prevent collapse under the pressures exerted by overlying wastes, waste cover materials, and equipment used at the landfill; (iv) Designed and operated to minimize clogging during the active life and post-closure care period; and (v) Constructed with sumps and liquid removal methods (e.g., pumps) of sufficient size to collect and remove liquids from the sump and prevent liquids from backing up into the drainage layer. Each unit must have its own sump(s). The design of each sump and removal system must provide a method for measuring and recording the volume of liquids present in sump and of liquids removed.		
Leak detection system action leakage rate	(a) The action leakage rate is the maximum design flow rate that the leak detection system (LDS) can remove without the fluid head on the bottom liner exceeding l foot. The action leakage rate must include an adequate safety margin to allow for uncertainties in the design (e.g., slope, hydraulic conductivity, thickness of drainage material), construction, operation, and location of the LDS, waste and leachate characteristics, likelihood and amounts of other sources of liquids in the LDS, and proposed response actions. (b) To determine if the action leakage rate has been exceeded, the owner or operator must convert the weekly or monthly flow rate from the monitoring data obtained under part 264.303(c) of this paragraph to an average daily flow rate (gallons per acre per day) for each sump.		40 CFR 264.302 TDEC 0400-12-01-.06(c)
	Storm Water Control for Landfill		
Run-on/runoff control systems	Run-on control system must be capable of preventing flow onto the active portion of the landfill during peak discharge from a 25-year storm event.	Design of a RCRA landfill—**applicable**	40 CFR 264.301(g) TDEC 0400-12-01-.06(14)(b)(7)
	Run-off management system must be able to collect and control the water volume from a runoff resulting from a 24-hour, 25-year storm event.		40 CFR 264.301(h) TDEC 0400-12-01-.06(14)(b)(8)
	If the landfill site is below the 100-year floodwater elevation, the operator shall provide surface water diversion dikes around the perimeter of the landfill site with a minimum height equal to two feet above the 100-year floodwater elevation. If the landfill site is above the 100-year floodwater elevation, the operators shall provide diversion structures capable of diverting all of the surface water runoff from a 24-hour, 25-year storm.	Design of a TSCA landfill—**applicable**	40 CFR 761.75(b)(4)(i) and (ii)

Table G-5. Action-specific ARARs and TBC Guidance (Design Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation
RCRA Tank System and Impoundment Designs			
Design of a RCRA Tank System	Must prepare an assessment attesting that the tank system design has sufficient structural integrity and is acceptable for the storing/treating of hazardous waste. The assessment must include the information specified in 40 CFR 264.192(a)(1)-(5) [TDEC 0400-12-01-.06(10)(c)(1)-(5)].	Storage of RCRA hazardous waste in a new tank system—**relevant and appropriate**	40 CFR 264.192(a) TDEC 0400-12-01-.06(10)(c)(1)
	Ancillary equipment (i.e., piping) must be supported and protected against physical damage and excessive stress due to settlement, vibration, expansion, or contraction.		40 CFR 264.192(e) TDEC 0400-12-01-.06(10)(c)(5)
	Must provide the degree of corrosion protection based upon the information in 40 CFR 264.192(a)(3) (TDEC 0400-12-01-.06[10][c][1][iii]) to ensure the integrity of the tank system during use. Installation of field fabricated corrosion protection system must be supervised by an independent corrosion expert.		40 CFR 264.192(f) TDEC 0400-12-01-.06(10)(c)(6)
	Must provide secondary containment in order to prevent release of hazardous waste or constituents into the environment.		40 CFR 264.193(a)(1) TDEC 0400-12-01-.06(10)(d)(1)
	Secondary containment systems must be: • Designed, installed, and operated to prevent any migration of wastes or accumulated liquid out of the system to the soil, ground water, or surface water at any time during the use of the tank system; and • Capable of detecting and collecting releases and accumulated liquids until the collected material is removed.		40 CFR 264.193(b) TDEC 0400-12-01-.06(10)(d)(2)

Table G-5. Action-specific ARARs and TBC Guidance (Design Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation
	Secondary containment systems must be at a minimum: • Constructed of or lined with materials that are compatible with the wastes(s) to be placed in the tank system and must have sufficient strength and thickness to prevent failure owing to pressure gradients (including static head and external hydrological forces), physical contact with the waste to which it is exposed, climatic conditions, and the stress of daily operation (including stresses from nearby vehicular traffic). • Placed on a foundation or base capable of providing support to the secondary containment system, resistance to pressure gradients above and below the system, and capable of preventing failure due to settlement, compression, or uplift; • Provided with a leak-detection system that is designed and operated so that it will detect the failure of either the primary or secondary containment structure or the presence of any release of hazardous waste or accumulated liquid in the secondary containment system within 24 hours, or at the earliest practicable time if the owner or operator can demonstrate to the Regional Administrator that existing detection technologies or site conditions will not allow detection of a release within 24 hours; and • Sloped or otherwise designed or operated to drain and remove liquids resulting from leaks, spills, or precipitation. Spilled or leaked waste and accumulated precipitation must be removed from the secondary containment system within 24 hours, or in as timely a manner as is possible to prevent harm to human health and the environment, if the owner or operator can demonstrate to the Regional Administrator that removal of the released waste or accumulated precipitation cannot be accomplished within 24 hours.		40 CFR 264.193(c) TDEC 0400-12-01-.06(10)(d)(3)
	Secondary containment for tanks must include one or more of the following devices: • a liner (external to the tank); • a vault; • a double-walled tank; or • an equivalent device as approved by the EPA.		40 CFR 264.193(d) TDEC 0400-12-01-.06(10)(d)(4)

Table G-5. Action-specific ARARs and TBC Guidance (Design Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation
	External liner systems must be: • designed and operated to contain 100 percent of the capacity of the largest tank within its boundary; • designed or operated to prevent run-on or infiltration of precipitation into the secondary containment system unless the collection system has sufficient excess capacity to contain run-on or infiltration. (Such additional capacity must be sufficient to contain precipitation from a 25 year, 24-hour rainfall event); • free of cracks or gaps; and • designed and installed to surround the tank completely and to cover all surrounding earth likely to come into contact with the waste if the waste is released from the tank(s) (i.e., capable of preventing lateral as well as vertical migration of the waste).		40 CFR 264.193(e)(1) TDEC 0400-12-01-.06(10)(d)(5)(i)
	Vault system must be: • designed or operated to contain 100 percent of the capacity of the largest tank within its boundary; • designed or operated to prevent run-on or infiltration of precipitation into the secondary containment system unless the collection system has sufficient excess capacity to contain run-on or infiltration. (Such additional capacity must be sufficient to contain precipitation from a 25 year, 24-hour rainfall event); • constructed of chemical-resistant water stops in all joints (if any); • provided with an impermeable interior coating or lining that is compatible with the stored waste and that will prevent migration of the waste into the concrete; • provided with a means to protect against formation of and ignition of vapors within the vault if the waste being stored or treated meets the definition of ignitable or reactive waste under 40 CFR 261.21 or 261.23; and • provided with an exterior moisture barrier or otherwise designed or operated to prevent migration of moisture into the vault if the vault is subject to hydraulic pressure.		40 CFR 264.193(e)(2) TDEC 0400-12-01-.06(10)(d)(5)(ii)
	Double-walled tanks must be: • designed as an integral structure (i.e., an inner tank completely enveloped within and outer shell) so that any release from the inner tank is contained by the outer shell; • protected, if constructed of metal, from both corrosion of the primary tank interior and of the external surface of the outer shell; and • provided with a built-in continuous leak detection system capable of detecting a release within 24 hours, or at the earliest practicable time.		40 CFR 264.193(e)(3) TDEC 0400-12-01-.06(10)(d)(5)(iii)

Table G-5. Action-specific ARARs and TBC Guidance (Design Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation
	Ancillary equipment must be provided with secondary containment (e.g., trench, jacketing, double-walled piping) that meets the requirements of 40 CFR 264.193(b) and (c) (TDEC 0400-12-01-.06[10][d][2] and [3]) except for: • aboveground piping (exclusive of flanges, joints, valves, and other connections) that are visually inspected for leaks on a daily basis; • welded flanges, welded joints and welded connections, that are visually inspected for leaks on a daily basis; • seamless or magnetic coupling pumps and seal-less valves, that are visually inspected for leaks on a daily basis; and • pressurized aboveground piping systems with automatic shut-off devices (e.g., excess flow check valves, flow metering shutdown devices, loss of pressure actuated shut-off devices) that are visually inspected for leaks on a daily basis.		40 CFR 264.193(f) TDEC 0400-12-01-.06(10)(d)(6)
Design and installation of a RCRA surface impoundment	Must install a liner system consisting of two or more liners and a leachate collection and removal system, constructed in accordance with 40 CFR 264.221(c)(1)-(4) (TDEC 0400-12-01-.06[11][b][3][i]-[iv]).	Storage of RCRA hazardous waste in a new surface impoundment**—relevant and appropriate**	40 CFR 264.221(c) TDEC 0400-12-01-.06(11)(b)(3)
	Must implement a leak detection system capable of detecting, collecting and removing leaks of hazardous constituents from all areas of the top liner during the active life and post-closure care period.		40 CFR 264.221(c)(2) TDEC 0400-12-01-.06(11)(b)(3)(ii)
	Must design, construct and maintain dikes with sufficient structural integrity to prevent massive failure.		40 CFR 264.221(h) TDEC 0400-12-01-.06(11)(b)(8)
	Alternative design practices to those in 40 CFR 264.221(c) (TDEC 0400-12-01-.06[11][b][3]) may be approved by the Regional Administrator.		40 CFR 264.221(d) TDEC 0400-12-01-.06(11)(b)(4)
Design and operation of a RCRA container storage area	Storage areas that store containers holding only wastes that do not contain free liquids need not have a containment system defined by paragraph (b) of this section, except as provided by paragraph (d) of this section or provided that: (1) Area must be sloped or otherwise designed and operated to drain liquid from precipitation, or (2) The containers must be elevated or otherwise protected from contact with accumulated liquid.	Storage of RCRA hazardous waste in containers that do not contain free liquids—**applicable**	40 CFR 264.175(c) TDEC 0400-12-01-.06(9)(f)(3)

Table G-5. Action-specific ARARs and TBC Guidance (Design Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation
	Area must have a containment system designed and operated in accordance with 40 CFR 264.175(b) as follows: • a base must underlie the containers which is free of cracks or gaps and is sufficiently impervious to contain leaks, spills and accumulated precipitation until the collected material is detected and removed; • base must be sloped or the containment system must be otherwise designed and operated to drain and remove liquids resulting from leaks, spills or precipitation, unless the containers are elevated or are otherwise protected from contact with accumulated liquids; • must have sufficient capacity to contain 10 percent of the volume of containers or volume of largest container, whichever is greater; • run-on into the system must be prevented unless the collection system has sufficient capacity to contain along with volume required for containers; and • spilled or leaked waste and accumulated precipitation must be removed from the sump or collection area in a timely manner as or necessary to prevent overflow.	Storage of RCRA hazardous waste with free liquids or F020, F021, F022, F023, F026 and F027 in containers—**applicable**	40 CFR 264.175(a), (b), and (d) TDEC 0400-12-01-.06(9)(f)

Table G-6. Action-specific ARARs and TBC Guidance (Construction Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative

Action	Requirements	Prerequisite	Citation
Pre-construction activities	Prior to excavation, all bore holes drilled or dug during subsurface investigation of the site, piezometers, and abandoned wells which are either in or within 100 feet of the areas to be filled must be backfilled with a bentonite slurry or other sealant approved by the Commissioner to an elevation at least ten feet greater than the elevation of the lowest point of the landfill base (including any liner), or to the ground surface if the site will be excavated less than ten feet below grade.	Construction of a solid waste disposal facility**—relevant and appropriate**	TDEC 0400-11-01-.04(2)(l)
Activities causing fugitive dust emissions	Shall take reasonable precautions to prevent particulate matter from becoming airborne. Reasonable precautions shall include, but are not limited to the following:	Use, construction, alteration, repair or demolition of a building, or appurtenances or a road or the handling, transport or storage of material**—applicable**	TDEC 1200-3-8-.01(1)
	Use, where possible, of water or chemicals for control of dust in demolition of existing buildings or structures, construction operations, grading of roads, or the clearing of land;		TDEC 1200-3-8-.01(1)(a)
	Application of asphalt, oil, water, or suitable chemicals on dirt roads, materials stock piles, and other surfaces which can create airborne dusts;		TDEC 1200-3-8-.01(1)(b)
	Shall not cause or allow fugitive dust to be emitted in such a manner to exceed 5 minute/hour or 20 minute/day beyond property boundary lines on which emission originates.		TDEC 1200-3-8-.01(2)
Activities causing stormwater runoff (e.g., clearing, grading, excavation)	Implement good construction management techniques (including sediment and erosion, vegetative controls, and structural controls) in accordance with the substantive requirements of General Permit No. TNR10-0000 and TNR05-0000, to ensure stormwater discharge is properly managed. • does not violate water quality criteria as stated in TDEC 0400-40-03-.03, including, but not limited to, prevention of discharges that cause a condition in which visible solids, bottom deposits, or turbidity impairs the usefulness of waters of the state for any designated uses for that water body by TDEC 0400-40-04; • does not contain distinctly visible floating scum, oil, or other matter; • does not cause an objectionable color contrast in the receiving stream; and • results in no materials in concentrations sufficient to be hazardous or otherwise detrimental to humans, livestock, wildlife, plant life, or fish and aquatic life in the receiving stream.	Stormwater discharges associated with construction activities at industrial sites - disturbance of ≥ 1 acre total**—relevant and appropriate**	TCA 69-3-108(1) Tennessee General Permit No. TNR10-0000 (effective May 24, 2011) **(TBC)** Tennessee General Permit No. TNR10-0000, Section 5.3.2 Tennessee General Permit No. TNR05-0000, Sector K **(TBC)**

Table G-6. Action-specific ARARs and TBC Guidance (Construction Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation
Construction quality assurance	During construction or installation, liners and cover systems must be inspected for uniformity, damage and imperfections (e.g., holes, cracks, thin spots, etc.). Immediately after construction or installation: (1) Synthetic liners and covers must be inspected to ensure tight seams and joints and the absence of tears, punctures, or blisters; and (2) Soil-based and admixed liners and covers must be inspected for imperfections including lenses, cracks, channels, root holes, or other structural non-uniformities that may cause an increase in the permeability of the liner or cover.	Construction of a RCRA landfill**—applicable**	40 CFR 264.303(a) TDEC 0400-12-01-.06(14)(d)(1)
Construction of new outfall structure for discharge of wastewater	Construction, maintenance, repair, rehabilitation or replacement of intake or outfall structures shall be carried out in such a way that work: • Does not violate water quality criteria as stated in TDEC 0400-40-03-.03 including but not limited to prevention of discharges that causes a condition in which visible solids, bottom deposits, or turbidity impairs the usefulness of waters of the state for any of the designated uses for that water body by TDEC 0400-40-04. • Activities in non-navigable streams shall be conducted in the dry; in navigable streams, where impracticable to work in the dry, work may be conducted within the water column. • Shall be located and oriented so as to avoid permanent alteration or damage to the integrity of the stream channel including the opposite stream bank. Alignment of the structure (except for diffusers) should be as parallel to the stream flow as is practicable, with the discharge pointed downstream. Diffusers may be placed perpendicular to stream flow for more complex mixing. • Intake and outfall structures shall be designed to minimize harm and prevent impoundment of normal or base flows. • Velocity dissipation devices shall be placed as needed at discharge locations to provide a non-erosive velocity from the structure. • Activity may not be conducted in a manner that would permanently disrupt the movement of fish and aquatic life. • Material may not be placed in a location or manner so as to impair surface water flow into or out of any wetland area. • Backfill activities must be accomplished in a manner that stabilizes the streambed and banks to prevent erosion. All contours must be returned to pre-project conditions to the extent practicable and completed activities may not disrupt or impound stream flow. • Stream beds must not be used as transportation routes for construction equipment; • Temporary stream crossings shall be limited to one point in the construction area	Construction of intake and outfall structures in waters of the state**—applicable**	TCA 69-3-108(l) TDEC 0400-40-07-.01 TDEC General Permit for Construction of Intake and Outfall Structures (effective July 1, 2010) (TBC)

Table G-6. Action-specific ARARs and TBC Guidance (Construction Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation
	and erosion control measures shall be utilized where stream banks are disturbed. Crossing shall be constructed so that stream flow is not obstructed. Following work, all materials used for temporary crossing must be removed and disturbed stream banks restored and stabilized. • Materials used in intake and outfall structures must be free of contaminants and wastes as defined by TCA 69-3-103(18). • Clearing, grubbing and other disturbances to riparian vegetation shall be kept to a minimum necessary for slope construction and equipment operations. Unnecessary tree removal is prohibited. • Sediment shall be prevented from entering waters of the state. Erosion and sediment control measures shall be properly selected, installed, and maintained and must be in place and functional before earth moving operations begin. • Litter, construction debris, and construction chemicals exposed to storm water shall be picked up prior to anticipated storm events or otherwise prevented from becoming a pollutant source during storms. • Excavated materials, removed vegetation, construction debris, and other wastes shall be removed to an upland location and properly stabilized or disposed of to prevent reentry into the waterway. • Take appropriate steps to ensure petroleum products or other chemical pollutants are prevented from entering waters of the state. In event of a spill, take immediate measures to prevent pollution of waters of the state.		
Pre-operation/operation of a RCRA tank system (tanks and piping)	Prior to use, must ensure that proper handling procedures are adhered to in order to prevent damage to the system during installation.		40 CFR 264.192(b) TDEC 0400-12-01-.06(10)(c)(2)
	Prior to use, must inspect the system for the presence of weld breaks, punctures, scrapes of protective coatings, cracks, corrosion, other structural damage, or inadequate construction/installation. All discrepancies must be remedied before the system is covered, enclosed or placed in use.		40 CFR 264.192(b)(1)-(6) TDEC 0400-12-01-.06(10)(c)(2)(i)-(vi)
	Prior to use, tanks and ancillary equipment must be tested for tightness. If a tank system is found not to be tight, all repairs necessary to remedy the leak(s) must be performed prior to the system being placed into use.		40 CFR 264.192(d) TDEC 0400-12-01-.06(10)(c)(4)

Table G-7. Action-specific ARARs and TBC Guidance (Operations Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative

Action	Requirements	Prerequisite	Citation
Emissions and Effluents			
Control of air emissions from an above-grade RCRA tank system	The requirements of 40 CFR 264 Subpart CC do not apply to a waste management unit that is used solely for on-site treatment or storage of hazardous waste that is generated as a result of implementing remedial activities required under CERCLA authorities.	Storage of RCRA hazardous waste in a new tank system—**relevant and appropriate**	40 CFR 264.1080(b)(5) TDEC 0400-12-01-.32(a)(2)(v)
Control of emissions from a WWTU treatment system	On-site remediation and treatment of contaminated water using air strippers is an exempted air contaminant source provided the emissions are no more than 5 tons per year of any regulated pollutant that is not a hazardous air pollutant and less than 1,000 pounds per year of each hazardous air pollutant.	Emissions of air pollutants from new air contaminant sources**—applicable**	TDEC 1200-03-09-.04(4)(d)(24)
Activities causing stormwater runoff (e.g., during operations)	Shall develop and implement storm water management controls to insure compliance with the terms and conditions of *General Permit No. TNR050000* ("Stormwater Multi-Sector General Permit for Industrial Activities") or any applicable site-specific permit and with TDEC 0400-40-10.03(2)(c).	Storm water discharges associated with industrial activity**—applicable**	TCA 69-3-108(l) General Permit No. TNR05-0000, Sector K (effective June 1, 2009) (**TBC** guidance)
	Shall develop and maintain a storm water pollution prevention/control plan prepared in accordance with good engineering practices and with the factors outlined in 40 CFR 125.3(d)(2) or (3) as appropriate and any additional requirements listed in Part XI for the particular sector of industrial activity. The plan shall identify potential sources of pollution that may reasonably be expected to affect the quality of storm water discharges associated with industrial activity.		General Permit No. TNR050000,Section 4
	Storm water pollution prevention plans shall include, at a minimum, the items identified in *General Permit No. TNR050000 Sector K.3*, including a description of potential pollution sources, storm water management measures and controls, preventive maintenance, spill prevention and response procedures, and sediment and erosion controls.	Storm water discharges associated with industrial activity at hazardous waste treatment, storage or disposal facilities**—TBC**	General Permit No. TNR050000 Sector K.3
	Shall monitor at least annually the identified storm water outfalls in accordance with the monitoring requirements specified in General Permit No. TNR050000 Sector K.5 and the parameters listed in Table K-1 of General Permit No. TNR050000 Sector K, as appropriate. Sampling waivers are available under the conditions specified in General Permit No. TNR050000 Sector K.5.1.3.		General Permit No. TNR050000 Sector K.5
Secondary Waste and Waste Acceptance Criteria Attainment			
Characterization of solid waste (e.g., contaminated PPE, equipment, spent filters)	Must determine if waste is hazardous waste or if waste is excluded under 40 CFR 261.4; and	Generation of solid waste as defined in 40 CFR 261.2, and which is not excluded under 40 CFR 261.4(a) **—applicable**	40 CFR 262.11(a) TDEC 0400-12-01-.03(1)(b)(1)

Table G-7. Action-specific ARARs and TBC Guidance (Operations Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative

Action	Requirements	Prerequisite	Citation
	Must determine if waste is listed under Subpart D of 40 CFR Part 261; or		40 CFR 262.11(b) TDEC 0400-12-01-.03(1)(b)(2)
	Must characterize waste by using prescribed testing methods or applying generator knowledge based on information regarding material or processes used.		40 CFR 262.11(c) TDEC 0400-12-01-.03(1)(b)(3)
Characterization of hazardous waste	If waste is determined to be hazardous, must refer to Parts 261, 262, 264, 266, 268, and 273 of Title 40 for possible exclusions or restrictions pertaining to management of the specific waste.	Generation of RCRA hazardous waste for storage, treatment or disposal—**applicable**	40 CFR 262.11(d) TDEC 0400-12-01-.03(1)(b)(4)
	Must obtain a detailed chemical and physical analysis of a representative sample of the waste(s) which at a minimum contains all the information which must be known to treat, store, or dispose of the waste in accordance with 40 CFR 264 and 268.		40 CFR 264.13(a)(1) TDEC 0400-12-01-.06(2)(d)(1)
	Must determine if the waste meets the treatment standards in 40 CFR 268.40, 268.45, or 268.49 by testing in accordance with prescribed methods or use of generator knowledge of waste.		40 CFR 268.7(a) TDEC 0400-12-01-.10(1)(g)(1)
	Must determine each EPA Hazardous Waste Number (Waste Code) to determine the applicable treatment standards under 40 CFR 268.40 et seq.		40 CFR 268.9(a) TDEC 0400-12-01-.10(1)(i)(1)
	Must determine the underlying hazardous constituents (as defined in 40 CFR 268.2[i]) in the waste.	Generation of RCRA characteristically hazardous waste (and is not D001 non-wastewaters treated by CMBST, RORGS, or POLYM of Section 268.42 Table 1) for storage, treatment or disposal—**applicable**	40 CFR 268.9(a); TDEC 0400-12-01-.10(1)(i)(1)
Management of hazardous waste on site	A generator who treats, stores, or disposes of hazardous waste on-site must comply with the applicable [substantive] standards and requirements set forth in 40 CFR parts 264, 265, 266, 268, and 270.	Generation of RCRA hazardous waste for storage, treatment or disposal on-site—**applicable** if secondary wastes are determined to be hazardous	40 CFR 262.10, Note 2 TDEC 0400-12-01-.03(1)(a)(3)
Temporary storage of hazardous waste in containers on-site – "Satellite Accumulation Area"	A generator may accumulate as much as 55 gal. of hazardous waste at or near any point of generation where wastes initially accumulate which is under the control of the operator of the process generating the waste provided that he: • complies with 40 CFR 265.171, 265.172 and 265.173(a); and	Accumulation of 55 gal. or less of RCRA hazardous waste at or near any point of generation—**applicable**	40 CFR 262.34(c)(1)(i) TDEC 0400-12-01-.03(4)(e)(5)(i)(I)

Table G-7. Action-specific ARARs and TBC Guidance (Operations Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative

Action	Requirements	Prerequisite	Citation
	• container is be marked with the words "Hazardous Waste" or with other words that identify contents.		40 CFR 262.34(c)(1)(ii) TDEC 0400-12-01-.03(4)(e)(5)(i)(II)
Temporary storage of hazardous waste in containers on-site – "90-Day Storage Area"	A generator may accumulate hazardous waste at the facility provided that: • the waste is placed in containers that comply with Subparts I, AA, BB, and CC of 40 CFR 265; and	Accumulation of RCRA hazardous waste on-site as defined in 40 CFR 260.10—**applicable**	40 CFR 262.34(a)(1)(i) TDEC 0400-12-01-.03(4)(e)(2)(i)(I)
	• container is marked with the date upon which each period of accumulation begins and is visible for inspection; and		40 CFR 262.34(a)(2) TDEC 0400-12-01-.03(4)(e)(2)(ii)
	• container is marked with the words "Hazardous Waste"		40 CFR 262.34(a)(3) TDEC 0400-12-01-.03(4)(e)(2)(iii)
Use and management of hazardous waste in containers	If container is not in good condition (e.g., severe rusting, structural defects) or if it begins to leak, must transfer waste into container in good condition.	Storage of RCRA hazardous waste in containers—**applicable**	40 CFR 264.171 TDEC 0400-12-01-.06(9)(b)
	Use container made or lined with materials compatible with waste to be stored so that the ability of the container is not impaired.		40 CFR 264.172 TDEC 0400-12-01-.06(9)(c)
	Container holding hazardous waste must always be kept closed during storage, except to add/remove waste.		40 CFR 264.173(a) TDEC 0400-12-01-.06(9)(d)
	Container holding hazardous waste must not be opened, handled, or stored in a manner which may rupture the container or cause it to leak.		40 CFR 264.173(b) TDEC 0400-12-01-.06(9)(d)
Operation of a RCRA container area	Area must be sloped or otherwise designed and operated to drain liquid from precipitation, or containers must be elevated or otherwise protected from contact with accumulated liquid.	Storage in containers of RCRA hazardous waste that do not contain free liquids—**applicable**	40 CFR 264.175(c) TDEC 0400-12-01-.06(9)(f)(3)
Storage of RCRA hazardous waste with free liquids in containers	Area must have a containment system designed and operated in accordance with 40 CFR 264.175(b) as follows:	Storage of RCRA hazardous waste with free liquids or storage of waste codes F020, F021, F022, F023, F026 and F027 that do not contain free liquids in containers—**applicable**	40 CFR 264.175(a) and (d) TDEC 0400-12-01-.06(9)(f)(1) – (2)
	• a base must underlie the containers which is free of cracks or gaps and is sufficiently impervious to contain leaks, spills and accumulated precipitation until the collected material is detected and removed;		40 CFR 264.175(b)(1) TDEC 0400-12-01-.06(9)(f)(2)(i)
	• base must be sloped or the containment system must be otherwise designed and operated to drain and remove liquids resulting from leaks, spills or precipitation, unless the containers are elevated or are otherwise protected from contact with		40 CFR 264.175(b)(2) TDEC 0400-12-01-.06(9)(f)(2)(ii)

Table G-7. Action-specific ARARs and TBC Guidance (Operations Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative

Action	Requirements	Prerequisite	Citation
	accumulated liquids;		
	• must have sufficient capacity to contain 10 percent of the volume of containers or volume of largest container, whichever is greater;		40 CFR 264.175(b)(3) TDEC 0400-12-01-.06(9)(f)(2)(iii)
	• run-on into the system must be prevented unless the collection system has sufficient capacity to contain any run-on which might enter the system, along with the volume required for containers as listed immediately above; and		40 CFR 264.175(b)(4) TDEC 0400-12-01-.06(9)(f)(2)(iv)
	• spilled or leaked waste and accumulated precipitation must be removed from the sump or collection area in as timely a manner as is necessary to prevent overflow of the collection system.		40 CFR 264.175(b)(5) TDEC 0400-12-01-.06(9)(f)(2)(v)
Characterization and management of universal waste	A large quantity handler of universal waste must manage universal waste in accordance with [substantive requirements of] 40 CFR 273 in a way that prevents releases of any universal waste or component of a universal waste to the environment.	Generation of universal waste [as defined in 40 CFR 273] for disposal—**applicable**	40 CFR 273 TDEC 0400-12-01-.12
	Must label or mark the universal waste to identify the type of universal waste.		40 CFR 273.34 TDEC 0400-12-01-.12(3)(e)
	A large quantity handler of universal waste must immediately contain all releases of universal wastes and other residues from universal wastes, and must determine whether any material resulting from the release is hazardous waste, and if so, must manage the hazardous waste in compliance with all applicable requirements.		40 CFR 273.37 TDEC 0400-12-01-.12(3)(h)
Disposal of universal waste	The generator of the universal waste must determine whether the waste exhibits a characteristic of hazardous waste. If it is determined to exhibit such a characteristic, it must be managed in accordance with 40 CFR 260 through 272 [TDEC 0400-1-11-.01 through .10]. If the waste is not hazardous, the generator may manage and dispose of it in any way that is in compliance with applicable federal, state, and local solid waste regulations.	Generation of universal waste [as defined in 40 CFR 273] for disposal—**applicable**	40 CFR 273.33 TDEC 0400-12-01-.12(3)(d)
Operation of a Subtitle D solid waste landfill	A facility must be operated and maintained in a manner to minimize litter. Fencing, diking and/or other practices shall be provided as necessary to confine solid wastes subject to dispersal. All litter must be collected for disposal in a timely manner.	Operation of a Subtitle D solid waste landfill—**relevant and appropriate**	TDEC 0400-11-01-.04(2)(d)
	There must be maintained on-site operating equipment capable of spreading and properly compacting the volume of solid wastes received, and capable of handling the earthwork required. Back-up equipment must be available within 24 hours of primary equipment breakdown.		TDEC 0400-11-01-.04(2)(g)
	Cover material sufficient to meet the initial and intermediate cover requirements of this rule must be available at the facility. If such material must be hauled in from off-		TDEC 0400-11-01-.04(2)(h)

Table G-7. Action-specific ARARs and TBC Guidance (Operations Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative

Action	Requirements	Prerequisite	Citation
	site, at least a 30-day supply shall be maintained on site at all times. [*Note: Off-site, as referred to here, is assumed to mean off of the ORR.*]		
	Collection and holding facilities associated with run-on and run-off control systems must be emptied or otherwise managed expeditiously after storms to maintain design capacity of the system. Run-on and run-off must be managed separately from leachate. Other control measures (e.g. temporary mulching or seeding, silt barriers) must be taken as necessary to control erosion of the site.		TDEC 0400-11-01.04(2)(i)
	The operator must take dust control measures as necessary to prevent dust from creating a nuisance or safety hazard to adjacent landowners or to persons engaged in supervising, operating, and using the site. The use of any dust suppressants (other than water) must be approved prior to use.		TDEC 0400-11-01.04(2)(j)
	There must be installed on-site a permanent benchmark (e.g., concrete marker) of known elevation.		TDEC 0400-11-01.04(2)(o)
Waste handling activities at a solid waste landfill	Solid waste disposal activities shall be confined to the smallest practicable area. Compaction will be performed as necessary to ensure a stable fill..	Land disposal of solid waste—**relevant and appropriate**	TDEC 0400-11-01-.04(6)(b)(1)
	Emplaced solid wastes shall be covered with soil or other material of such depths and at such intervals as is necessary to prevent fire hazards, promote a stable fill, minimize potential harmful releases of solid wastes or solid waste constituents.		TDEC 0400-11-01-.04(6)(b)(2)
Management and storage of used oil	Used oil generators shall not store used oil in units other than tanks, containers, or units subject to regulation under parts 264 or 265 of this chapter.	Generation and storage of used oil, (as defined in 40 CFR 279.1) and possible release**—applicable**	40 CFR 279.22(a) TDEC 0400-12-01-.11(3)(c)(1)
	Containers and aboveground tanks used to store used oil at generator facilities must be in good condition (no severe rusting, apparent structural defects or deterioration); and not leaking (no visible leaks).		40 CFR 279.22(b)(1) and (2) TDEC 0400-12-01-.11(3)(c)(2)(i) and (ii)
	Containers and aboveground tanks used to store used oil at generator facilities must be labeled or marked clearly with the words “Used Oil.”		40 CFR 279.22(c)(1) and (2) TDEC 0400-12-01-.11(3)(c)(3)(i) and (ii)

Table G-7. Action-specific ARARs and TBC Guidance (Operations Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative

Action	Requirements	Prerequisite	Citation
	Upon detection of a release of used oil to the environment, a generator must stop the release; contain, clean up, and properly manage the released used oil; and, if necessary, repair or replace any leaking used oil storage containers or tanks prior to returning them to service.		40 CFR 279.22(d) TDEC 0400-12-01-.11(3)(c)(4)
Management of PCB waste (e.g., contaminated PPE, equipment, wastewater)	Any person storing or disposing of PCB waste must do so in accordance with 40 CFR 761, Subpart D	Generation of waste containing PCBs at concentrations ≥ 50 ppm—**applicable**	40 CFR 761.50(a)
	Any person cleaning up and disposing of PCBs shall do so based on the concentration at which the PCBs are found.	Generation of PCB remediation waste as defined in 40 CFR 761.3—**applicable**	40 CFR 761.61
Temporary storage of PCB waste (e.g., PPE, rags) in a container(s)	Storage area must be clearly marked as required by 40 CFR 761.40(a)(10). Any leaking PCB items and their contents shall be transferred immediately to a properly marked non-leaking container(s). Container(s) shall be in accordance with requirements set forth in DOT HMR at 49 *CFR* 171-180.	Storage of PCBs and PCB items at concentration ≥ 50 ppm for disposal—**applicable**	40 CFR 761.65(c)(3) 40 CFR 761.65(c)(5) 40 CFR 761.65(c)(6)
Disposal of containers of TSCA PCB wastes	Container(s) shall be marked as illustrated in 40 *CFR* 761.45(a).	Disposal of PCBs or PCB items in chemical waste landfill—**applicable**	40 CFR 761.40(a)(1)
Disposal of PCB cleaning solvents, abrasives, and equipment	May be reused after decontamination in accordance with 761.79.	Generation of PCB wastes from the cleanup of PCB remediation wastes—**applicable**	40 *CFR* 761.61(a)(5)(v)(B)
Risk-based disposal of PCB remediation waste or bulk product waste	May dispose of in a manner other than prescribed in 40 CFR 761.61(a) or (b) if approved in writing by EPA and method will not pose an unreasonable risk of injury to health or the environment.	Disposal of PCB remediation waste—**applicable**	40 CFR 761.61(c) 40 CFR 761.62(c)
Performance-based disposal of PCB remediation waste	Shall be disposed according to 40 CFR 761.60(a) or (e), or decontaminate in accordance with 40 CFR 761.79.	Disposal of liquid PCB remediation waste—**applicable**	40 CFR 761.61(b)(1)
	May dispose by one of the following methods: • in a high-temperature incinerator approved under 40 CFR 761.70(b); • by an alternate disposal method approved under 40 CFR 761.60(e); • in a chemical waste landfill approved under 40 CFR 761.75;	Disposal of nonliquid PCB remediation waste (as defined in 40 CFR 761.3)—**applicable**	40 CFR 761.61(b)(2) 40 CFR 761.61(b)(2)(i)

Table G-7. Action-specific ARARs and TBC Guidance (Operations Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative

Action	Requirements	Prerequisite	Citation
	• in a facility with a coordinated approval issued under 40 CFR 761.77; or		
	• through decontamination in accordance with 40 CFR 761.79.		40 CFR 761.61(b)(2)(ii)
Performance-based disposal of PCB bulk product waste	PCB bulk product waste may disposed of by one of the following: • in a chemical waste landfill approved under Section 761.75; • in a hazardous waste landfill permitted by EPA under §3004 of RCRA or by authorized state under §3006 of RCRA;	Disposal of PCB bulk product waste as defined in 40 CFR 761.3—**applicable**	40 CFR 761.62(a)(2) and (3)
Disposal of PCB decontamination waste and residues	Such waste shall be disposed of at their existing PCB concentration unless otherwise specified in 40 CFR 761.79(g)(1-6).	Generation of PCB decontamination waste and residues—**applicable**	40 CFR 761.79(g)
Disposal of decontaminated PCB wastes as non-TSCA wastes	Materials from which PCBs have been removed in accordance with the standards under 40 CFR 761.79(b) or to an alternate risk-based decontamination standard approved by EPA under 40 CFR 761.79(h)(5) are considered unregulated for disposal under Subpart D of TSCA.	Generation of PCB wastes, including water, organic liquids—**applicable**	40 CFR 761.79(a)(4)
Disposal of TSCA PCB wastes	PCBs and PCB items shall be placed in a manner that will prevent damage to containers or articles.	Disposal of PCBs or PCB items in chemical waste landfill—**applicable**	40 CFR 761.75(b)(8)(i)
Disposal of TSCA PCB wastes (e.g., from drained electrical equipment)	Bulk liquids not exceeding 500 ppm PCBs may be disposed of provided such waste is pretreated and/or stabilized (e.g., chemically fixed, evaporated, mixed with dry inert absorbent) to reduce its liquid content or increase its solid content so that a non-flowing consistency is achieved to eliminate the presence of free liquids prior to final disposal. PCB Container of liquid PCBs with a concentration between 50 and 500 ppm PCB may be disposed of if each container is surrounded by an amount of inert sorbent material capable of absorbing all of the liquid contents of the container.	Disposal of PCB container with liquid PCB between 50 ppm and 500 ppm into a TSCA chemical waste landfill—**applicable**	40 CFR 761.75(b)(8)(ii)
Placement of untreated waste in a land disposal facility	This part identifies hazardous wastes that are restricted from land disposal and defines those limited circumstances under which an otherwise prohibited waste may continue to be land disposed.	Treatment of characteristic hazardous waste—**applicable**	40 CFR 268.1 (a)
Disposal of RCRA hazardous waste in a land-based unit	May be land disposed only if it meets the requirements in the table "Treatment Standards for Hazardous Waste" at 40 CFR 268.40 before land disposal. The table lists either "total waste" standards, "waste-extract" standards, or "technology-specific" standards (as detailed further in 40 CFR 268.42).	Land disposal, as defined in 40 CFR 268.2, of RCRA restricted waste—**applicable**	40 CFR 268.40(a) TDEC 0400-12-01-.10(3)(a)

Table G-7. Action-specific ARARs and TBC Guidance (Operations Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative

Action	Requirements	Prerequisite	Citation
	For characteristic wastes (D001 – D043) that are subject to the treatment standards, all underlying hazardous constituents must meet the UTSs specified in 40 CFR 268.48.	Land disposal of restricted RCRA characteristic wastes (D001-D043) that are not managed in a wastewater treatment unit that is regulated under the CWA, that is CWA equivalent, or that is injected into a Class I nonhazardous injection well**—applicable**	40 CFR 268.40(e) TDEC 0400-12-01-.10(3)(a)(5)
	Are not prohibited if the wastes no longer exhibit a characteristic at the point of land disposal, unless the wastes are subject to a specified method of treatment other than DEACT in 40 CFR 628.40, or are D003 reactive cyanide.	Land disposal of RCRA-restricted characteristic wastes—**applicable**	40 CFR 268.1(c)(4)(iv) TDEC 0400-12-01-.10(1)(a)(3)(iv)
	Prior to land disposal, soil contaminated with hazardous waste must be treated to meet the applicable alternative treatment standards of 40 CFR 268.49(c) or according to the applicable Universal Treatment Standards in 40 CFR 268.48 applicable to the listed hazardous waste and/or applicable characteristic of hazardous waste if the soil is characteristic.	Land disposal, as defined in 40 CFR 268.2, of RCRA-restricted hazardous soils **—applicable**	40 CFR 268.49(b) TDEC 0400-12-01-.10(3)(j)(2)
Variance from a treatment standard for RCRA restricted hazardous wastes	A variance from a treatment standard may be approved if it is: • not physically possible to treat the waste to the level specified in the treatment standard, or by the method specified as the standard; or • inappropriate to require the waste to be treated to the level specified in the treatment standard or by the method specified as the treatment standard even though such treatment is technically possible.	Generation of a RCRA hazardous waste requiring treatment prior to land disposal—**applicable**	40 CFR 268.44 TDEC 0400-12-01-.10(3)(e)

Table G-7. Action-specific ARARs and TBC Guidance (Operations Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative

Action	Requirements	Prerequisite	Citation
Treatment and disposal of hazardous debris in a land disposal unit	(a) *Treatment standards.* Hazardous debris must be treated prior to land disposal as follows unless EPA determines under §261.3(f)(2) of this chapter that the debris is no longer contaminated with hazardous waste or the debris is treated to the waste-specific treatment standard in this subpart for the waste contaminating the debris: (1) *General.* Hazardous debris must be treated for each "contaminant subject to treatment" defined by paragraph (b) of this section using the technology or technologies identified in Table 1 of this section. (2) *Characteristic debris.* Hazardous debris that exhibits the characteristic of ignitability, corrosivity, or reactivity identified under §261.21, 261.22, and 261.23 of this chapter, respectively, must be deactivated by treatment using one of the technologies identified in Table 1 of this section. (3) *Mixtures of debris types.* The treatment standards of Table 1 in this section must be achieved for each type of debris contained in a mixture of debris types. If an immobilization technology is used in a treatment train, it must be the last treatment technology used. (4) *Mixtures of contaminant types.* Debris that is contaminated with two or more contaminants subject to treatment identified under paragraph (b) of this section must be treated for each contaminant using one or more treatment technologies identified in Table 1 of this section. If an immobilization technology is used in a treatment train, it must be the last treatment technology used. (5) *Waste PCBs.* Hazardous debris that is also a waste PCB under 40 CFR part 761 is subject to the requirements of either 40 CFR part 761 or the requirements of this section, whichever are more stringent.	Treatment of characteristic hazardous debris—**applicable**	40 CFR 268.45(a)
	(b) *Contaminants subject to treatment.* Hazardous debris must be treated for each "contaminant subject to treatment." The contaminants subject to treatment must be determined as follows: (1) *Toxicity characteristic debris.* The contaminants subject to treatment for debris that exhibits the Toxicity Characteristic (TC) by §261.24 of this chapter are those EP constituents for which the debris exhibits the TC toxicity characteristic.		40 CFR 268.45(b)(1)
	(c) *Conditioned exclusion of treated debris.* Hazardous debris that has been treated using one of the specified extraction or destruction technologies in Table 1 of this section and that does not exhibit a characteristic of hazardous waste identified under subpart C, part 261, of this chapter after treatment is not a hazardous waste and need not be managed in a subtitle C facility. Hazardous debris contaminated with a listed waste that is treated by an immobilization technology specified in		40 CFR 268.45(c)

Table G-7. Action-specific ARARs and TBC Guidance (Operations Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative

Action	Requirements	Prerequisite	Citation
	Table 1 is a hazardous waste and must be managed in a subtitle C facility.		
Disposal requirements for particular RCRA waste forms and types	Except as provided in paragraph (b) of this section, and in §264.316, ignitable or reactive RCRA waste must not be placed in a landfill unless the waste and the landfill meet all applicable provisions of 40 CFR Part 268; and (1) the resulting waste, mixture or dissolution of material no longer meets the definition of ignitable or reactive waste under §261.21 or §261.23 of this chapter; and (2) 40 CFR 264.17(b) is complied with.	Disposal of ignitable or reactive RCRA waste—**applicable**	40 CFR 264.312(a) TDEC 0400-12-01-.06(14)(m)(1)
	Must not be placed into a cell unless 40 CFR 264.17(b) is compiled with (see below).	Disposal of incompatible wastes in a RCRA landfill—**applicable**	40 CFR 264.313 TDEC 1200-1-11-.06(14)(n)
Treatment and disposal of ignitable, reactive, or incompatible RCRA wastes	Must take precautions to prevent reactions which: • generate extreme heat, pressure, fire or explosion, or produce uncontrolled fumes or gases which pose a risk of fire or explosion;	Operation of a RCRA facility that treats, stores, or disposes of ignitable, reactive, or incompatible wastes—**applicable**	40 CFR 264.17(b) TDEC 1200-1-11-.06(2)(h)(2)
	• produce uncontrolled toxic fumes or gases which threaten human health or the environment;		
	• damage the structural integrity of the device or facility		
Disposal of bulk or containerized liquids in a RCRA landfill	May not dispose of bulk or non-containerized liquid hazardous waste or hazardous waste containing free liquids (whether or not sorbents have been added) in any landfill.	Placement of bulk or non-containerized RCRA hazardous waste—**applicable**	40 CFR 264.314(a) TDEC 0400-12-01-.06(14)(o)(1)
Disposal of containers in RCRA landfill	May not place containers holding free liquid in a landfill unless the liquid is mixed with an absorbent, solidified, removed, or otherwise eliminated.	Placement of containers containing RCRA hazardous waste in a landfill—**applicable**	40 CFR 264.314(c) TDEC 0400-12-01-.06(14)(o)(3)
	Sorbents used to treat free liquids to be disposed of in landfills must be non-biodegradable as described in 264.314(d)(1).		40 CFR 264.314(d) TDEC 0400-12-01-.06(14)(o)(5)
	Unless they are very small, containers must be either at least 90% full when placed in the landfill, or crushed, shredded, or similarly reduced in volume to the maximum practical extent before burial in the landfill.		40 CFR 264.315 TDEC 0400-12-01-.06(14)(p)
Construction and operation of a volume reduction facility (miscellaneous treatment facility)	Follow design and operating standards that ensure protection of human health and the environment for units in which hazardous waste is treated.	Processes involving treatment of RCRA hazardous waste in a miscellaneous unit as defined in 40 CFR 260.10—**applicable** to volume reduction facility	40 CFR 264.601 TDEC 0400-12-01-.06(27)(b)
	Prevent any releases that may have adverse effects on human health or the environment due to migration of waste constituents, specifically preventing adverse effects in: • the ground water or subsurface environment • surface water, or wetlands, or the soil surface; • the air		40 CFR 264.601(a) through (c) TDEC 0400-12-01-.06(27)(b)(1) through (3)

Table G-7. Action-specific ARARs and TBC Guidance (Operations Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative

Action	Requirements	Prerequisite	Citation
	A miscellaneous unit that is a disposal unit must be maintained in a manner that complies with §264.601 during the post-closure care period. In addition, if a treatment or storage unit has contaminated soils or ground water that cannot be completely removed or decontaminated during closure, then that unit must also meet the requirements of §264.601 during post-closure care. The post-closure plan under §264.118 must specify the procedures that will be used to satisfy this requirement.		40 CFR 264.603 TDEC 0400-12-01-.06(27)(d)
Characterization of LLW (e.g., wastewater, contaminated PPE)	Shall be characterized using direct or indirect methods and the characterization documented in sufficient detail to ensure safe management and compliance with the WAC of the receiving facility.	Generation of LLW for storage and disposal at a DOE facility—**TBC**	DOE M 435.1-1(IV)(I)*
	Characterization data shall, at a minimum, include the following information relevant to the management of the waste: • physical and chemical characteristics; • volume, including the waste and any stabilization or absorbent media; • weight of the container and contents; • identities, activities, and concentrations of major radionuclides; • characterization date; • generating source.		DOE M 435.1-1(IV)(I)(2)*
Packaging of LLW for disposal	Must not be packaged for disposal in cardboard or fiberboard boxes.	Generation of LLW for disposal at a LLW disposal facility—**relevant and appropriate**	TDEC 0400-20-11-.17(7)(a)(1)
	Must be solidified or packaged in sufficient absorbent material to absorb twice the volume of liquid.	Generation of liquid LLW for disposal at a LLW disposal facility—**relevant and appropriate**	TDEC 0400-20-11-.17(7)(a)(2)
	Shall contain as little free standing and noncorrosive liquid as is reasonably achievable, but in no case shall the liquid exceed 1 percent of the volume.	Generation of solid LLW containing liquid for disposal at a LLW disposal facility—**relevant and appropriate**	TDEC 0400-20-11-.17(7)(a)(3)
	Must not be capable of detonation or of explosive decomposition or reaction at normal pressures and temperatures or of explosive reaction with water.	Generation of LLW for disposal at a LLW disposal facility—**relevant and appropriate**	TDEC 0400-20-11-.17(7)(a)(4)
	Must not contain, or be capable of, generating quantities of toxic gases, vapor, or fumes.		TDEC 0400-20-11-.17(7)(a)(5)
	Must not be pyrophoric.		TDEC 0400-20-11-.17(7)(a)(6)
	Must have structural stability either by processing the waste or placing the waste in a		TDEC 0400-20-11-.17(7)(b)(1)

Table G-7. Action-specific ARARs and TBC Guidance (Operations Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative

Action	Requirements	Prerequisite	Citation
	container or structure that provides stability after disposal.		
	Must be converted into a form that contains as little free standing and noncorrosive liquid as is reasonably achievable, but in no case shall the liquid exceed 1 percent of the volume of the waste when the waste is in a disposal container designed to ensure stability, or 0.5 percent of the volume of the waste for waste processed to a stable form.	Generation of liquid LLW or LLW containing liquids for disposal at a LLW disposal facility—**relevant and appropriate**	TDEC 0400-20-11-.17(7)(b)(2)
	Void spaces within the waste and between the waste and its package must be reduced to the extent practicable.	Generation of LLW for disposal at a LLW disposal facility—**relevant and appropriate**	TDEC 0400-20-11-.17(7)(b)(3)
Temporary storage of LLW	Shall not be readily capable of detonation, explosive decomposition, reaction at anticipated pressures and temperatures, or explosive reaction with water.	Management of LLW at a DOE facility—**TBC**	DOE M 435.1-1(IV)(N)(1)*
	Shall be stored in a location and manner that protects the integrity of waste for the expected time of storage and minimizes worker exposure.		DOE M 435.1-1(IV)(N)(3)*
	Shall be managed to identify and segregate LLW from mixed waste.		DOE M 435.1-1(IV)(N)(6)*
	Shall be packaged in a manner that provides containment and protection for the duration of the anticipated storage period and until disposal is achieved or until the waste has been removed from the container.	Storage of LLW in containers at a DOE facility—**TBC**	DOE M 435.1-1(IV)(L)(1)(a)*
	Vents or other measures shall be provided if the potential exists for pressurizing or generating flammable or explosive concentrations of gases within the waste container.		DOE M 435.1-1(IV)(L)(1)(b)*
	Containers shall be marked such that their contents can be identified.		DOE M 435.1-1(IV)(L)(1)(c)*
Treatment of LLW	Treatment to provide more stable waste forms and to improve the long-term performance of a LLW disposal facility shall be implemented as necessary.	Generation for disposal of LLW at a DOE facility—**TBC**	DOE M 435.1-1(IV)(O)*
Disposal of LLW at an off-site disposal facility or in the EMWMF	LLW shall be certified as meeting waste acceptance requirements before it is transferred to the receiving facility.		DOE M 435.1-1(IV)(J)(2)*
	Transportation		
Transportation of hazardous waste on-site	The generator manifesting requirements of 40 CFR 262.20-262.32(b) do not apply. Generator or transporter must comply with the requirements set forth in 40 CFR 263.30 and 263.31 in the event of a discharge of hazardous waste on a private or public right-of-way.	Transportation of hazardous wastes on a public or private right-of-way within or along the border of contiguous property under the control of the same person, even if such contiguous property is divided by a public or private right-of-	40 CFR 262.20(f) TDEC 0400-12-01-.03(3)(a)(6)

Table G-7. Action-specific ARARs and TBC Guidance (Operations Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative

Action	Requirements	Prerequisite	Citation
		way—**applicable**	
Transportation of universal waste off-site	Off-site shipments of universal waste by a large quantity handler of universal waste shall be made in accordance with 40 CFR 273-38 (TDEC 0400-1-11-.12[3][i]).	Preparation of off-site shipments of universal waste by a large quantity generator of universal waste—**applicable**	40 CFR 273.38 TDEC 0400-1-11-.12(3)(i)
Transportation of used oil off-site	Except as provided in paragraphs (a) to (c) of this rule, generators must ensure that their used oil is transported by transporters who have obtained U.S. EPA ID numbers.	Preparation of off-site shipment of used oil by generators of used oil—**applicable**	40 CFR 279.24 TDEC 0400-1-11-.11(3)(e)
Transportation of LLW off-site	LLW waste shall be packaged and transported in accordance with DOE O 1460.1A and DOE O 460.2.	Preparation of off-site shipment of LLW—**TBC**	DOE M 435.1-1(I)(1)(E)(11)*
	To the extent practicable, the volume of waste and number of shipments shall be minimized.		DOE M 435.1-1(IV)(L)(2)*
	General Operations		
Incompatible wastes	Incompatible wastes must not be placed in the same landfill cell unless 40 CFR 264.17(b) is complied with.	Disposal of incompatible wastes in a RCRA landfill—**applicable**	40 CFR 264.313 TDEC 0400-12-01-.06(14)(n)
Waste placement	Wastes must be emplaced in a manner that maintain the package integrity during emplacement, minimizes the void spaces between packages and permit the void spaces to be filled.	Disposal of LLW on land—**relevant and appropriate**	TDEC 0400-20-11-.17(3)(d)
	Void spaces between packages must be filled with earth or other material to reduce future subsidence within the disposal unit.		TDEC 0400-20-11-.17(3)(e)
	Closure and stabilization measures as set forth in the closure plan must be carried out as each disposal unit is filled and covered.		TDEC 0400-20-11-.17(3)(i)
	Active waste disposal operations must not have an adverse effect on completed closure and stabilization measures.		TDEC 0400-20-11-.17(3)(j)
Security system	Must prevent the unknowing entry and minimize the possibility for unauthorized entry of persons or livestock onto active portion of the facility or comply with provisions of 40 CFR 264.14(b) and (c).	Operation of a RCRA landfill—**applicable**	40 CFR 264.14 TDEC 0400-12-01-.06(2)(e)

Table G-7. Action-specific ARARs and TBC Guidance (Operations Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative

Action	Requirements	Prerequisite	Citation
	Unless a natural barrier adequately deters access by the general public, either warning signs and fencing must be installed and maintained as follows, or the requirements of paragraph (c)(1) of this section must be met. (1) Warning signs must be displayed at all entrances and at intervals of 100 m (330 ft) or less along the property line of site or along the perimeter of the sections of site where asbestos-containing waste material is deposited. The warning signs must: (i) Be posted in such a manner and location that a person can easily read the legend; and (ii) Conform to the requirements of 51 cm × 36 cm (20″×14″) upright format signs specified in 29 CFR 1910.145(d)(4) and this paragraph; and (iii) Display the legend, as listed in 40 CFR 61.154(b)(1)(iii), in the lower panel with letter sizes and styles of a visibility at least equal to those specified in this paragraph.	Operation of an active waste disposal site that receives asbestos-containing material from a source covered under 40 CFR 61.145—**applicable**	40 CFR 61.154(b)(1)
	The perimeter of the disposal site must be fenced in a manner adequately to deter access by the general public.		40 CFR 61.154(b)(2)
	Supporting facilities: (i) A 6-ft woven mesh fence, wall or similar device shall be placed around the site to prevent unauthorized access. (ii) Roads shall be maintained to and within the site which are adequate to support the operation and maintenance of the site without causing safety or nuisance problems or hazardous conditions. (iii) Site shall be operated and maintained to prevent hazardous conditions resulting from spilled liquids and windblown materials.	Construction of a TSCA chemical waste landfill—**applicable**	40 CFR 761.75(b)(9)
General inspections	Operators must inspect facility for malfunctions and deterioration, operator errors, and discharges, often enough to identify and correct any problems.	Operation of a RCRA hazardous waste landfill—**applicable**	40 CFR 264.15(a) TDEC 0400-12-01-.06(2)(f)(1)
	Operators must remedy any deterioration or malfunction of equipment or structures on a schedule that ensures that the problem does not lead to an environmental or human health hazard.		40 CFR 264.15(c) TDEC 0400-12-01-.06(2)(f)(3)
Inspection of landfill following storms	Must inspect landfill weekly and after storm events to ensure proper functioning of: (i) Deterioration, malfunctions, or improper operation of run-on and run-off control systems; (ii) Proper functioning of wind dispersal control systems, where present; and (iii) The presence of leachate in and proper functioning of leachate collection and	Operation of a RCRA hazardous waste landfill—**applicable**	40 CFR 264.303(b) TDEC 0400-12-01-.06(14)(d)(2)

Table G-7. Action-specific ARARs and TBC Guidance (Operations Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative

Action	Requirements	Prerequisite	Citation
	removal systems, where present.		
Inspection of landfill	Must record the amount of liquids removed from the leak detection system sumps at least weekly during the active life and closure period.		40 CFR 264.303(c)(1) TDEC 0400-12-01-.06(14)(d)(3)(i)
Personnel training	Operators must ensure personnel adequately trained in hazardous waste, emergency response, monitoring equipment maintenance, alarm system procedures, etc.		40 CFR 264.16 TDEC 0400-12-01-.06(2)(g)
Construction quality assurance program	Operators must develop and implement a Construction Quality Assurance Program to ensure that the unit meets or exceeds all design criteria and specifications for all physical components including: foundations, dikes, liners, geomembranes, leachate collection and removal systems, leak detection systems and final covers in accordance with remaining provisions of 40 CFR 264.19.		40 CFR 264.19 TDEC 0400-12-01-.06(2)(j)
Contingency plan	Operators must have a contingency plan, designed to minimize hazards to human health and the environment from fires, explosions or other unplanned sudden releases of hazardous waste to air, soil, or surface water in accordance with 40 CFR 264.52.		40 CFR 264.51 TDEC 0400-12-01-.06(4)(b)
	Operators must have at least one emergency coordinator on the facility premises responsible for coordinating emergency response measures in accordance with 40 CFR 264.56.		40 CFR 264.55 TDEC 0400-12-01-.06(4)(f)
Inventory requirements	The owner or operator of a landfill must maintain the following items in the operating record required under §264.73: (a) On a map, the exact location and dimensions, including depth, of each cell with respect to permanently surveyed benchmarks; and (b) The contents of each cell and the approximate location of each hazardous waste type within each cell.	Operation of a RCRA hazardous waste landfill—**applicable**	40 CFR 264.309 TDEC 0400-12-01-.06(14)(j)
	Maintain, until closure, records of the location, depth and area, and quantity in cubic yards of asbestos containing material within the disposal site on a map or diagram.	Operation of an active waste disposal site that receives asbestos-containing material from a source covered under 40 CFR 61.145—**applicable**	40 CFR 61.154(f)
	Disposal records shall include information on the PCB concentration in the liquid wastes and the three dimensional burial coordinates for PCBs and PCB items.	Operation of a TSCA chemical waste landfill—**applicable**	40 CFR 761.75(b)(8)(iv)
	The boundaries and locations of each disposal unit must be accurately located and mapped by means of a land survey. Disposal units must be marked in such a way that the boundaries of each unit can be easily defined. Three permanent survey marker control points, referenced to USGS or NGS survey control stations, must be established on the site to facilitate surveys. The USGS or NGS control states must provide horizontal and vertical	Land disposal of LLW—**relevant and appropriate**	TDEC 0400-20-11-.17(3)(g)

Table G-7. Action-specific ARARs and TBC Guidance (Operations Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative

Action	Requirements	Prerequisite	Citation
	controls as checked against USGS or NGS record files.		
Leak detection system operation	Must collect and remove liquids in the leak detection system sumps to minimize the head on the bottom liner.	Operation of a RCRA landfill—**applicable**	40 CFR 264.301(c)(4) TDEC 0400-12-01-.06(14)(b)3(iv)
Run-on/runoff control systems	Collection and holding facilities must be emptied or otherwise expeditiously managed after storm events to maintain design capacity of the system		40 CFR 264.301(i) TDEC 0400-12-01-.06(14)(b)(9)
Wind dispersal control system	Must cover or manage the landfill to control wind dispersal of particulate matter		40 CFR 264.301(j) TDEC 0400-12-01-.06(14)(b)(10)
Control wind dispersal of asbestos wastes	Must be no visible emissions to the outside air; or	Operation of an active waste disposal site that receives asbestos-containing material from a source covered under 40 CFR 61.145—**applicable**	40 CFR 61.154(a)
	Rather than meet the no visible emission requirement of paragraph (a) of this section, at the end of each operating day, or at least once every 24-hour period while the site is in continuous operation, the asbestos-containing waste material that has been deposited at the site during the operating day or previous 24-hour period shall: (1) Be covered with at least 15 centimeters (6 inches) of compacted non-asbestos-containing material, or (2) Be covered with a resinous or petroleum-based dust suppression agent that effectively binds dust and controls wind erosion. Such an agent shall be used in the manner and frequency recommended for the particular dust by the dust suppression agent manufacturer to achieve and maintain dust control.		40 CFR 61.154(c)
Response actions for leak detection system	Must have a response action plan which sets forth the actions to be taken if action leakage rate has been exceeded.	Operation of a RCRA landfill leak detection system—**applicable**	40 CFR 264.304(a) TDEC 0400-12-01-.06(14)(e)(1)
	Must determine to the extent practicable the location, size and cause of any leak.	Flow rate into the leak detection system exceeds action leakage rate for any sump—**applicable**	40 CFR 264.304(b)(3) TDEC 0400-12-01-.06(14)(e)(2)(iii)
	Must determine whether waste receipt should cease or be curtailed; whether any waste should be removed from the unit for inspection, repairs, or controls, and whether or not the unit should be closed.		40 CFR 264.304(b)(4) TDEC 0400-12-01-.06(14)(e)(2)(iv)
	Must determine any other short or long-term actions to be taken to mitigate or stop leaks.		40 CFR 264.304(b)(5) TDEC 0400-12-01-.06(14)(e)(2)(v)

Table G-7. Action-specific ARARs and TBC Guidance (Operations Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative

Action	Requirements	Prerequisite	Citation
	To make the leak and/or remediation determinations, must: (i)(I) Assess the source and amounts of the liquids by source; (i)(II) Conduct a hazardous constituent or other analyses of the liquids in the leak detection system to identify sources and possible location of leaks, and the hazard and mobility of the liquid; and (i)(III) Assess the seriousness of leaks in terms of potential for escaping into the environment; or (ii) Document why such assessments are not needed.	Operation of a RCRA landfill leak detection system—**applicable**	40 CFR 264.304(c) TDEC 0400-12-01-.06(14)(e)(3)
Operation of a RCRA tank system	Hazardous wastes or treatment reagents must not be placed in the tank system if they could cause the tank, its ancillary equipment or the containment system to rupture, leak, corrode, or otherwise fail.	Storage of RCRA hazardous waste in a new tank system—**relevant and appropriate**	40 CFR 264.194(a) TDEC 0400-12-01-.06(10)(e)(1)
	Must use appropriate controls and practices to prevent spills an overflows from the tank or containment system. These include at a minimum: • spill prevention controls (e.g., check valves, dry disconnect couplings); • overfill prevention controls (e.g., level sensing devices, high level alarms, automatic feed cutoff, or bypass to a standby tank; and • maintenance of sufficient freeboard in uncovered tanks to prevent overtopping by wave or wind action or by precipitation.		40 CFR 264.194(b) TDEC 0400-12-01-.06(10)(e)(2)
	Must comply with the requirements of 40 CFR 264.196 (TDEC 0400-12-01-.06[10][g]) if a leak or a spill occurs in the tank system.		40 CFR 264.194(c) TDEC 0400-12-01-.06(10)(e)(3)
Operation of a RCRA surface impoundment	Design and operate facility to prevent overtopping resulting from normal or abnormal operations; overfilling; wind and wave action; rainfall; run-on; malfunctions of level controllers, alarms and other equipment; and human error.	Storage of RCRA hazardous waste in a surface impoundment—**relevant and appropriate**	40 CFR 264.221(g) TDEC 0400-12-01-.06(11)(b)(7)
	Remove surface impoundment from operation if the dike leaks or if there is a sudden drop in liquid level.		40 CFR 264.227 TDEC 0400-12-01-.06(11)(h)
Operation of a landfill accepting asbestos waste	Either discharge no visible emissions to the outside air; or	Disposal of asbestos-containing material—**applicable**	40 CFR 61.154(a)(1)
	Rather than meet the no visible emission requirement of paragraph (a) of this section, at the end of each operating day, or at least once every 24-hour period while the site is in continuous operation, the asbestos-containing waste material that has been deposited at the site during the operating day or previous 24-hour period shall: (1) Be covered with at least 15 centimeters (6 inches) of compacted non-asbestos-containing material, or (2) Be covered with a resinous or petroleum-based dust suppression agent that		40 CFR 61.154(c)(1)

Table G-7. Action-specific ARARs and TBC Guidance (Operations Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative

Action	Requirements	Prerequisite	Citation
	effectively binds dust and controls wind erosion. Such an agent shall be used in the manner and frequency recommended for the particular dust by the dust suppression agent manufacturer to achieve and maintain dust control.		
	Unless a natural barrier adequately deters access by the general public, either warning signs and fencing must be installed and maintained as follows, or the requirements of paragraph (c)(1) of this section must be met. (1) Warning signs must be displayed at all entrances and at intervals of 100 m (330 ft) or less along the property line of the site or along the perimeter of the sections of the site where asbestos-containing waste material is deposited. The warning signs must: (i) Be posted in such a manner and location that a person can easily read the legend; and (ii) Conform to the requirements of 51 cm × 36 cm (20″×14″) upright format signs specified in 29 CFR 1910.145(d)(4) and this paragraph; and (iii) Display the legend, as listed in 40 CFR 61.154(b)(1)(iii), in the lower panel with letter sizes and styles of a visibility at least equal to those specified in this paragraph.	Operation of an active waste disposal site that receives asbestos-containing material from a source covered under 40 CFR 61.145**—applicable**	40 CFR 61.154(b)(1)
	The perimeter of the disposal site must be fenced in a manner adequately to deter access by the general public.		40 CFR 61.154(b)(2)

*The action/requirement/prerequisite identified has been included in this ARAR's tabulation due to the unique nature of this cleanup activity. DOE, EPA and TDEC agree that adherence to these actions/requirements/prerequisites will be determined solely by DOE, and that a DOE determination of consistency with these actions/requirements/prerequisites is not an action which may lead to or generate a formal or informal dispute.

Table G- 8. Action-specific ARARs and TBC Guidance (Environmental Monitoring Requirements – All Phases) for CERCLA Waste Disposal, On-site Disposal Alternative

Action	Requirements	Prerequisite	Citation
Pre-operations monitoring	A preoperational monitoring program must be conducted to provide basic environmental data on the disposal site characteristics including information about the ecology, meteorology, climate, hydrology, geology, geochemistry and seismology of the disposal site. For those characteristics that are subject to seasonal variation, data must cover at least a 12-month period.	Land disposal of LLW—**relevant and appropriate**	TDEC 0400-20-11-.17(4)(a)
Corrective measures based on monitoring	Must have plans for taking corrective measures if migration of radionuclides would indicate that the performance objectives may not be met. *[Note: Performance Objectives are those given at TDEC 0400-20-11-.16(1), (2), and (5).]*	Land disposal of LLW—**relevant and appropriate**	TDEC 0400-20-11-.17(4)(b)
Construction and operations monitoring	During site construction and operation, shall maintain a monitoring program, including a monitoring system. The monitoring system must be capable of providing early warning of releases of radionuclides from the disposal unit before they leave the site boundary.	Land disposal of LLW—**relevant and appropriate**	TDEC 0400-20-11-.17(4)(c)
Post-operations monitoring	After the disposal site is closed, post-operational surveillance of the disposal site shall be maintained by a monitoring system based on the operating history and the closure and stabilization of the disposal site.	Land disposal of LLW—**relevant and appropriate**	TDEC 0400-20-11-.17(4)(d)
Ground water and surface water monitoring	The ground water and surface water from the disposal site area must be sampled prior to commencing operation for use as baseline data	Construction of TSCA chemical waste landfill—**applicable**	40 CFR 761.65(b)(6)(i)(A)
Surface water monitoring	Designated surface water course shall be sampled at least monthly when the landfill is being used for disposal.	Operation of a TSCA chemical waste landfill—**applicable**	40 CFR 761.75(b)(6)(i)(B)
Leachate collection system	Leachate collection systems shall be monitored monthly for quantity and physicochemical characteristics of leachate produced. The leachate should be either treated to acceptable limits for discharge in accordance with a State or Federal permit or disposed of by another State or Federally approved method. Water analysis shall be conducted as provided in paragraph (b)(6)(iii) of this section.	Operation of a TSCA chemical waste landfill—**applicable**	40 CFR 761.75(b)(7)
Monitoring well construction and operation	All monitoring wells shall be cased and the annular space between the monitor zone (zone of saturation) and the surface shall be completely backfilled with Portland cement or an equivalent material and plugged with Portland cement to effectively prevent percolation of surface water into the well bore. The well opening at the surface shall have a removable cap to provide access and to prevent entrance of rainfall or stormwater runoff. The ground water monitoring well shall be pumped to remove the volume of liquid initially contained in the well before obtaining a sample for analysis. The discharge shall be treated to meet applicable State or Federal standards or recycled to the chemical waste landfill.	Construction and operation of a TSCA ground water monitoring well—**applicable**	40 CFR 761.75(b)(6)(ii)(B)

Table G-8. Action-specific ARARs and TBC Guidance (Environmental Monitoring Requirements – All Phases) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation
Operation of leachate collection system	After the cover is installed, must record the amount of liquids removed from the leak detection system at least monthly. If the liquid level in the sump stays below the pump operating level for two consecutive months, the amount of liquids in the sumps must be recorded at least quarterly. If the liquid level in the sump stays below the pump operating level for two consecutive quarters, the amount of liquids in the sumps must be recorded at least semi-annually. If at any time during the post-closure care period the pump operating level is exceeded at units on quarterly or semi-annual recording schedules, the owner or operator must return to monthly recording of amounts of liquids removed from each sump until the liquid level again stays below the pump operating level for two consecutive months.	Closure of a RCRA landfill—**applicable**	40 CFR 264.303(c)(2) TDEC 0400-12-01-.06(14)(d)(3)(ii)
General post-closure care	Must maintain and monitor a ground water monitoring system and comply with all other applicable provisions of 40 CFR 264, Subpart F.		40 CFR 264.310(b)(4) TDEC 0400-12-01-.06(14)(k)(2)(iv)
Determining RCRA Concentration Limits	Concentration limits shall be determined taking into account those constituents that are reasonably expected to be contained in or derived from waste present in the landfill. These limits must not exceed those listed in TDEC 0400-12-.06(6)(f)(1), Table 1.	RCRA hazardous constituents detected in ground water in the uppermost aquifer underlying a hazardous waste landfill—**applicable**	40 *CFR* § 264.94(a) TDEC 0400-12-.06(6)(f)(1)
Ground water monitoring well construction	All monitoring wells must be cased in a manner that maintains the integrity of the monitoring well bore hole. This casing must be screened or perforated and packed with gravel or sand, where necessary, to enable collection of ground-water samples. The annular space (i.e., the space between the bore hole and well casing) above the sampling depth must be sealed to prevent contamination of samples and the ground water.	Construction of RCRA ground water monitoring well—**applicable**	40 *CFR* § 264.97(c) TDEC 0400-12-01-.06(6)(h)(3)
Ground water monitoring requirements for RCRA hazardous waste landfills	The ground water monitoring system must consist of a sufficient number of wells, installed at appropriate locations and depths to yield samples from the uppermost aquifer that: • Represent the quality of background ground water; • Represent the quality of ground water passing the point of compliance; and • Allow for the detection of contamination when the hazardous waste or constituents have migrated from the waste management area to the uppermost aquifer.	Operation of a detection monitoring program under 40 *CFR* § 264.98—**applicable**	40 *CFR* § 264.97(a) TDEC 0400-12-01-.06(6)(h)(1)
	Ground water monitoring program must include consistent sampling and analysis procedures that are designed to ensure monitoring results that provide a reliable indication of ground water quality below the waste management area.		40 *CFR* § 264.97(d) TDEC 0400-12-01-.06(6)(h)(4)
	Ground water monitoring program must include sampling and analytical methods that are appropriate and accurately measure hazardous constituents in ground water samples.		40 *CFR* § 264.97(e) TDEC 0400-12-01-.06(6)(h)(5)
	Ground water monitoring program must include a determination of the ground water surface elevation each time ground water is sampled.		40 *CFR* § 264.97(f) TDEC 0400-12-01-.06(6)(h)(6)

Table G-8. Action-specific ARARs and TBC Guidance (Environmental Monitoring Requirements – All Phases) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation
	The number and size of samples collected to establish background and measure ground water quality at the point of compliance shall be appropriate for the form of statistical test employed following generally accepted statistical principles.		40 *CFR* § 264.97(g) TDEC 0400-12-01-.06(6)(h)(7)
	The owner or operator will specify one of the following statistical methods to be used in evaluating ground water monitoring data for each hazardous constituent. The statistical test chosen shall be conducted separately for each hazardous constituent in each well. Where PQLs are used in any of the following statistical procedures to comply with §264.97(i)(5), the PQL must be proposed by the owner or operator and approved by Tennessee and EPA through the CERCLA process. Use of any of the following statistical methods must be protective of human health and the environment and must comply with the performance standards outlined in 40 *CFR* § 264.97(i).	Operation of a detection monitoring program under 40 *CFR* § 264.98—**applicable**	40 *CFR* § 264.97(h) TDEC 0400-12-01-.06(6)(h)(8)
	• A parametric analysis of variance (ANOVA) followed by multiple comparisons procedures to identify statistically significant evidence of contamination. The method must include estimation and testing of the contrasts between each compliance well's mean and the background mean levels for each constituent.		40 *CFR* § 264.97(h)(1) TDEC 0400-12-01-.06(6)(h)(8)(i)
	• An analysis of variance (ANOVA) based on ranks followed by multiple comparisons procedures to identify statistically significant evidence of contamination. The method must include estimation and testing of the contrasts between each compliance well's median and the background median levels for each constituent.		40 *CFR* § 264.97(h)(2) TDEC 0400-12-01-.06(6)(h)(8)(ii)
	• A tolerance or prediction interval procedure in which an interval for each constituent is established from the distribution of the background data and the level of each constituent in each compliance well is compared to the upper tolerance or prediction limit.		40 *CFR* § 64.97(h)(3) TDEC 0400-12-01-.06(6)(h)(8)(iii)
	• A control chart approach that gives control limits for each constituent.		40 *CFR* § 64.97(h)(4) TDEC 0400-12-01-.06(6)(h)(8)(iv)
	• Another statistical test method submitted by the owner or operator and approved by Tennessee and EPA through the CERCLA process.		40 *CFR* § 64.97(h)(5) TDEC 0400-12-01-.06(6)(h)(8)(iv)
	Any statistical method chosen under § 264.97(h) shall comply with the following performance standards, as appropriate:	Operation of a detection monitoring program under 40 *CFR* § 264.98—**applicable**	40 *CFR* § 264.97(i) TDEC 0400-12-01-.06(6)(h)(9)
	• The statistical method used to evaluate ground water monitoring data shall be appropriate for the distribution of chemical parameters or hazardous constituents. If the distribution of the chemical parameters or hazardous constituents is shown by the owner or operator to be inappropriate for a normal theory test, then the data should be transformed or a distribution-free theory test should be used. If the distributions for		40 *CFR* § 264.97(i)(1) TDEC 0400-12-01-.06(6)(h)(9)(i)

Table G-8. Action-specific ARARs and TBC Guidance (Environmental Monitoring Requirements – All Phases) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation
	the constituents differ, more than one statistical method may be needed.		
	• If an individual well comparison procedure is used to compare an individual compliance well constituent concentration with background constituent concentrations or a ground-water protection standard, the test shall be done at a Type I error level no less than 0.01 for each testing period. If a multiple comparisons procedure is used, the Type I experiment wise error rate for each testing period shall be no less than 0.05; however, the Type I error of no less than 0.01 for individual well comparisons must be maintained. This performance standard does not apply to tolerance intervals, prediction intervals, or control charts.		40 *CFR* § 264.97(i)(2) TDEC 0400-12-01-.06(6)(h)(9)(ii)
	• If a control chart approach is used to evaluate ground water monitoring data, the specific type of control chart and its associated parameter values shall be proposed by the owner or operator and approved by Tennessee and EPA through the CERCLA process.		40 *CFR* § 264.97(i)(3) TDEC 0400-12-01-.06(6)(h)(9)(iii)
	• If a tolerance interval or a prediction interval is used to evaluate ground water monitoring data, the levels of confidence, and, for tolerance intervals, the percentage of the population that the interval must contain, shall be proposed by the owner or operator and approved by Tennessee and EPA through the CERCLA process. These parameters will be determined after considering the number of samples in the background data base, the data distribution, and the range of the concentration values for each constituent of concern.		40 *CFR* § 264.97(i)(4) TDEC 0400-12-01-.06(6)(h)(9)(iv)
	• The statistical method shall account for data below the limit of detection with one or more statistical procedures that are protective of human health and the environment. Any PQL approved by Tennessee and EPA through the CERCLA process under § 264.97(h) that is used in the statistical method shall be the lowest concentration level that can be reliably achieved within specified limits of precision and accuracy during routine laboratory operating conditions that are available to the facility.		40 *CFR* § 264.97(i)(5) TDEC 0400-12-01-.06(6)(h)(9)(v)
	• If necessary, the statistical method shall include procedures to control or correct for seasonal and spatial variability as well as temporal correlation in the data.		40 *CFR* § 264.97(i)(6) TDEC 0400-12-01-.06(6)(h)(9)(vi)

Table G-8. Action-specific ARARs and TBC Guidance (Environmental Monitoring Requirements – All Phases) for CERCLA Waste Disposal, On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation
Detection monitoring	Must monitor for specified indicator parameters, waste constituents or reaction products that provide a reliable indication of the presence of hazardous constituents in ground water.	Operation of a detection monitoring program under 40 *CFR* § 264.98—a**pplicable**	40 *CFR* § 264.98(a) TDEC 0400-12-01-.06(6)(i)(1)
	Must install a ground water monitoring system at the compliance point as specified under 40 *CFR* § 264.95 that complies with 40 *CFR* § 264.97(a)(2) and (c).		40 *CFR* § 264.98(b) TDEC 0400-12-01-.06(6)(i)(2)
	Must conduct a monitoring program for each specified chemical parameter and hazardous constituent.		40 *CFR* § 264.98(c) TDEC 0400-12-01-.06(6)(i)(3)
	Sampling frequency shall be sufficient to determine whether there is statistically significant evidence of contamination.		40 *CFR* § 264.98(d) TDEC 0400-12-01-.06(6)(i)(4)
	Must determine the ground water flow rate and direction in the uppermost aquifer annually at a minimum.		40 *CFR* § 264.98(e) TDEC 0400-12-01-.06(6)(i)(5)
	Must determine whether there is statistically significant evidence of contamination of any specified chemical parameter or hazardous constituent at a specified frequency.		40 *CFR* § 264.98(f) TDEC 0400-12-01-.06(6)(i)(6)
	If there is statistically significant evidence of contamination at any monitoring well at the compliance point, must follow the substantive provisions of this subsection [§264.98(g)].		40 *CFR* § 264.98(g) TDEC 0400-12-01-.06(6)(i)(7)
Surface water monitoring post-closure	Designated surface water course shall be sampled on a frequency of no less than once every six months after final closure of the disposal area.	Closure of a TSCA chemical waste landfill**—applicable**	40 CFR 761.75(b)(6)(i)(C)

Table G-9. Action-specific ARARs and TBC Guidance (Closure and Post-closure Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative

Action	Requirements	Prerequisite	Citation
Decontamination/disposal of equipment	During the partial and final closure periods, all equipment, structures, etc. must be properly disposed of or decontaminated unless otherwise specified in §§ 264.197, 264.228, 264.258, 264.280 or § 264.310.	Closure of a RCRA landfill—**applicable**	40 CFR 264.114 TDEC 0400-12-01-.06(7)(e)
Closure of RCRA landfill and other RCRA hazardous waste management units	Must close the unit in a manner that: (a) Minimizes the need for further maintenance; and (b) Controls, minimizes or eliminates, to the extent necessary to protect human health and the environment, post-closure escape of hazardous waste, hazardous constituents, leachate, contaminated run-off, or hazardous waste decomposition products to the ground or surface waters or to the atmosphere; and (c) Complies with the closure requirements of this part, including, but not limited to, the requirements of §§264.178, 264.197, 264.228, 264.258, 264.280, 264.310, 264.351, 264.601 through 264.603, and 264.1102.	Closure of a RCRA hazardous waste management facility—**applicable**	40 CFR 264.111 TDEC 0400-12-01-.06(7)(b)
Closure of RCRA landfill	Must cover the landfill or cell with a final cover designed and constructed to: (1) Provide long-term minimization of migration of liquids through the closed landfill; (2) Function with minimum maintenance; (3) Promote drainage and minimize erosion or abrasion of the cover; (4) Accommodate settling and subsidence so that the cover's integrity is maintained; and (5) Have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present.		40 CFR 264.310(a) TDEC 0400-12-01-.05(14)(k)
Clean closure of a RCRA container storage area	Must remove all hazardous waste and residues from containment system. Remaining containers, liners, bases and soil containing or contaminated with hazardous waste or residues must be decontaminated or removed.	Management of RCRA hazardous waste in a container storage area—**applicable**	40 CFR 264.178 TDEC 0400-12-01-.06(9)(i)
Clean closure of TSCA storage facility	A TSCA/RCRA storage facility closed under RCRA is exempt from the TSCA closure requirements of 40 CFR 761.65(e).	Closure of TSCA/RCRA storage facility—**applicable**	40 CFR 761.65(e)(3)
Closure of ground water monitoring well(s)	Shall be accomplished by a licensed driller.	Permanent plugging and abandonment of a well—**relevant and appropriate**	TDEC 0400-45-09-.16(2)
	Shall be completely filled and sealed in such a manner that vertical movement of fluid either into or between formation(s) containing ground water classified pursuant to rule 0400-45-06-.05(1) through the bore hole is not allowed.		TDEC 0400-45-06-.09(6)(d)

G-9. Action-specific ARARs and TBC Guidance (Closure and Post-closure Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative

Action	Requirements	Prerequisite	Citation
Decontamination/disposal of equipment	During the partial and final closure periods, all equipment, structures, etc. must be properly disposed of or decontaminated unless otherwise specified in §§ 264.197, 264.228, 264.258, 264.280 or § 264.310.	Closure of a RCRA landfill—**applicable**	40 CFR 264.114 TDEC 0400-12-01-.06(7)(e)
Closure of RCRA landfill and other RCRA hazardous waste management units	Must close the unit in a manner that: (d) Minimizes the need for further maintenance; and (e) Controls, minimizes or eliminates, to the extent necessary to protect human health and the environment, post-closure escape of hazardous waste, hazardous constituents, leachate, contaminated run-off, or hazardous waste decomposition products to the ground or surface waters or to the atmosphere; and (f) Complies with the closure requirements of this part, including, but not limited to, the requirements of §§264.178, 264.197, 264.228, 264.258, 264.280, 264.310, 264.351, 264.601 through 264.603, and 264.1102.	Closure of a RCRA hazardous waste management facility—**applicable**	40 CFR 264.111 TDEC 0400-12-01-.06(7)(b)
Closure of RCRA landfill	Must cover the landfill or cell with a final cover designed and constructed to: (6) Provide long-term minimization of migration of liquids through the closed landfill; (7) Function with minimum maintenance; (8) Promote drainage and minimize erosion or abrasion of the cover; (9) Accommodate settling and subsidence so that the cover's integrity is maintained; and (10) Have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present.		40 CFR 264.310(a) TDEC 0400-12-01-.05(14)(k)
Clean closure of a RCRA container storage area	Must remove all hazardous waste and residues from containment system. Remaining containers, liners, bases and soil containing or contaminated with hazardous waste or residues must be decontaminated or removed.	Management of RCRA hazardous waste in a container storage area—**applicable**	40 CFR 264.178 TDEC 0400-12-01-.06(9)(i)
Clean closure of TSCA storage facility	A TSCA/RCRA storage facility closed under RCRA is exempt from the TSCA closure requirements of 40 CFR 761.65(e).	Closure of TSCA/RCRA storage facility—**applicable**	40 CFR 761.65(e)(3)
Closure of ground water monitoring well(s)	Shall be accomplished by a licensed driller.	Permanent plugging and abandonment of a well—**relevant and appropriate**	TDEC 0400-45-09-.16(2)
	Shall be completely filled and sealed in such a manner that vertical movement of fluid either into or between formation(s) containing ground water classified pursuant to rule 0400-45-06-.05(1) through the bore hole is not allowed.		TDEC 0400-45-06-.09(6)(d)

G-9. Action-specific ARARs and TBC Guidance (Closure and Post-closure Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative

Action	Requirements	Prerequisite	Citation
	Shall be performed in accordance with the provisions for Seals at 0400-45-06-(6)(e), (f), and (g); for Fill Materials at 0400-45-06-.09(6)(h) and (i); for Temporary Bridges at 0400-45-06-.09(6)(j); for Placement of Sealing Materials at 0400-45-06-.09(7)(a) and (b); and Special Conditions at 0400-45-06-09(8)(a) and (b), as appropriate		TDEC 0400-45-06-.09(6)(e) through (j) TDEC 0400-45-06.09(7) TDEC 0400-45-06.09(8)(a) TDEC 0400-45-06.09(8)(b)
Closure of a RCRA tank system	Must remove or decontaminate all waste residues, contaminated containment system components (liners, etc.) contaminated soils, and structures and equipment contaminated with waste, and manage them as hazardous waste, unless 40 CFR 261.3(d) (TDEC 0400-12-01-.02[1][c][4]) applies. If all contents cannot be practicably removed or decontaminated, consider the tank system a landfill and close in accordance with the landfill closure requirements of 40 CFR 264.310 (TDEC 0400-12-01-.06[14][k]).	Closure of a RCRA hazardous tank system—**relevant and appropriate** if wastewater is determined to be hazardous	40 CFR 264.197(a) and (b)TDEC 0400-12-01-.06(10)(h)(1) and (2)
Closure and post-closure care of a surface impoundment	Must remove or decontaminate all waste residues and contaminated materials; otherwise free liquids must be removed, the remaining wastes stabilized to a bearing capacity sufficient to support final cover, and the facility closed and covered with a final cover designed in accordance with 40 CFR 264.228(a)(2)(iii)(A)-(E) (TDEC 0400-12-01-.06[11][i][1][ii][III]). If some waste residues or contaminated materials are left in place at final closure, must comply with all postclosure requirements contained in §§264.117 through 264.120 (TDEC 0400-12-01-.06[7][h] through [k]), including maintenance and monitoring throughout the postclosure period. Must also: • maintain integrity and effectiveness of final cover, making repairs to the cap as necessary; • maintain and monitor leak detection system; • maintain and monitor ground water monitoring system; • prevent run-on and runoff from eroding or otherwise damaging final cover.	Closure of a hazardous waste surface impoundment—**relevant and appropriate** if wastewater is determined to be hazardous	40 CFR 264.228(a) and (b) TDEC 0400-12-01-.06(11)(i)(1) and (2)

G-9. Action-specific ARARs and TBC Guidance (Closure and Post-closure Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative

Action	Requirements	Prerequisite	Citation
Survey plat	Must submit to the local zoning authority or the authority with jurisdiction over local land use, a survey plat indicating the location and dimensions of landfill cells, with respect to permanently surveyed benchmarks. The plat must contain a note, prominently displayed which states the owner/operator obligation to restrict disturbance of the landfill.	Closure of a RCRA landfill—**applicable**	40 CFR 264.116 TDEC 0400-12-01-.06(7)(g)
	Within 60 days of a site becoming inactive and after the effective date of this subpart, record, in accordance with State law, a notation on the deed to the facility property and on any other instrument that would normally be examined during a title search; this notation will in perpetuity notify any potential purchaser of the property that: (1) The land has been used for the disposal of asbestos-containing waste material; (2) The survey plot and record of the location and quantity of asbestos-containing waste disposed of within the disposal site required in §61.154(f) have been filed with the Administrator; and (3) The site is subject to 40 CFR part 61, subpart M.	Closure of an asbestos-containing waste disposal site—**applicable**	40 CFR 61.151(e)
Duration	Post closure care must begin after closure and continue for at least 30 years after that date.	Closure of a RCRA landfill—**applicable**	40 CFR 264.117(a) TDEC 0400-12-01-.06(7)(h)
Protection of facility	Post-closure use of property must never be allowed to disturb the integrity of the final cover, liners, or any other components of the containment system or the facility's monitoring system unless necessary to reduce a threat to human health or the environment.		40 CFR 264.117(c) TDEC 0400-12-01-.06(7)(h)(3)
Post-closure plan	Must have a written post-closure plan which identifies planned monitoring activities and frequency at which they will be performed for ground water monitoring, containment systems and cap maintenance.		40 CFR 264.118 TDEC 0400-12-01-.06(7)(i)
Post-closure notices	Must submit to the local zoning authority a record of the type, location, and quantity of hazardous wastes disposed of within each cell of the unit.		40 CFR 264.119(a) TDEC 0400-12-01-.06(7)(j)(1)
Survey plat	Must record, in accordance with State law, a notation on the deed to the facility property - or on some other instrument which is normally examined during a title search - that will in perpetuity notify any potential purchaser of the property that the land has been used to manage hazardous wastes, and its use is restricted.		40 CFR 264.119(b) TDEC 0400-12-01-.06(7)(j)(2)

G-9. Action-specific ARARs and TBC Guidance (Closure and Post-closure Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative

Action	Requirements	Prerequisite	Citation
General post-closure care	After final closure, owner or operator must: (i) Maintain the effectiveness and integrity of the final cover including making repairs to the cap as necessary to correct effects of settling, erosion, etc.; (ii) Continue to operate the leachate collection and removal system until leachate is no longer detected; (iii) Maintain and monitor the leachate detection system in accordance with 40 CFR 264.301(a)(3)(iv) and (4) and 40 CFR 264.303(c); (iv) Maintain and monitor a ground water monitoring system and comply with all other applicable provisions of 40 CFR 264, Subpart F; (v) Prevent run-on and run-off from eroding or otherwise damaging final cover; and (vi) Protect and maintain surveyed benchmarks used to locate waste cells.		40 CFR 264.310(b) TDEC 0400-12-01-.06(14)(k)(2)
LLW disposal facility pre-closure activities	Prior to closure of the disposal site, the following information will be obtained: • Any additional geologic, hydrologic, or other disposal site data pertinent to the long-term containment of emplaced radioactive wastes obtained during the operation period. • The result of tests, experiments or other analyses relating to backfill of excavated areas, closure and sealing, waste migration and interaction with emplacement media, or any other test, experiments or analysis pertinent to the long-term containment of emplaced waste within the disposal site. • Any proposed revision of plans for decontamination and/or dismantlement of surface operational facilities, backfilling of excavated areas, or stabilization of the disposal site for postclosure care. • Any significant new information regarding the environmental impact of closure activities and long-term performance of the disposal site.	Closure of a LLW disposal facility—**relevant and appropriate**	TDEC 0400-20-11-.12(1)
Closure of a LLW landfill	Covers must be designed to minimize to the extent practicable water infiltration, to direct percolating or surface water away from the disposed waste and to resist degradation by surface geologic processes and biotic activity.	Closure of a LLW disposal landfill—**relevant and appropriate**	TDEC 0400-20-11-.17(2)(d)
Closure of an asbestos-containing waste disposal area	Upon closure, comply with the provisions of 40 CFR 61.151(a) – (c)[TDEC 1200-3-11-.02(2)(l)(1) – (3)]:	Closure/capping of a permitted asbestos disposal site—**relevant and appropriate**	40 CFR 61.154(g) TDEC 1200-3-11-.02(5)(g)
	Must either discharge no visible emissions to the outside air; <u>or</u>		40 CFR 61.151(a)(1) TDEC 1200-3-11-.02(2)(l)(1)(i)
	Cover the ACM with at least 6 in. of compacted non-asbestos-containing material and grow and maintain a cover of vegetation on the area adequate to prevent exposure of the asbestos-containing waste; <u>or</u>		40 CFR 61.151(a)(2) TDEC 1200-3-11-.02(2)(l)(1)(ii)

G-9. Action-specific ARARs and TBC Guidance (Closure and Post-closure Requirements) for CERCLA Waste Disposal, On-site Disposal Alternative

Action	Requirements	Prerequisite	Citation
	Cover the asbestos-containing waste with at least 2 ft of compacted non-asbestos-containing material and maintain it to prevent exposure of the waste.		40 CFR 61.151(a)(3) TDEC 1200-3-11-.02(2)(l)(1)(iii)
	Unless a natural barrier adequately deters access by the general public, install and maintain warning signs and fencing as detailed in 40 CFR 61.151(b)(1) – (3) <u>or</u> comply with 40 CFR 61.151(a)(2) or (a)(3).		40 CFR 61.151(b) TDEC 1200-3-11-.02(2)(l)(2)
	Owner may use an alternative control method that has received prior approval of the Administrator rather than comply with the requirements of 40 CFR 61.151(a) or (b).		40 CFR 61.151(c) TDEC 1200-3-11-.02(2)(l)(3)

Table G-10. Action-specific ARARs and TBC Guidance for Operation of an On-site Landfill Wastewater Treatment System

Action	Requirements	Prerequisite	Citation
Release of contact water and leachate into Bear Creek tributary	Shall receive the degree of treatment or effluent reduction necessary to comply with water quality standards and, where appropriate, will comply with the "Standard of Performance" as required by TN Water Quality Control Act at TCA §§69-3-101, et seq. For industrial discharges without applicable federal effluent guidelines, best professional judgment should be employed to determine appropriate effluent limitations and standards.	Point source discharge(s) of pollutants into waters of the U.S. **—applicable**	TCA §§69-3-101 *et seq.* TDEC 0400-40-03-.05(6) TDEC 0400-40-05-.09(1)(b)
Non-continuous batch discharges (those discharges which are not continuous as defined in 40 CFR 122.2) of leachate and contact water	Non-continuous discharges shall be particularly described and limited, considering the following factors, as appropriate: • Frequency • Total mass • Maximum rate of discharge of pollutants during the discharge; and • Mass or concentration of specified pollutants	Non-continuous discharge of pollutants to surface waters—**applicable** if water is released on a non-continuous batch basis rather than continuously	40 CFR 122.45(e) TDEC 0400-40-05-.08(1)(n)
Exclusion from 40 CFR 445 effluent discharge standards for RCRA Subtitle C landfills point source category	Pursuant to 40 CFR 445.1(e), RCRA Subtitle C landfills that only receive wastes generated by the industrial operations directly associated with the landfill are exempt from the CWA effluent standards under 40 CFR 445.11.	Point source discharge of wastewater from RCRA Subtitle C landfills [as defined in 40 CFR 445.2(f)] into waters of the U.S.**— applicable**	40 CFR 445.1(e)
Temporary bypass of waste stream	Bypass is prohibited unless: • Bypass was unavoidable to prevent loss of life, personal injury, or severe property damage; • There were no feasible alternatives to bypass; condition not satisfied if adequate backup equipment should have been installed in the exercise of reasonable engineering judgment to prevent a bypass which occurred during normal periods of equipment downtime or preventive maintenance	Bypass, as defined in TDEC 0400-40-05-.02(15), of waste stream**—applicable**	TDEC 0400-40-05-.07(2)(l)
	A bypass that does not cause effluent limitations to be exceeded may be allowed only if bypass is necessary for essential maintenance to assure efficient operation.		TDEC 0400-40-05-.07(2)(m)
Wastewater transferred by truck or pipeline to on-site on-ORR CWA-authorized WWTU	A user may not introduce into a wastewater facility any pollutant(s) which causes pass through or interference, and wastewater must meet the pretreatment standards and prohibitions [waste acceptance criteria and limits] set by the wastewater facility prior to transfer.	Transfer of contaminated wastewater to a CWA-authorized wastewater facility for treatment**—applicable**	TDEC 0400-40-14-.05(1) – (2) and (4)

Table G-10. Action-specific ARARs and TBC Guidance for Operation of an On-site Landfill Wastewater Treatment System

Action	Requirements	Prerequisite	Citation
Release of contact water and leachate into Bear Creek tributary	Shall receive the degree of treatment or effluent reduction necessary to comply with water quality standards and, where appropriate, will comply with the "Standard of Performance" as required by TN Water Quality Control Act at TCA §§69-3-101, et seq. For industrial discharges without applicable federal effluent guidelines, best professional judgment should be employed to determine appropriate effluent limitations and standards.	Point source discharge(s) of pollutants into waters of the U.S. —**applicable**	TCA §§69-3-101 *et seq.* TDEC 0400-40-03-.05(6) TDEC 0400-40-05-.09(1)(b)
Non-continuous batch discharges (those discharges which are not continuous as defined in 40 CFR 122.2) of leachate and contact water	Non-continuous discharges shall be particularly described and limited, considering the following factors, as appropriate: • Frequency • Total mass • Maximum rate of discharge of pollutants during the discharge; and • Mass or concentration of specified pollutants	Non-continuous discharge of pollutants to surface waters—**applicable** if water is released on a non-continuous batch basis rather than continuously	40 CFR 122.45(e) TDEC 0400-40-05-.08(1)(n)
Exclusion from 40 CFR 445 effluent discharge standards for RCRA Subtitle C landfills point source category	Pursuant to 40 CFR 445.1(e), RCRA Subtitle C landfills that only receive wastes generated by the industrial operations directly associated with the landfill are exempt from the CWA effluent standards under 40 CFR 445.11.	Point source discharge of wastewater from RCRA Subtitle C landfills [as defined in 40 CFR 445.2(f)] into waters of the U.S.— **applicable**	40 CFR 445.1(e)
Temporary bypass of waste stream	Bypass is prohibited unless: • Bypass was unavoidable to prevent loss of life, personal injury, or severe property damage; • There were no feasible alternatives to bypass; condition not satisfied if adequate backup equipment should have been installed in the exercise of reasonable engineering judgment to prevent a bypass which occurred during normal periods of equipment downtime or preventive maintenance	Bypass, as defined in TDEC 0400-40-05-.02(15), of waste stream—**applicable**	TDEC 0400-40-05-.07(2)(l)
	A bypass that does not cause effluent limitations to be exceeded may be allowed only if bypass is necessary for essential maintenance to assure efficient operation.		TDEC 0400-40-05-.07(2)(m)
Wastewater transferred by truck or pipeline to on-site on-ORR CWA-authorized WWTU	A user may not introduce into a wastewater facility any pollutant(s) which causes pass through or interference, and wastewater must meet the pretreatment standards and prohibitions [waste acceptance criteria and limits] set by the wastewater facility prior to transfer.	Transfer of contaminated wastewater to a CWA-authorized wastewater facility for treatment—**applicable**	TDEC 0400-40-14-.05(1) – (2) and (4)

Table G-10. Action-specific ARARs and TBC Guidance for Operation of an On-site Landfill Wastewater Treatment System (Continued)

Action	Requirements	Prerequisite	Citation
Management of water generated from EMWMF landfill	On-site wastewater treatment units that are part of a wastewater treatment facility subject to regulation under Section 402 or Section 307(b) of the CWA are exempt from the requirements of RCRA Subtitle C for all tank systems, conveyance systems (whether piped or trucked), and ancillary equipment used to store or transport RCRA contaminated water.	On-site wastewater treatment units subject to regulation under §402 or §307(b) of the CWA—**applicable** if water is determined to be hazardous	40 CFR 264.1(g)(6) 40 CFR 260.10 40 CFR 270.1(c)(2)(v) TDEC 0400-12-01-.07(1)(b)(4)(iv) 53 FR 34079, September 2, 1988
Disposal of wastewaters containing RCRA hazardous constituents	Disposal is not prohibited if the wastes are managed in a treatment system which subsequently discharges to waters of the U.S. under the CWA unless the wastes are subject to a specified method of treatment other than DEACT in 40 CFR 268.40 or are D003 reactive cyanide.	Disposal of RCRA restricted hazardous wastes that are hazardous only because they exhibit a hazardous characteristic and are not otherwise prohibited under 40 CFR 268—**applicable** if water is determined to be hazardous	40 CFR 268.1(c)(4)(i) TDEC 0400-12-01-.10(1)(a)(3)(iv)(I)

Table G-11. Action-specific ARARs and TBC Guidance for CERCLA Waste Disposal, Off-site Disposal Alternative

Action	Requirements	Prerequisite	Citation
Construction and operation of a volume reduction facility (miscellaneous treatment facility)	Follow design and operating standards that ensure protection of human health and the environment for units in which hazardous waste is treated.	Processes involving treatment of RCRA hazardous waste in a miscellaneous unit as defined in 40 CFR 260.10—**applicable** to volume reduction facility	40 CFR 264.601 TDEC 0400-12-01-.06(27)(b)
	Prevent any releases that may have adverse effects on human health or the environment due to migration of waste constituents, specifically preventing adverse effects in: • the ground water or subsurface environment • surface water, or wetlands, or the soil surface; • the air		40 CFR 264.601(a) through (c) TDEC 0400-12-01-.06(27)(b)(1) through (3)
	A miscellaneous unit that is a disposal unit must be maintained in a manner that complies with §264.601 during the post-closure care period. In addition, if a treatment or storage unit has contaminated soils or ground water that cannot be completely removed or decontaminated during closure, then that unit must also meet the requirements of §264.601 during post-closure care. The post-closure plan under §264.118 must specify the procedures that will be used to satisfy this requirement.		40 CFR 264.603 TDEC 0400-12-01-.06(27)(d)
Transportation of hazardous materials	Shall be subject to and must comply with all applicable provisions of the HMTA and HMR at 49 CFR 171-180.	Any person who, under contract with a department or agency of the federal government, transports "in commerce", or causes to be transported or shipped, a hazardous material**—applicable**	49 CFR 171.1(c)
Transportation of hazardous and radioactive materials off-site	The waste must meet packaging, labeling, marking, placarding and pre-transport requirements in accordance with DOT regulations.	Transportation of hazardous and radioactive materials above exempt quantities**—applicable**	49 CFR 171, 172, 173, 174, 177, 178, and 179
	Must meet packaging requirements based on the maximum activity of radioactive material in a package.	Packaging of radioactive materials above exempt quantities for public transport**—applicable**	49 CFR 173.431 49 CFR 173.433 49 CFR 173.435 49 CFR 173.411
Transportation of LLW off-site	LLW waste shall be packaged and transported in accordance with DOE O 1460.1A and DOE O 460.2.	Preparation of off-site shipment of LLW**—TBC**	DOE M 435.1-1(I)(1)(E)(11)*
	To the extent practicable, the volume of waste and number of shipments shall be minimized.		DOE M 435.1-1(IV)(L)(2)*
Transportation of PCB wastes off-site	Must comply with the manifesting provisions at 40 CFR 761.207 through 218.	Relinquishment of control over PCB wastes by transporting, or offering for transport**—applicable**	40 CFR 761.207(a)

Table G-11. Action-specific ARARs and TBC Guidance for CERCLA Waste Disposal, Off-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation
Transportation of hazardous waste off-site	Must comply with the generator requirements of 40 CFR 262.20-23 for manifesting, Sect. 262.30 for packaging, Sect. 262.31 for labeling, Sect. 262.32 for marking, Sect. 262.33 for placarding, Sect. 262.41(a) for record keeping requirements, and Sect. 262.12 to obtain EPA ID number.	Off site transportation of RCRA hazardous waste—**applicable**	40 CFR 262.10(h) TDEC 0400-12-01-.03(1)(a)(8)
	Must comply with the requirements of 40 CFR 263.11-263.31. (Standards applicable to transporters of hazardous waste.)	Transportation of hazardous waste within the United States requiring a manifest—**applicable**	40 CFR 263.11 - 263.31
	A transporter who meets all applicable requirements of 49 CFR 171-179 and the requirements of 40 CFR 263.11 and 263.31 will be deemed in compliance with 40 CFR 263.	Transportation of hazardous waste within the United States requiring a manifest—**applicable**	40 CFR 263.10(a)
Transportation of hazardous waste on-site	The generator manifesting requirements of 40 CFR 262.20-262.32(b) do not apply. Generator or transporter must comply with the requirements set forth in 40 CFR 263.30 and 263.31 in the event of a discharge of hazardous waste on a private or public right-of-way.	Transportation of hazardous wastes on a public or private right-of-way within or along the border of contiguous property under the control of the same person, even if such contiguous property is divided by a public or private right-of-way—**applicable**	40 CFR 262.20(f)
Transportation of universal waste off-site	Off-site shipments of universal waste by a large quantity handler of universal waste shall be made in accordance with 40 CFR 273-38 (TDEC 0400-1-11-.12[3][i]).	Preparation of off-site shipments of universal waste by a large quantity generator of universal waste—**applicable**	40 CFR 273.38 TDEC 0400-1-11-.12(3)(i)
Transportation of used oil off-site	Except as provided in paragraphs (a) to (c) of this rule, generators must ensure that their used oil is transported by transporters who have obtained U.S. EPA ID numbers.	Preparation of off-site shipment of used oil by generators of used oil—**applicable**	40 CFR 279.24 TDEC 0400-1-11-.11(3)(e)

*The action/requirement/prerequisite identified has been included in this ARAR's tabulation due to the unique nature of this cleanup activity. DOE, EPA and TDEC agree that adherence to these actions/requirements/prerequisites will be determined solely by DOE, and that a DOE determination of consistency with these actions/requirements/prerequisites is not an action which may lead to or generate a formal or informal dispute.

Tables G-2 through G-11 Acronyms

ACM = asbestos-containing material
ALARA = as low as reasonably achievable
ANOVA = analysis of variance
ARAP = aquatic resource alteration permit
ARAR = applicable or relevant and appropriate requirement
ARPA = Archaeological Resources Protection Act of 1979
CERCLA = Comprehensive Environmental Response, Compensation and Liability Act of 1980
CFR = *Code of Federal Regulations*
CMBST = combustion
CWA = Clean Water Act of 1972
DEACT = deactivation
DOE = U.S. Department of Energy
DOE M = Radioactive Waste Management Manual
DOE O = U.S. Department of Energy Order
DOT = U.S. Department of Transportation
EMWMF = Environmental Management Waste Management Facility

EP = extraction procedure
EPA = U.S. Environmental Protection Agency
FEMA = U.S. Federal Emergency Management Agency
HMR = Hazardous Materials Regulations
HMTA = Hazardous Materials Transportation Act of 1975 (Amendments of 1976)
ID = identification number
LDS = leak detection system
LLW = low-level (radioactive) waste
NRC = Nuclear Regulatory Commission
ORR = Oak Ridge Reservation
PCB = polychlorinated biphenyl
POLYM = polymerization
PPE = personal protective equipment
PQL = practical quantitation limit
RCRA = Resource Conservation and Recovery Act of 1976
RORGS = recovery of organics
SHPO = State Historic Preservation Officer
TBC = to be considered
TC = toxicity characteristic
TCA = Tennessee Code Annotated
TDEC = Tennessee Department of Environment and Conservation
T&E = threatened and endangered (species)
THPO = Tennessee Historic Preservation Officer
TN = Tennessee
TSCA = Toxic Substances Control Act of 1976
TWRA = Tennessee Wildlife Resources Agency
U.S. = United States
USC = *United States Code*
USGS = U.S. Geological Service
UTS = universal treatment standards
WWTU = wastewater treatment unit

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APPENDIX H:
ON-SITE DISPOSAL FACILITY
PRELIMINARY WASTE ACCEPTANCE CRITERIA

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CONTENTS

FIGURES

TABLES

ACRONYMS

ARAR	applicable or relevant and appropriate requirement
AWQC	ambient water quality criteria
BCV	Bear Creek Valley
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
COPC	contaminant of potential concern
DOE	U.S. Department of Energy
EBCV	East Bear Creek Valley
ELCR	Excess Lifetime Cancer Risk
EMDF	Environmental Management Disposal Facility
EMWMF	Environmental Management Waste Management Facility
EPA	U.S. Environmental Protection Agency
EPM	equivalent porous medium
FS	Feasibility Study
GCL	geosynthetic clay liner
HDPE	high-density polyethylene
HELP	Hydrologic Evaluation of Landfill Performance
HI	hazard index
K	hydraulic conductivity
K_d	solid-to-liquid partition coefficient
LDR	land disposal restrictions
LLW	low-level waste
M	million
MCL	maximum contaminant level
MEI	maximally exposed individual
MLLW	mixed low-level waste
MOC	Method of Characteristics
MSL	mean sea level
NT	Northern Tributary
ORR	Oak Ridge Reservation
PreWAC	preliminary Waste Acceptance Criteria
RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act of 1976
RI	Remedial Investigation
SA	specific activity
SOF	sum of fractions

TMR	telescopic mesh refinement
U.S.	United States
UBCV	Upper Bear Creek Valley
USGS	U.S. Geological Survey
Y-12	Y-12 National Security Complex

1. INTRODUCTION

The purpose of this Appendix is to develop preliminary analytic concentration limits for contaminants of potential concern (COPCs), referred to as preliminary Waste Acceptance Criteria (PreWAC), which would meet the applicable risk and HI criteria specified in the remedial action objectives (RAOs), using fate and transport analysis based on a resident farmer exposure scenario for the proposed Environmental Management Disposal Facility (EMDF). This analysis provides the basis for demonstrating that the proposed EMDF conceptual design for the East Bear Creek Valley (EBCV) site (On-site Option 5) would be protective of human health and the environment and be a viable disposal option for most future Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) waste. In demonstrating the ability to meet RAOs that ensure protection of human health and the environment, the modeling conducted to define PreWAC serves to fulfill the CERCLA risk evaluation, which in this instance forecasts long-term effectiveness (protectiveness in terms of residual risk) of the On-site Disposal Alternative at the EBCV Site. Other On-site Disposal Alternative Sites have not been modeled, but if selected, would be modeled as presented in this Appendix. It is expected that PreWAC would be similar to those developed for the EBCV Site.

Future CERCLA waste will be generated from environmental cleanup and deactivation and decommissioning activities on the United States (U.S.) Department of Energy (DOE) Oak Ridge Reservation (ORR). The On-site Disposal Alternative in this Remedial Investigation (RI)/Feasibility Study (FS) evaluates potential sites in Bear Creek Valley (BCV) for disposal of future CERCLA waste after the Environmental Management Waste Management Facility (EMWMF) reaches maximum capacity. This Appendix presents detailed contaminant fate and transport modeling and PreWAC development to meet RAOs for the EBCV site, located adjacent to and east of the current EMWMF site. The analysis also identifies key model parameters and critical assumptions that could be affected by differences in hydrogeologic attributes among the BCV site options, and discusses the implications of these differences for facility performance, conceptual design, and PreWAC limits.

1.1 APPENDIX ORGANIZATION

The site conceptual model and exposure pathways are discussed in Chapter 2. PreWAC development and the computer models used are introduced in Chapter 3. Chapter 4 describes site-specific model development and assumptions for the EBCV site and risk/hazard modeling and calculations, and includes model sensitivity evaluations. Chapter 5 provides analytic PreWAC calculations and results, PreWAC adjustments for daughter products and to ensure protection of water resources, and compares EMDF results to the EMWMF Waste Acceptance Criteria. Chapter 6 lists references used in the analysis. Attachment A is a summary of COPC information and parameters used in modeling. Attachment B provides supplemental modeling information.

2. CONCEPTUAL SITE MODEL

The proposed EMDF would be an on-site, radioactive low-level waste (LLW) and mixed waste landfill for disposal of waste generated by cleanup of the ORR. The facility would be designed to receive wastes resulting from remediation of contaminated areas and demolition of contaminated buildings from CERCLA cleanup projects. The EBCV site has a conceptual design capacity of 2.5 million (M) yd^3. However, for purposes of contaminant transport modeling a total waste disposal volume of 2.2 M yd^3 is assumed, consistent with the capacity requirements determined for the On-site Disposal Alternative in Section 2, and the waste volume assumptions adopted throughout the RI/FS.

Figure H-1 illustrates the site plan of the proposed EBCV Site. The EMDF conceptual design for the EBCV site is described in Section 6.2 of the RI/FS and site characteristics are described in Appendix E. Summary information about the EBCV site characteristics, conceptual site model, risk exposure pathways, receptor, receptor location, and risk criteria is provided below. Additional information on all BCV Site Options is provided in Appendix E, Description of Bear Creek Valley and Proposed Sites. If the selected CERCLA waste disposal alternative includes on-site disposal at one or more sites other than EBCV, appropriate modifications to the conceptual site model, contaminant transport modeling, risk exposure scenario, and calculated PreWAC will be made as necessary during the CERCLA remedial design effort.

2.1 EBCV SITE DESCRIPTION

The EBCV site lies on the southern slopes of Pine Ridge between Bear Creek Northern Tributary (NT)-2 and NT-3. (Refer to Appendix E Figure E-1 for a map of the Bear Creek watershed and the EBCV Site). Bear Creek is roughly 1,100 ft south of the site at the nearest point. In the vicinity of the site, the elevation of Pine Ridge ranges from 1,180–1,260 ft above mean sea level (MSL). The elevation of the BCV floor ranges from about 940–1,000 ft MSL. Bear Creek flows southwestward from its headwaters for approximately 4.5 miles along the BCV axis, and then turns northward, cutting through a water gap in Pine Ridge to flow into East Fork Poplar Creek. The drainage area of BCV is approximately 5.2 square miles (Robinson and Johnson 1995). Most of the tributaries of Bear Creek originate along the flanks of Pine Ridge.

The stratigraphic section in BCV includes rocks ranging in age from early to late Cambrian. The three rock sequences in the BCV (Rome Formation, Conasauga Group, and Knox Group) comprise a complex stratigraphic assemblage of shales, limestones, dolomites, siltstones, and sandstones (DOE 1998a). A more detailed description of EBCV site geology is provided in Appendix E.

The early Cambrian Rome Formation, which is the oldest unit exposed in the site area, outcrops on the ridge top of Pine Ridge and like all the formations in BCV dips typically 45° to the southeast beneath BCV. The Rome Formation consists of variegated shale, interbedded with siltstone, sandstone, and minor amounts of dolomite. Overlying the Rome Formation, and underlying the southern slope of Pine Ridge, is the middle to late Cambrian Conasauga Group, a sequence of primarily shales with some interbedded limestones and dolomites. Within BCV, the Conasauga Group is subdivided into six formations: Pumpkin Valley, Rutledge, Rogersville, Maryville, Nolichucky, and Maynardville. Of these formations, only the Pumpkin Valley through Maryville formations directly underlie the conceptual facility footprint at the EBCV site. The Maynardville Formation, composed mostly of limestone, underlies the lowest portions of the valley floor south of the EBCV site. The Knox Group of late Cambrian is composed primarily of massive, siliceous dolomite that forms Chestnut Ridge on the south side of BCV.

Small-scale geologic features, such as fractures in clastic formations and solution features primarily in the Maynardville, are a major factor in ground water movement through the formations underlying the BCV. Master fractures may exist; however, extensive conduit systems are not likely given that shales and shaley carbonates are the dominant lithologies underlying the southern slope of Pine Ridg. These bedrock features provide the pathways for ground water flow through geologic formations, such as shales and limestones, which typically have little intrinsic permeability. Fractures occur in all stratigraphic units as a result of tectonic activity and geostatic relief, and are the most pervasive ground water transmitting feature on the ORR (Hatcher et al. 1992). The most prominent and well-developed fracture sets are oriented parallel to geologic strike and result in dominant strike-parallel ground water flow paths. Fracture aperture width and frequency generally decrease with depth in all formations and thus restrict the depth of active ground water circulation. The unconsolidated materials, or regolith, overlying bedrock in the EBCV site include a thin topsoil layer underlain by a clayey residuum and bedrock remnants and weathered bedrock (saprolite) above less weathered to unweathered variably fractured bedrock. Porous unconsolidated colluvium and alluvium occur as shallow surficial mixtures of clay, silt, sand, and gravel along and adjacent to the tributary valley floors at the EBCV site.

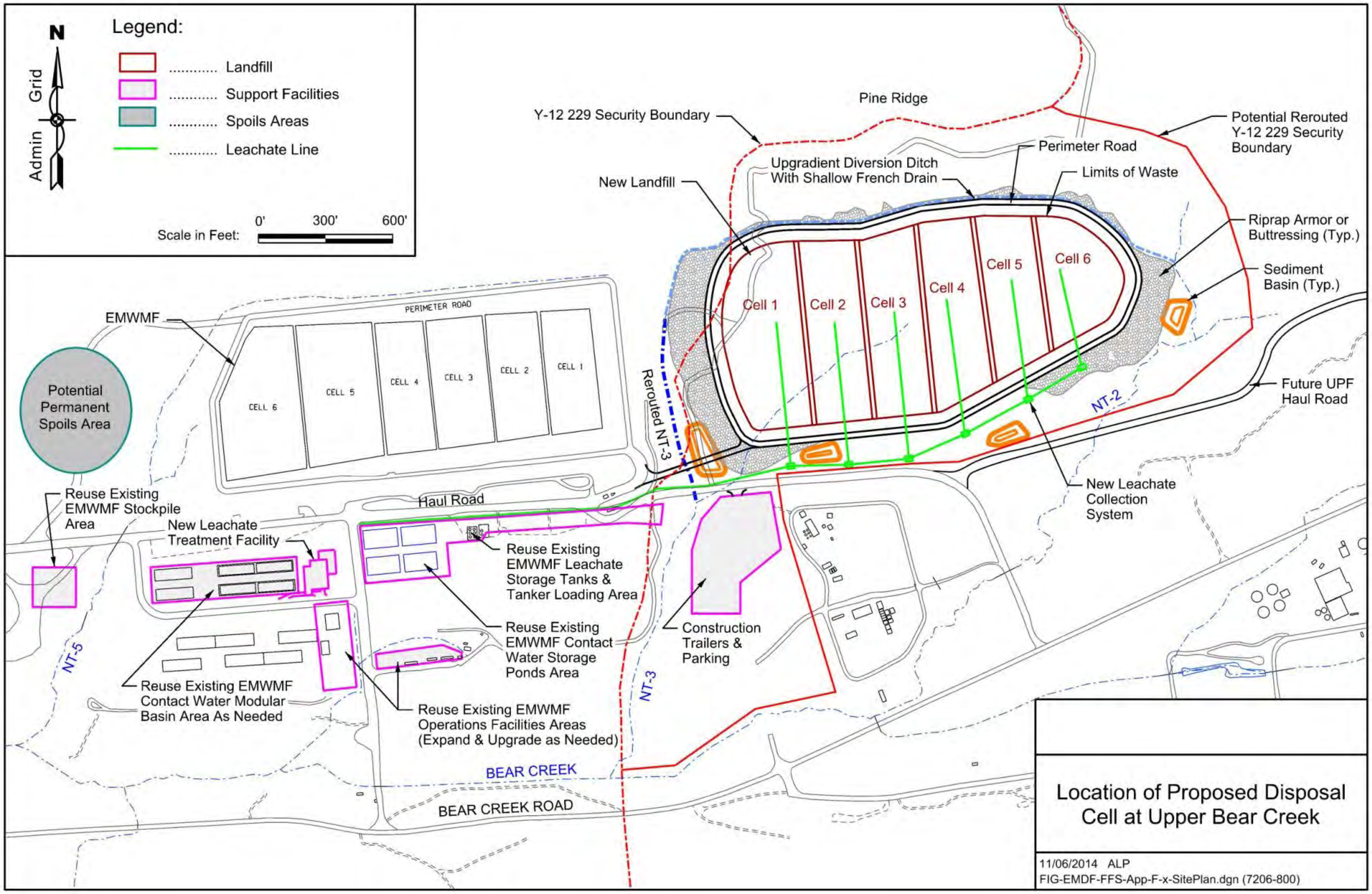


Figure H-1. Conceptual Layout of the Proposed EMDF in East Bear Creek Valley

Within BCV, the majority of water flow occurs primarily within the upper 100 ft of the aquifer system (Solomon et al. 1992). Ground water flow at and near the EBCV site generally follows surface topography and moves from higher upland areas such as Pine Ridge and subsidiary ridges to lower elevation valley floors where tributary streams convey surface water runoff and ground water discharge toward Bear Creek. Shallow to intermediate ground water flow converges toward the valley floors of NT-2 and NT-3 within the EMDF conceptual footprint. According to the subsurface hydrologic framework of Solomon et al (1992), ground water flux occurs predominantly via a near surface stormflow zone that may account for as much as 90% of the estimated subsurface water flux with relatively rapid discharge to streams and valley floors after rainfall events. Ground water that is not diverted laterally via the stormflow zone moves through preferential pathways in the underlying vadose zone to a water table interval that transmits 8% or more of the estimated ground water flux. Below the water table interval, the intermediate ground water interval accounts for <2% of the estimated ground water flux. The deep ground water interval accounts for <1% of the estimated flux. The decreasing ground water flux is attributed to the decrease in the effective porosity and permeability of the regolith and weathered and unweathered bedrock with depth (refer to Appendix E for additional details related to site hydrogeology and the site conceptual model). Documented hydraulic conductivity and ground water flow rates decrease progressively from the stormflow zone to the water table interval and into the intermediate and deep intervals of the saturated zone as the number, width, density and interconnectivity of fractures decreases. The occurrence and movement of ground water in the bedrock is closely related to the presence of bedding planes, joints, and fractures, and of solution cavities within carbonate beds of the Maynardville Limestone and Copper Ridge Dolomite. In general, ground water in the bedrock occurs under water-table conditions but becomes increasingly confined with depth. Downward ground water flow occurs along the flanks of Pine Ridge and Chestnut Ridge, whereas upward hydraulic gradients occur deeper in the subsurface and further downslope at ground water discharge zones along the valley floors.

BCV hydrogeologic units behave as an anisotropic system in all three dimensions, as evidenced by the elongated drawdown along strike direction observed during pumping tests and the spatial distribution of contaminant plumes and ground water tracers. The anisotropic nature of hydraulic conductivity associated with the bedrock underlying BCV results from the orientation and intersection of fractures, joints, and/or bedding planes. Due to this anisotropy, a large portion of ground water flow moves primarily along strike (i.e., east to west) with discharge along topographically lower tributaries or fractures that trend perpendicular to strike and eventually flow into Bear Creek and the Maynardville Limestone.

2.2 CONCEPTUAL MODEL AND EXPOSURE PATHWAYS

Development of a conceptual model of the site is necessary prior to evaluating the likely impact of potential contaminant releases from the proposed EMDF. A conceptual site model identifies the key elements of fate and transport, which include the media that contaminants may move through and the receptor(s) that could become exposed to such contaminants. The primary pathways for contaminant migration are ground water and surface water that could be impacted by leakage of contaminants from the EMDF. Ground water modeling used to simulate future contaminant migration treats the subsurface material as an equivalent porous medium (EPM), meaning that while flow actually occurs in both pores and fracture networks, at the scale of the model these can be represented as a single, equivalent Darcian-flow system. While the conceptual site model and EPM approach are a simplification of the ground water flow and contaminant transport processes, they capture the primary controls on these processes for purposes of estimating risk to human receptors. See Section 2.2 of Appendix E for additional geological information about the conceptual site model for the EMDF.

Figure H-2 shows the conceptual disposal cell, leachate movement, and generalized ground and surface water flow paths in the area of concern. Contaminant migration pathways include leachate movement through the waste, liner, and geologic buffer; through the vadose zone below the landfill; and into ground water and surface water. After closure of the disposal cell and degradation of synthetic components in the cap and liner, water is able to infiltrate the waste and leach contaminants from the waste. Contaminants would then migrate vertically through the unsaturated (vadose) zone and into the ground water (saturated) zone where they could be transported horizontally to a nearby well and also discharged to surface water. The conceptual site model assumes that most of the ground water flow occurs in the upper part of the soil and bedrock system, with discharge at nearby springs and seeps and into Bear Creek and its tributaries, such as NT-2 and NT-3 at the EBCV site.. The modeling and PreWAC development process is centered on estimating the risks related to contaminant exposure for a defined hypothetical residential receptor, a maximally exposed individual (MEI), which is the most conservative exposure scenario and land use assumption. Ground water from the well is assumed to be used for drinking water, and surface water is assumed to be used for watering livestock and irrigating crops, resulting in further uptake by the MEI from consumption of crops, milk, and meat. Development of the analytic PreWAC is based on an evaluation of this hypothetical residential exposure scenario.

An inadvertent intruder (e.g., someone digging through the final cap and being directly exposed to the waste after landfill closure) will be examined as part of the DOE O 435.1 compliance.

2.3 HYPOTHETICAL RECEPTOR

For the proposed EMDF, concentration-based “analytic” PreWAC are developed assuming a hypothetical resident farmer receptor as the MEI. The receptor scenario involves a family of four using ground water from a well between the facility and Bear Creek for domestic needs and surface water from Bear Creek for agricultural purposes. In accordance with current practices in Tennessee, the upper, more active weathered bedrock part of the unconfined aquifer (nominally a 30–50 ft stratum between the water table and competent bedrock) would not be used for domestic water supplies. Therefore, the well configuration assumes that the shallow weathered bedrock and the top of the competent bedrock are cased to approximately 60 ft and the well is screened an additional 90 ft below the casing as shown in Figure H-2. An average of 240 gallons per day is pumped from the well, based on domestic needs of a family of four.

The contaminant leaching/transport analysis and exposure conceptual model is presented in Figure H-2. For a rural residential farmer (who represents the MEI) there is a potential for exposure to contaminated media through the following activities:

- Ingestion of ground water from a domestic well.
- Consumption of home-grown vegetables/fruits irrigated with surface water.
- Consumption of milk and meat from livestock drinking surface water and fed with vegetation irrigated using surface water.

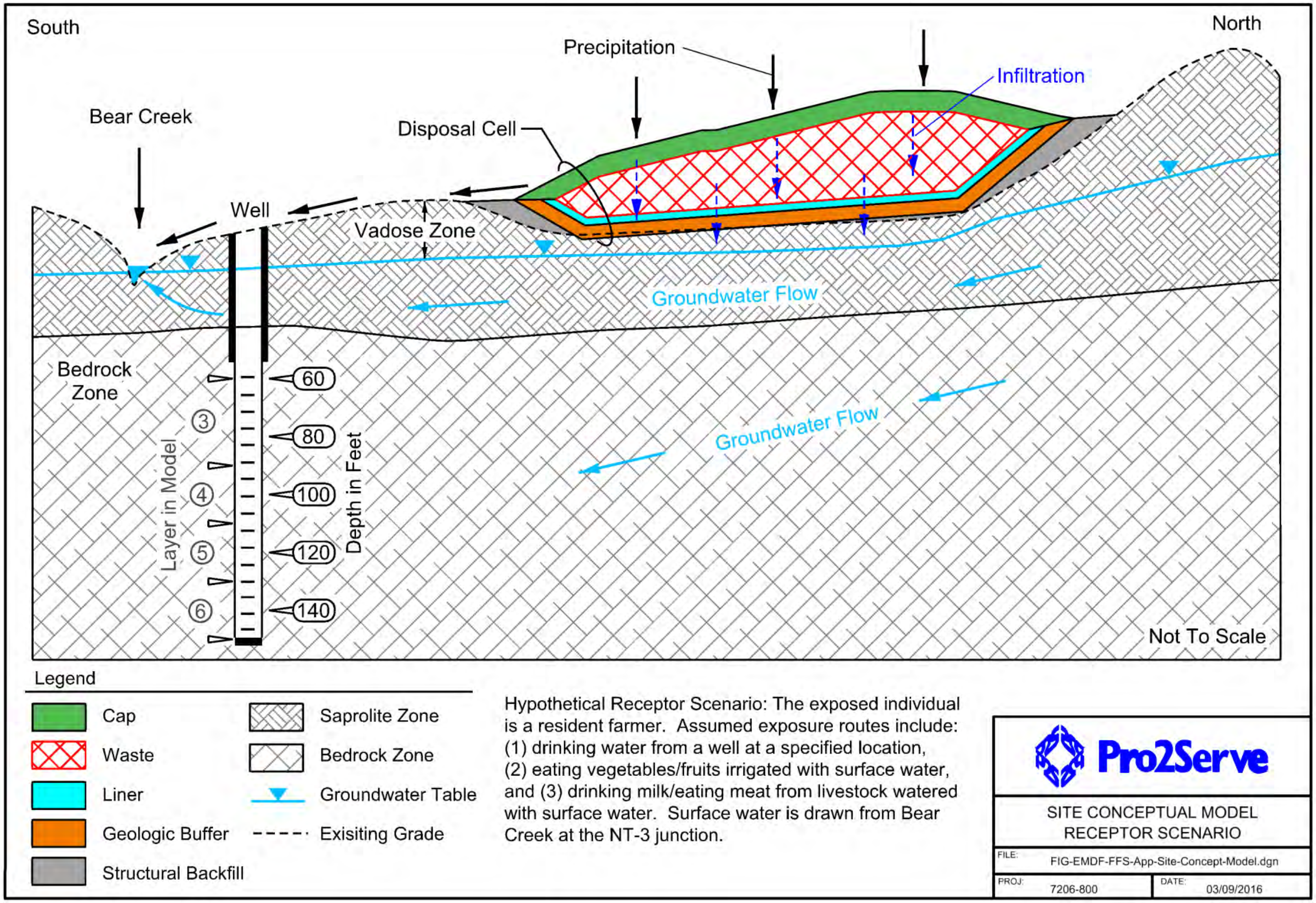


Figure H-2. Conceptual Site Model and Hypothetical Receptor Scenario

2.4 RECEPTOR LOCATION

A further key assumption in the resident scenario development and risk evaluation is the location of the hypothetical receptor. As this is the location at which the On-siteDisposal Alternative must meet the CERCLA defined risk criteria (e.g., 10^{-4} to 10^{-6} Excess Lifetime Cancer Risk [ELCR]), it is appropriate to look to CERCLA guidance on placement of the future hypothetical receptor. Per The U.S. Environmental Protection Agency's (EPA's) *Risk Assessment Guidance for Superfund Volume I Human Health Evaluation manual (Part A)* [EPA 1989], this placement or location is the "exposure point." This is the point where MEI contact with the highest contaminant concentration is made "if the site is currently used, if access to the site under current conditions is not restricted or otherwise limited (e.g., by distance), or if contact is possible under an alternate future land use." The EBCV site is within Zone 3 of Bear Creek with a future land use designation of "DOE-controlled Industrial Use," where access is currently restricted by DOE, and for the foreseeable future will be under DOE control as described in the BCV Phase I Record of Decision (DOE 2000). This future land use designation has been supported and approved by public stakeholders in the End Use Working Group (documented in the *Final Report of the Oak Ridge Reservation End Use Working Group*, July 1998). Accordingly, the nearest possible exposure point for a future hypothetical resident, and point of highest expected concentration based on ground water and surface water flows, would be the intersection of the "DOE-controlled Industrial Use" Zone 3 boundary with Bear Creek shown in Figure H-3, approximately 1.5 miles to the west of the EMDF.

Ultimately, a much more conservative approach is taken, and the receptor well location assumed for EBCV (Figure H-3) is located at a more proximal location to the landfill. The drinking water well is assumed to be 100 m from the edge of the waste at the location of maximum contaminant concentration, consistent with the MEI assumption. An important consideration for the surface water point of exposure is to assume a location that would provide the most consistent annual surface water flow. A surface water exposure location on Bear Creek at the junction of tributary NT-3 was selected because year-round flow is more typically encountered there than in surface water tributaries closer to the landfill.

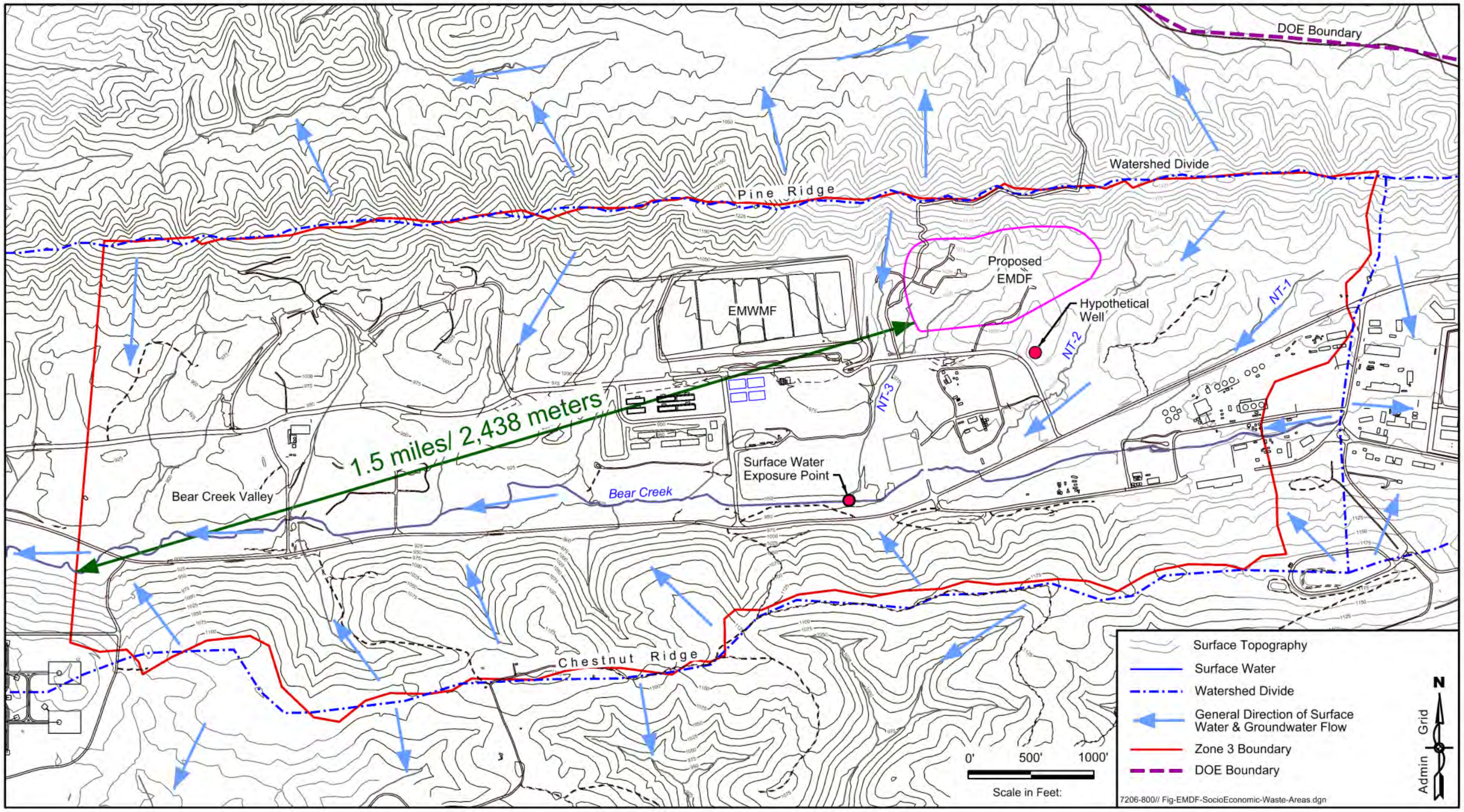


Figure H-3. EBCV Site Location and Zone 3 (DOE-controlled Industrial Use) Boundaries

2.5 RISK CRITERIA AND TIMEFRAMES FOR PREWAC DEVELOPMENT

DOE performed this analysis of the proposed low-level waste disposal facility performance with limited reliance on long-term maintenance and the man-made components of the landfill (i.e., geosynthetics). The risk criteria and performance timeframes utilized to develop PreWAC are summarized in Table H-1. For radiological and hazardous COPCs predicted to peak in ground water or surface water within a compliance period of 1,000 years beginning at closure of the landfill, PreWAC are derived to meet carcinogenic risk or hazard index (HI) limits and to ensure protection of water resources, as described below. For radionuclides predicted to peak between 1,000 and 2,000-years post-closure, PreWAC are set to meet carcinogenic risk limits that are an order of magnitude higher (less restrictive) than limits for radionculides predicted to peak within the 1,000 year compliance period. For radioisotopes predicted to peak after 2,000-years post-closure, preliminary administrative limits based on modeling exposures at 100 m have been assigned, considering DOE, International Commission on Radiological Protection, and proposed Nuclear Regulatory Commission exposure limit guidelines. As preliminary limits, these values are subject to modification prior to finalization in the WAC Attainment (Compliance) Plan. For non-radiological COPCs other than Uranium predicted to peak after 1,000 year post-closure, waste treatment to meet land disposal restrictions (LDR) for hazardous waste per Resource Conservation and Recovery Act of 1976 (RCRA) regulations will ensure protectiveness, rather than PreWAC derived to meet risk or hazard-based criteria. There is no RCRA LDR limit for for disposal of uranium as a hazardous element, therefore HI-based PreWAC for uranium are derived to meet HI ≤ 3.

Table H-1. Risk and DoseHI-based Criteria for EMDF PreWAC Development

Modeled Time to Peak Exposure	Type of COPC	
	Radionuclides	**Hazardous elements and chemical compounds**
< 1,000 years	ELCR = 10^{-5}	ELCR = 10^{-5} and/or HI ≤ 1
	Modeled concentrations meet MCLs in ground water and AWQCs in surface water	
> 1,000 and < 2,000 years	ELCR = 10^{-4}	Compliance with RCRA regulations (LDR) to ensure protective disposal of hazardous waste. HI ≤ 3 for uranium (peak > 10,000 yr).
> 2,000 years*	Model-based exposure limits	

*PreWAC were not derived for COPCs with model predicted peak times greater than 1 million years, due to the extreme uncertainty in deterministic predictions for such long time scales

To calculate analytic PreWAC, the proposed EMDF was conceptualized as one large waste cell containing 2.2 M yd^3 of waste with a uniformly distributed unit concentration of a single COPC at closure. Risk posed to the receptor for each COPC was calculated based on the model-predicted peak surface water and ground water concentrations given the assumed unit concentration in the waste. Analytic PreWAC (concentration-based units) were then determined by multiplying the ratio of the assumed unit concentration to the corresponding model-based risk (or dose, for hazardous COPCs) by the appropriate risk (or dose) goal. The appropriate risk goal is based upon the time of peak risk and the type of risk (e.g., radioactive or hazardous) being calculated, as given in Table H-1.

To ensure protection of water resources, for COPCs that peak within the 1,000 year compliance period, well water concentrations were checked against maximum contaminant levels (MCLs), or a 4 mrem/yr dose-based surogate, for radionuclides without an MCL, and PreWAC were adjusted if necessary to ensure that MCLs would be met. A similar PreWAC adjustment based on predicted surface water concentrations was made if necessary to ensure that COPCs that peak within the 1,000 year compliance period meet appropriate ambient water quality criteria (AWQC) for surface water.

Detailed description of thess methods and the results obtained follows in subsequent chapters.

3. PRELIMINARY WAC DEVELOPMENT AND MODELS

Information about the PreWAC development steps, modeling, and calculation methods is provided in this Chapter. An overview of the process is described in Section 3.1 and a description of the individual models used is provided in Section 3.2. Details regarding application of the models in this risk evaluation, assumptions, and site-specific parameters are covered in Chapter 4.

3.1 OVERVIEW OF PREWAC DEVELOPMENT

The PreWAC development process used for the proposed EMDF is similar to the process that was used for EMWMF. The contaminant leaching/transport analysis and exposure scenario includes the following processes:

- Infiltration of (rain) water into the waste cell.
- Leaching of contaminants from the waste into the underlying vadose and ground water zones.
- Transport of contaminants from the site to the receptor well and discharge to surface water bodies.
- Uptake by the hypothetical receptor via applicable ground water and surface water exposure routes.

Application of the hydrologic and contaminant leaching/transport models used to estimate exposure and risk, key model inputs, linkages among the models, and successive calculations used to develop the PreWAC are depicted in Figure H-4 and summarized in the remainder of Section 3.1.

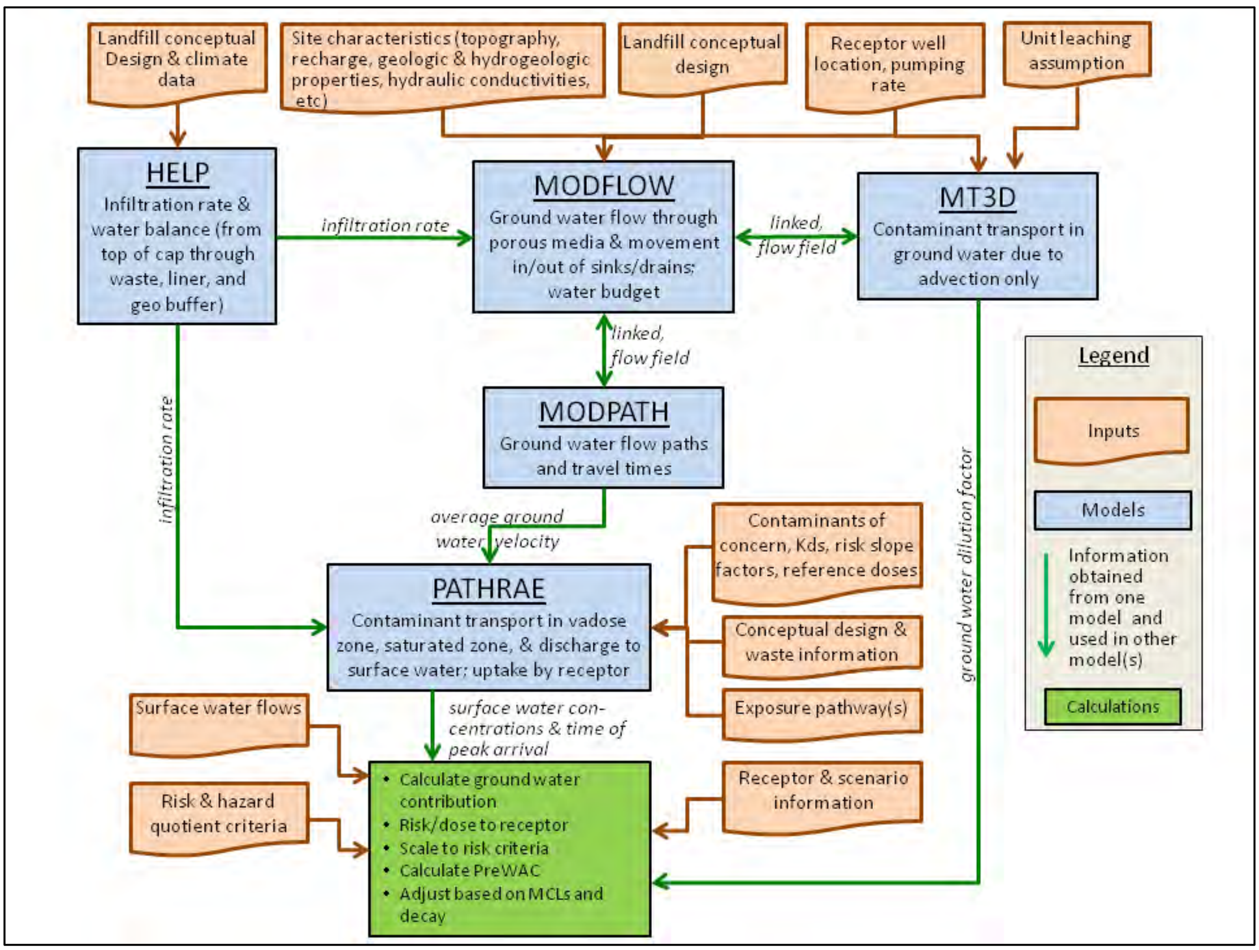


Figure H-4. PreWAC Model Linkage and Application

The exposure pathway from disposal cell to surface water was analyzed using the PATHRAE-HAZ/RAD semi-analytical models (Rogers and Associates Engineering 1995a and 1995b), a revised version of the original PATHRAE-EPA risk performance code developed for EPA (EPA 1987). Results from hydrologic models supply key input data for PATHRAE-HAZ/RAD modeling. The Hydrologic Evaluation of Landfill Performance (HELP) computer code (Schroeder et al. 1994) provides the infiltration rate through the landfill. MODFLOW simulation (McDonald and Harbaugh 1988) provides the ground water flow field and water table elevations, and MODPATH (Pollock 1989) provides the average ground water travel time as determined by the MODFLOW-defined flow fields. The MT3D fate and transport model (Zheng 1990) was used to simulate the pattern of contaminant dilution downgradient of the disposal cell. A brief synopsis of the sequence of modeling steps, key model inputs and linkages, and PreWAC calculations is given below; details are provided in Section 3.2 and Section 4 of this Appendix.

- Determination of water infiltrating the final cover, passing through the waste, liner, and geologic buffer, and entering the vadose zone and ground water was accomplished by mass balance analysis of precipitation and evapotranspiration, cap drain removal of water, and hydraulic flow using the Hydrologic Evaluation of Landfill Performance (HELP) computer code (Schroeder et al. 1994). Major inputs include the characteristics of each layer of the cover and liner systems as defined by the conceptual design. Characteristics of the final cover and liner system were adjusted to account for progressive component/media degradation in calculating the steady state infiltration rate for each stage of the landfill cover performance scenario.
- Ground water flow characteristics in the disposal cell area and ground water travel time to tributaries and Bear Creek were evaluated using the three-dimensional, finite difference, time-dependent MODFLOW and MODPATH models, respectively. Major inputs include the site characteristics (e.g. topography, hydrogeologic features and parameters, recharge rates including HELP-derived values, and assumed boundary conditions), receptor well location, and conceptual landfill design features.
- Contaminant leaching, transport through the vadose zone and contaminated ground water discharging to Bear Creek was simulated with the PATHRAE one-dimensional models. The PATHRAE predicted surface water concentration includes the effects of source depletion, radioactive decay, advection, saturated zone dispersion, contaminant specific retardation due to sorption in the vadose zone and shallow aquifer, and dilution by surface water. For purposes of relating risk to contaminant loading, the PATHRAE runs assume 2.2 M yd^3 of waste having a unit concentration of each COPC. The HELP-predicted infiltration/recharge rate, the MODPATH-based average ground water velocity, and Bear Creek flow rates were key PATHRAE inputs.
- Soil solid-liquid partition coefficients (K_d) for each contaminant were used for one-dimensional, time-dependent PATHRAE modeling of source zone leaching and chemically retarded (sorption-limited) contaminant transport in the vadose zone and saturated zone (see Attachment A to this Appendix).
- Three-dimensional, time-dependent patterns of ground water dilution due to advection only (relative to an assumed unit leachate concentration) were simulated using the MT3D model (Zheng 1990) in conjuction with MODFLOW. The modeled three-dimensional ground water dilution field was used to determine the location of maximum contaminant concentration at a distance of 100 m from the waste boundary, i.e. the assumed location of the receptor well.
- PATHRAE-predicted peak surface water concentration was multiplied by the ratio (DF_{creek}) of the annual volumetric water flux from the disposal cell to the average annual Bear Creek volumetric flow rate to approximate contaminant-specific leachate concentrations entering the saturated zone. This leachate concentration was then scaled by the MT3D ground water dilution factor for the receptor well (DF_{well}) to yield predicted ground water concentrations for each COPC.

- An equivalent uptake of surface water (EU_{sw}) that represents ingestion of contaminated agricultural products is calculated by the PATHRAE code, utilizing the model-predicted surface water concentrations, assumed receptor ingestion rates, and contaminant specific bioaccumulation factors for produce, animal forage, milk, and meat production.
- Peak annual uptake of each COPC via combined ingestion of (well) water and food is based on model-predicted EU_{sw}, assumed annual consumption of well water by the resident receptor, and the modeled contaminant concentrations in surface water and ground water. The peak annual uptake is multiplied by a water ingestion slope factor (ORNL 2014) to estimate an ELCR, and/or scaled by a reference dose (EPA 1989) to derive a HI, for each COPC.
- Based on the estimated ELCR or HI derived by assuming a unit concentration of each COPC, analytic PreWAC concentration limits for individual radiological and chemical constituents are calculated that ensure carcinogenic risk and HI toxicity goals are met. This calculation consists of multiplying the ratio of the assumed unit concentration to the corresponding model-based risk (or dose, for hazardous COPCs) by the appropriate risk (or dose) goal given in Table H-1. These limits correspond to the maximum permissible concentration of each constituent that could be placed in the facility if waste containing that single constituent were to occupy the entire disposal cell volume in a soil like matrix.

All COPCs were considered initially (see Attachment A to this Appendix). CertainCOPCs were removed from consideration under specific assumptions; for example, radionuclides with half-lives less than five years were removed from consideration since they decay to insignificant concentrations over relatively short time frames.

3.2 MODELS USED TO SUPPORT PREWAC DEVELOPMENT

The relevant HELP, MODFLOW/MODPATH, MT3D, and PATHRAE-HAZ/RAD models are briefly described in the following subsections. Details regarding application of the models for the site-specific risk evaluation in terms of assumptions and site-specific parameters used, and development of PreWAC are covered in Chapter 4.

3.2.1 HELP Model

The HELP model (Version 3.07, Schroeder et al., 1994) is used to evaluate the water budget for the proposed EMDF and estimate infiltration rates to ground water. This information is needed for ground water flow and fate and transport modeling as the precursor to risk/hazard analysis using PATHRAE-HAZ/RAD and ground water modeling using MODFLOW.

HELP is a quasi two-dimensional hydrologic model of water movement across, into, through, and out of landfills. The model accepts climate, soil, and design data, and uses estimation techniques that account for the effects of surface storage, snowmelt, runoff, infiltration, evapotranspiration, vegetative growth, soil moisture storage, lateral subsurface drainage, leachate recirculation, and unsaturated vertical drainage as well as leakage through soil, geomembrane, or composite liners. These input data are described in Section 2.0 of Attachment B to this Appendix. Landfill systems including various combinations of vegetation, cover soils, waste cells, lateral drain layers, low permeability barrier soils, and synthetic geomembrane liners may be modeled. The HELP model was developed to assist hazardous waste landfill designers and regulators in evaluating the hydrologic performance of proposed landfill designs. The program was developed to conduct water balance analyses of landfills, cover systems, and solid waste disposal and containment facilities. The model facilitates rapid estimation of the amounts of runoff, evapotranspiration, drainage, leachate collection, and liner leakage that may be expected to result from the operation of a wide variety of landfill designs.

3.2.2 MODFLOW and MODPATH Models

MODFLOW (Version 88, McDonald and Harbaugh 1988) and MODPATH (Version1.0, Pollock 1989) are used to evaluate the hydrogeologic conditions and parameters at the proposed waste disposal site. The parameters estimated include ground water flow path, travel time, ground water velocity, and flux rate.

MODFLOW is a modular, block-centered finite-difference ground water flow code developed by the U.S. Geological Survey (USGS). MODFLOW is capable of simulating both transient and steady-state saturated ground water flow in one, two, or three dimensions. MODFLOW calculates potentiometric head distribution, flow rates, velocities, and water balances throughout an aquifer system. It also includes modules simulating recharge, flow toward wells, and ground water flowing into drains and rivers. A number of different boundary conditions are available, including specified head, areal recharge, injection or extraction wells, evapotranspiration, drains, and streams or rivers. Aquifers can be simulated as unconfined, confined, or a combination of unconfined and confined. The finite-difference equations may be solved using a strongly implicit procedure, slice-successive over-relaxation, or preconditioned conjugate gradient method.

MODFLOW implicitly considers that the aquifer can be characterized as a porous media. The application of a porous media code (i.e., MODFLOW) to a fractured bedrock system, such as BCV, is termed the equivalent porous media approach. This approach assumes that the media is fractured to the extent that it behaves hydraulically as a porous media. Three dimensional representation of hydraulic properties within MODLFOW also provides flexibility to present fracture orientation and distribution. This approach is acceptable for BCV given the large scale of the model domain (948 acres) compared to the fractured nature of the underlying geologic units (on the order of centimeters to meters within BCV), and the degree of accuracy that is required to support the PreWAC analysis.

MODFLOW is widely used by the industrial, scientific, and governmental communities. The code has been rigorously tested and verified, and a variety of software tools are publicly available for graphical pre- and post-processing. Various MODFLOW models have been developed for the Oak Ridge area; these models were developed for the BCV RI/FS and EMWMF modeling and performance evaluations, and received tri-party approval under the CERCLA process. (Bailey 1988; BJC 2003, DOE 1996, 1998b, 2010).

MODPATH is a three-dimensional particle tracking program designed for use with output from steady-state simulations obtained from the MODFLOW results. MODPATH can be used to compute three-dimensional path lines, position of particles at specified points in time, discharge point coordinates, and total time of travel for each particle. MODPATH uses a semi-analytical particle tracking scheme. The method is based on the assumption that each directional velocity component varies linearly within a grid cell in its own coordinate direction. This assumption allows an analytical expression to be obtained describing the flow path within a grid cell. Given the initial position of a particle anywhere in a cell, the coordinates of any other point along its path line within the cell and the time of travel between them can be computed directly.

3.2.3 MT3D Model

The movement of contaminants from the waste cell to specified locations outside of the waste disposal site via ground water is simulated using MT3D (Version 1.0, Zheng, 1990), a three dimensional fate-transport model code.

MT3D is a comprehensive three-dimensional numerical simulation code that models the fate and transport of dissolved contaminants in complex ground water systems. MT3D calculates concentration distributions, concentration histories at selected points and hydraulic sinks (for example, extraction wells), and the mass of contaminants in the ground water system. The code can simulate three-dimensional transport in complex steady-state and transient flow fields and can represent anisotropic dispersion, source-sink mixing processes, first-order transformation reactions, and linear and nonlinear sorption. MT3D offers the user a choice of four solution options that make it uniquely well-suited for handling a wide range of conditions, one of which, the Method of Characteristics (MOCs) technique, is best-suited for handling advection-dominated problems.

MT3D is linked with the USGS ground water flow simulator, MODFLOW, and is designed specifically to handle advectively-dominated transport problems without the need to construct refined models specifically for solute transport. MT3D is the world's most popular three-dimensional solute transport code and has been used successfully to model thousands of sites. MT3D is widely accepted by regulators and the ground water consulting and research communities.

3.2.4 PATHRAE-HAZ/RAD Model

PATHRAE-HAZ/RAD (Version 2.2d, Rogers and Associates Engineering, 1995a and 1995b), is a family of computer codes capable of assessing multiple transport pathways for hazardous/radiological contaminants that have the potential to impact human receptors. PATHRAE-HAZ/RAD was originally developed for EPA (PATHRAE-EPA) to use in preparing standards for management of LLW (Rogers and Hung, 1987). PATHRAE-HAZ/RAD can be used to estimate risks and doses to humans from possible releases and subsequent transport of contaminants through multiple pathways from land disposal units containing chemical and radioactive wastes. The code can be used to calculate risks at specified points in time and peak risks (in time) to individuals at any number of key locations inside or outside the boundaries of a disposal facility.

The PATHRAE-HAZ/RAD code is available in the public domain. The model performs similar tasks to other pathway analysis codes, such as RESRAD (Yu et al. 1993). A benchmarking comparative study by a RESRAD team concluded that the doses predicted by RESRAD and PATHRAE codes for the inhalation and ingestion pathways were in relatively good agreement (Faillace, Cheng, and Yu, 1994).

One of the advantages of the PATHRAE-HAZ/RAD family of codes is their simplicity of operation and presentation of results, while still allowing the analysis of a comprehensive set of contaminants and pathways to human receptors. This allows the easy identification of parameters important for the protection of the public from potential releases.

One pathway modeled by PATHRAE-HAZ/RAD is movement of contaminants via ground water to surface water; this is the only pathway modeled with PATHRAE in this risk evaluation. (The ground water to well pathway is evaluated using the results from MODFLOW and MT3D codes, the PATHRAE surface water results, and calculations completed outside of the code.) This movement of contaminants via ground water to surface water results from the leaching of contaminants in precipitation that infiltrates through the cap and percolates through the waste. PATHRAE models one-dimensional vertical movement through a uniform vadose zone. Once the contaminants reach the saturated zone, their horizontal movement to the point of discharge into the surface water is modeled as one-dimensional movement through a uniform medium as well. For the migration of radionuclides through the saturated zone, the in-growth of daughter radionuclides can be calculated for any of seven radioactive decay chains; however, this feature is not used in the risk evaluation and development of PreWAC since only a single contaminant occupying the landfill is assumed. The analysis of decay products is conducted outside of the model (see Section 5.1.1.2 of this Appendix), and further PreWAC limits on parent nuclides are implemented where necessary.

Although PATHRAE-HAZ/RAD can also model movement of contaminants to a ground water well, it uses a simple one-dimensional flow assumption that would not be representative of the complex BCV ground water flow regime. Therefore, the contaminant movement in the aquifer system is modeled using the MODFLOW and MT3D codes. That output is combined with output from PATHRAE to evaluate total risk to a receptor from both surface water and ground water pathways.

4. DEVELOPMENT OF SITE-SPECIFIC MODELS

Development of a site-specific HELP model, site-specific ground water flow (MODFLOW/MODPATH) models, and application of the fate-transport models (MT3D and PATHRAE) for the proposed EMDF site are described, respectively, in the following Sections 4.1–4.4. Within each section, the site-specific model concept and parameters are described followed by the assumptions and bases of those assumptions for each model. The results determined by executing each model for the risk evaluation scenarios of this RI/FS are summarized at the end of each of Sections 4.1-4.4. Section 4.5 Presents model sensitivity evaluations and discusses the implications for modeling uncertainty and conservatism.

4.1 HELP MODEL APPLICATION

The landfill conceptual design, assumptions for executing the HELP model (Version 3.07, Schroeder et al. 1994), and model simulation and results for the proposed EMDF are described below.

4.1.1 Site-specific HELP Model Development

Site-specific input information for the HELP model is based on the conceptual design of the facility. A conceptual design for an on-site waste disposal facility at the EBCV site, developed in RI/FS Chapter 6, has been used to evaluate the facility's ability to effectively manage the volumes and types of waste (i.e., radiological and hazardous waste streams) projected to be placed in the cell. Because the facility would manage waste with RCRA, Toxic Substance Control Act of 1976, and radioactive contaminants, a number of elements associated with the various design requirements of the waste management regulations for each of these waste types are incorporated in the facility conceptual design.

The cover design of the proposed EMDF includes multiple layers designed to reduce water infiltration, minimize erosion, and prevent intrusion into the wastes. There are eight discrete layers incorporated into the cover design and eight layers incorporated into the basal liner design below the waste. Additional geotextile layers incorporated into the design to protect the geomembrane layers were not considered in the HELP model as they do not alter or retard the movement of infiltrating water. The conceptual design of these components for the proposed EMDF is consistent with the approved design for the currently operating EMWMF and with design applicable or relevant and appropriate requirements (ARARs).

The cell design includes the following key components:

- The total cover thickness is 11 ft and includes a 4 ft vegetation layer (a soil/rock matrix) on its top slope, underlain by a 1 ft filter layer (graded natural materials such as sand and gravel) and a 2 ft biointrusion layer (larger rocks and boulders), which is followed by a 1 ft lateral drainage layer. The filter, biointrusion, and drainage layers will be constructed of siliceous rock that is not easily degraded. Combined, these four layers simultaneously provide a robust medium to support root systems in the upper layer, drain away water to remove the chance for deeper root penetration, and create a significant barrier to deep root development. The biointrusion layer would inhibit penetration by humans, burrowing animals, and plants. The upper portion of the cover further prevents long term erosion and protects the underlying clay barrier layers from the degrading effects of desiccation and the freeze-thaw cycle.
- The cover includes a composite barrier layer that consists of a 40 mil thick high density polyethylene (HDPE) geomembrane layer (HELP Model Layer 5) over a two-part 2 ft thick low-permeability clay layer (Layers 6 and 7). The two-part clay layer is comprised of a 1 ft thick compacted amended clay layer (natural clay mixed with bentonite clay) over a 1 ft thick compacted natural clay layer beneath the bio-intrusion and drainage layers, presenting a significant barrier against water infiltration. The predicted combined effects of evapotranspiration in the vegetated layer, lateral transport from the cover by the drainage layer, and the presence of

the barrier layers result in negligible infiltration into the wastes. The bottom layer of the cover is installed as part of the interim cover; it is a granular contour layer, which provides a working/contouring surface over the waste (HELP Model Layer 8).

- The waste layer is assumed to consist of contaminated soil, cement-stabilized soil-like materials, cement-solidified waste, and debris (rubble). These wastes are assumed to be placed in lifts to minimize void spaces within the waste layer. Void spaces are filled with soil or soil-like material to provide structural strength and reduce settling due to waste compaction. For modeling purposes, all waste is conservatively assumed to be soil-like (see Section 4.4 of this Appendix).
- Underneath the waste, the liner system, made up of eight layers, includes a system to collect and remove any leachate generated during waste disposal operations, any water that may infiltrate the waste before final cover construction is completed, and any transient drainage that occurs shortly after the disposal cell is capped and closed. The liner also includes a secondary leak detection system to confirm that the cell liner system is functioning properly and to collect leachate if the primary system fails. When fully functional, these drainage layers will intercept all the water migrating from the waste.
- The liner design has a composite barrier layer consisting of a geomembrane overlaying a geosynthetic clay liner (GCL) layer, a composite layer consisting of a geomembrane overlaying a 3 ft low-permeability clay layer, and a 10 ft geologic buffer layer. For waste constituents, these layers present a barrier to contaminant leaching downward out of the cell. They also help prevent water from intruding into the waste from beneath the cell. The fully designed and fully functional landfill system will preclude infiltration of precipitation into the waste zone and will eliminate all ground water recharge beneath the facility footprint.

The liner and cover layers of the EMDF conceptual design are illustrated in Figure 6-9 in Chapter 6 of the RI/FS. Table H-2 summarizes the disposal cell layer profile and soil, waste, and geosynthetic material characteristics used in the HELP model.

4.1.2 HELP Model Assumptions

Assumptions for the HELP model are summarized here, along with justifications for those assumptions.

1. Table H-2 summarizes the landfill layers modeled for the conceptual design final cover (eight layers), waste profile (single layer), liner system (eight layers), and structural fill (single layer) for a total of 18 layers modeled. Assumed layer thicknesses, part of the conceptual design of the cover/liner systems, are given in the table. The 84 inch thickness of structural fill material is an average value for the facility foot print. This fill material is included in the HELP model because it is part of the vadose zone material thickness assumed for PATHRAE modeling, and because HELP-predicted water content for Layers 16-18 are used to derive the vadose water content input to PATHRAE. Layer types and soil texture types, which correspond to those defined in the HELP manual (Schroeder et. al. 1994), were assumed for each layer based on the layer function, and the HELP default soil properties for the assumed layer and texture types are given in the table as well. See Attachment B of this Appendix for additional layer parameters.
2. Table H-2 gives drain slopes and lengths for lateral drainage layers. These slopes and lengths were varied for both the liner and cap drainage layers in order to evaluate their effect on the infiltration rate based on the conceptual design. The cap drainage layer slope was varied between 5% and 25% and the length was varied between 100 ft and 400 ft. The liner drainage layer slopes were varied between 2.5% and 10% and then lengths varied between 100 ft and 400 ft. The differences in the resulting infiltration rates were negligible and demonstrated that for the EBCV site these parameters do not have a significant effect on the results of the HELP modeling.
3. The waste was assumed to be represented by a moderately compacted, loamy soil (texture type 22), see Table H-2.

4. Leachate characteristics, including pH and contaminant levels, will not significantly accelerate the normal degradation of HDPE geomembranes. Observations at the EMWMF indicate that water moving through the waste will form leachate with an average pH of 7.3 and a range from 5.69–9.13. Research suggests that pH values and contaminant concentrations in leachates from typical LLW and mixed low-level waste (MLLW) disposal facilities will not significantly accelerate degradation processes in HDPE geomembranes (Bonaparte et al. 2016).
5. Climatic conditions, including average precipitation and temperature, are assumed to be steady. Although current climate change science suggests that temperature and precipitation in East Tennessee are likely to increase in the coming centuries, there is considerable uncertainty in the magnitude of these changes. Evaluation of HELP model sensitivity to precipitation and performance scenario assumptions (Section 4.5 of this Appendix) suggests that increases in predicted cover infiltration due to increased precipitation are small relative to the effects of cover system drainage and clay layer degradation.
6. Information on growing season, average quarterly relative humidity, maximum leaf area index, evaporative zone depth, and latitude were taken from HELP's onboard database using the default values for the Knoxville, Tennessee, area (see Attachment B of this Appendix for tabulated values).
7. A 30-year record of daily average precipitation and temperature for the Oak Ridge area was provided as input for the HELP surface water balance model simulation.These data result in a HELP-simulated average annual rainfall total of 54.39 inches.
8. Performance scenario for engineered components of the disposal facility – The performance of the conceptual design (cover and liner specifically) was assumed to change over time. Four performance periods or stages were defined as follows:
    - Stage 1 (0-200 years): The best case, short-term performance of the cover/liner systems is assumed. All layers fully function. This stage is assumed to continue through the first 200 years following closure of the landfill. The cover system composite barrier (the compacted and amended clay layers and geosynthetic layers) in conjunction with the overlying lateral drainage layer serve to divert infiltrating water away from the underlying waste and transport the water to the perimeter drainage system, thus minimizing infiltration into the waste. Given the thickness of the proposed geomembrane (40 mil), the 200 year duration for Stage 1 is a very conservative assumption, supported by research that indicates the service life of much thinner HDPE geomembranes can exceed 500 years (Bonaparte et al. (2002) and that antioxidant depletion lifetime is extended with membrane thickness. Other studies suggest that pH values and contaminant concentrations in leachates from typical LLW and MLLW disposal facilities will not significantly accelerate degradation processes in HDPE geomembranes and that, given favorable temperature, moisture,and exposure conditions, HDPE geomembranes may function as designed for over 1,000 years (Benson 2014, Rowe and Islam 2009, Bonaparte, et al. 2002; Hsuan 2002; Koerner et al. 2011; Giroud 1984)
    - Stage 2 (200-500 years): HDPE geomembrane failure is assumed to occur at 200 years. The three geomembrane layers are assumed to be degraded and no longer function. This period is assumed to last until 500 years post-closure. During Stage 2, enhanced infiltration through the cover system and waste zone is largely prevented from reaching the saturated zone by the fully functioning leachate collection system and liner compacted clay layer. The HELP model Layers 5, 12, and 15 of the Stage 1 profile are removed from the model to predict the rates of cover infiltration and contaminated recharge beneath the disposal facility.
    - Stage 3 (500-1,000 years): Complete failure of the leachate collection and leak detection layers and the GCL in the liner system is assumed to occur at 500 years post-closure. Layers 11 and 14 of the Stage 1 profile are designated as vertical percolation layers rather

than lateral drainage layers, and Layer 13 (the GCL) is eliminated from the profile. Partial erosion of the vegetated erosion control layer (Layer 1) is assumed to occur; Layer 1 thickness is reduced by 20%.

- Stage 4 (>1,000 years): Long-term degradation of cover system performance (i.e. decreased lateral drainage and increased infiltration) is represented by decreasing the saturated hydraulic conductivity (K) of the cover drainage layer by two orders of magnitude (from 3.0E-01 cm/s to 3.0E-01 cm/s) and increasing the K of the cover amended clay layer by a factor of 2, from 3.5E-08 cm/s to 7.0E-08 cm/s. Long-term erosion of the vegetated erosion control layer is assumed; Layer 1 thickness is reduced to 24 inches (50% of the Stage 1 thickness).

  The lower compacted clay layer (Stage 1 profile Layer 7) beneath the amended clay layer is assumed to remain below 7 ft of overburden for performance Stage 4. This clay barrier layer is assumed to retain it's hydraulic conductivity parameters based on the depth below ground surface, which ensures that there is no direct exposure to freeze-thaw conditions and no desiccation; no cracking/tunneling due to roots or burrowing animals/insects; little temperature or moisture variation; and that the layer is subjected to high pressure. Research has actually shown decreasing hydraulic conductivities with increased confining stress as is associated with significant overburden pressures (Boynton and Daniel 1985; Albrecht and Benson, 2001). This assumption is in line with what is recommended in DOE guidance concerning liner and cover performance based on the thought that degradation mechanisms affecting the compacted clay layer should be adequately addressed during the design process (SRNL 2014). While field studies have been published that demonstrate compacted clay is highly susceptible to environmental factors that can cause it to quickly degrade, those studies were performed on cover systems where the clay layer was quite shallow within the cover system, was under-protected from the environment, and lacked redundancy. Case studies cited as having cover systems that were effective at limiting infiltration had very thick surface layers over the compacted clay barrier, utilized drainage layers to help move water, and used geomembranes over the clay to create a composite barrier layer (Albrecht et. al 2006). The EMDF design contains these features.

Table H-2. EMDF Conceptual Design Profile and Material Characteristics for the HELP Model Stage 1 Profile

System	Layer #	Material/Description	Layer Type*	Layer Thickness (in.)	Soil Texture Type**	Total Porosity (vol/vol)	Field Capacity (vol/vol)	Wilting Point (vol/vol)	Saturated Hydraulic Conductivity (cm/sec)	Drainage Length (ft)	Drain Slope (%)
Final Cover	1	Top Soil/Rock Mix (vegetative/erosion control layer)	1	48	4	0.437	0.105	0.047	1.70E-03		
	2	Sand/Gravel (granular filter/drainage layer)	1	12	3	0.457	0.083	0.033	3.10E-03		
	3	Large rock/rip-rap (biointrusion layer)	1	24	1	0.417	0.045	0.018	1.00E-02		
	4	Gravel (lateral drainage layer)	2	12	21	0.397	0.032	0.013	3.00E-01	100	5
	5	HDPE -FML (geomembrane layer)	4	0.08	35				2.00E-13		
	6	Amended Compacted Clay (low permeability layer)	3	12	0	0.427	0.418	0.367	3.50E-08		
	7	Cover Compacted Clay (low permeability layer)	1	12	16	0.427	0.418	0.367	1.00E-07		
	8	Contour Gravel (waste surface layer)	1	12	21	0.397	0.032	0.013	3.00E-01		
Waste	9	Waste (assumed to be soil-like)	1	600	22	0.419	0.307	0.18	1.90E-05		
Liner	10	Protective Soil (layer protects liner)	1	12	26	0.445	0.393	0.277	3.7E-04		
	11	Drainage (Leachate collection system)	2	12	21	0.397	0.032	0.013	3.00E-01	100	2.5
	12	HDPE-FML (geomembrane layer)	4	0.08	35				2.00E-13		
	13	Geosynthetic Clay Liner [GCL] (low permeability layer)	3	0.24	17	0.75	0.747	0.4	3.00E-09		
	14	Geonet Leak Detection Layer (leak detection)	2	0.3	20	0.85	0.01	0.005	1.00E+01	100	2.5
	15	HDPE-FML (geomembrane layer)	4	0.08	35				2.00E-13		
	16	Compacted Clay Layer (low permeability layer)	3	36	16	0.427	0.418	0.367	1.00E-07		
	17	Soil Geobuffer (barrier layer)	1	120	26	0.445	0.393	0.277	1.90E-06		
Fill	18	Structural Fill Material	1	84	25	0,437	0.373	0.266	3.6E-06		

FML flexible membrane liner
GCL geosynthetic clay liner
*Layer type:
- 1 – vertical percolation
- 2 – lateral drainage
- 3 – barrier soil liner
- 4 – geomembrane layer

**Soil texture type and its characteristics are defined in HELP (Schroeder et. al. 1994)

4.1.3 HELP Model Results

It was assumed that performance of the system will degrade over time, represented by four stage performance scenario following closure of the EMDF. Performance of the proposed EMDF cell cover/liner system is analyzed using the HELP model, incorporating the assumptions and sequential changes in layer characteristics specified for the performancescenario. Gradual, progressive degradation of the geosynthetic materials and clay bariers over time is more likely than the discrete changes at specific points in time assumed in the performance scenario. However, for hydrologic and contaminant transport modeling to support landfill performance analysis and PreWAC development, the assumed step-function increase in infiltration is a sufficiently realistic approximation of progressive cover system degradation, given the conservative assumptions adopted for the performance scenario.

The HELP-simulated water balance at the surface of the disposal facility is identical for each stage of the performance scenario because the assumed precipitation inputs and cover surface characteristics do not vary over time. Average annual simulated values for components of the surface water balance are: precipitation (P) = 54.39 inches, surface runoff (R) = 0.69 inches, evapotranspiration (ET) = 30.90 inches. These values imply that average annual surface infiltration = P-R-ET = 22.81 inches. The fraction of this surface infiltration that is transferred through the cover system barriers and into the waste zone, and the fraction that passes through the waste and the liner system barriers to enter the underlying vadose zone varies according to the assumed cover and liner system characteristics for each stage of the performance scenario (Table H-3). These model results provide the key hydrologic input variable (percolation though the waste zone and recharge to the aquifer) for MODFLOW, MT3D, and PATHRAE modeling of contaminant leaching and transport from the disposal facility.

Table H-3 shows the results of HELP Model analysis for the assumed performance scenario. Section 2.0 of Attachment B to this Appendix provides additional detail about the HELP model.

Table H-3. HELP Model Assumed Parameter Values and Predicted Percolation Rates for Various Performance Stages

<table>
<tr><th colspan="3" rowspan="2">Key Help Model Assumptions and Results for Cover System and Liner System Components</th><th colspan="4">Performance Stage (Years after cell closure)</th></tr>
<tr><th>Stage 1 (0-200)</th><th>Stage 2 (201-500)</th><th>Stage 3 (501-1,000)</th><th>Stage 4 (>1,000)</th></tr>
<tr><td rowspan="6">Cover System</td><td rowspan="4">Cover Layer Assumptions</td><td>Protective Cover Thickness</td><td>4 ft</td><td>4 ft</td><td>3.2 ft (20% erosion)</td><td>2 ft (50% erosion)</td></tr>
<tr><td>Lateral Drainage Layer Hydraulic Conductivity</td><td>3.0E-01 cm/s</td><td>3.0E-01 cm/s</td><td>3.0E-01 cm/s</td><td>3.0E-03 cm/s</td></tr>
<tr><td>HDPE Geomembrane Function</td><td>Functional</td><td>Degraded</td><td>Degraded</td><td>Degraded</td></tr>
<tr><td>Amended Clay Hydraulic Conductivity</td><td>3.5E-08 cm/s</td><td>3.5E-08 cm/s</td><td>3.5E-08 cm/s</td><td>7.0E-08 cm/s</td></tr>
<tr><td rowspan="2">HELP Model Results (in/yr)</td><td>Lateral Drainage Collected</td><td>22.79</td><td>22.36</td><td>22.37</td><td>21.48</td></tr>
<tr><td>Percolation through clay barrier and into waste zone</td><td>0</td><td>0.43</td><td>0.43</td><td>1.32</td></tr>
<tr><td rowspan="8">Liner System</td><td rowspan="5">Liner Layer Assumptions</td><td>Leachate Collection Drainage Layer Function</td><td>Functional</td><td>Functional</td><td>Not Functional</td><td>Not Functional</td></tr>
<tr><td>HDPE Geomembrane Function</td><td>Functional</td><td>Degraded</td><td>Degraded</td><td>Degraded</td></tr>
<tr><td>Geosynthetic Clay Layer Function</td><td>Functional</td><td>Functional</td><td>Degraded</td><td>Degraded</td></tr>
<tr><td>Leak Detection Drainage Layer Function</td><td>Functional</td><td>Functional</td><td>Not Functional</td><td>Not Functional</td></tr>
<tr><td>HDPE Geomembrane Function</td><td>Functional</td><td>Degraded</td><td>Degraded</td><td>Degraded</td></tr>
<tr><td rowspan="3">HELP Model Results (in/yr)</td><td>Leachate Collection Layer Drainage</td><td>0.00076</td><td>0.39</td><td>0</td><td>0</td></tr>
<tr><td>Leak Detection Layer Drainage</td><td>0</td><td>0.0043</td><td>0</td><td>0</td></tr>
<tr><td>Percolation through compacted clay barrier</td><td>0</td><td>0.033</td><td>0.43</td><td>1.32</td></tr>
</table>

Note: Model layer function *Degraded* indicates the layer has been removed from the HELP profile for that performance stage. For lateral drainage layers in the liner system, *Not Functional* indicates that the layer type has been changed to vertical percolation in the HELP profile.

4.2 GROUND WATER FLOW (MODFLOW/MODPATH) MODELS APPLICATION

To develop required key input parameters to support analytic PreWAC development and future design of a potential new disposal facility, a site-specific ground water flow model for the Upper BCV (UBCV) area has been developed for the EBCV site based on the Bear Creek regional ground water flow model (DOE 1997) and more recent EMWMF models (BJC 2003, DOE 1998b, and 2010). The model was developed using MODFLOW (Version 88, McDonald and Harbaugh 1988), the ground water flow portion of the code, and MODPATH (Version 1.0, Pollock 1989), the particle tracking portion of the software.

Development of the original BCV flow model for the BCV FS (DOE 1997), including calibration and validation against field data, sensitivity analysis, and subsequent model refinement and application to the EMWMF site has been a multi-year effort, documented in the *Summary Report on the 2010 Environmental Management Waste Management Facility Groundwater Model and Flow/Fate-Transport Analyses, Oak Ridge Tennessee* (BJC 2010). Creation of the UBCV model for the current CERCLA Waste Disposal RI/FS is a continuation of this ongoing modeling effort, and relies upon the progressive model improvements and cumulative experience developed over time. Some of the pertinent parametrization and calibration efforts are described in Sections 4.2.1.3 and 4.2.1.4.

A telescopic mesh refinement (TMR) modeling approach was used to develop a refined UBCV model from the calibrated BCV flow model originally constructed by the Jacobs Environmental Management Team (DOE 1997). The TMR approach enables the user to develop a site-specific model using existing regional information and allows focus on areas of interest with increased model grid resolution and more accurate representation of site-specific features. The TMR approach utilizes the results from the calibrated regional flow model to initialize boundary conditions (constant heads) and model parameters in the TMR model. Further refinements of locations of streams and waste units were made after the site-specific flow model was constructed.

4.2.1 Site-specific MODFLOW/MODPATH Model Development

The UBCV model was developed in two stages. The UBCV model representing current site conditions (as of year 2012) was the first stage. The current condition model was compared to existing and current site-specific data (such as stream flow and ground water levels); model parameters were then adjusted to ensure model results corresponded to these actual measured conditions.

The current condition model forms the foundation for the EMDF future condition model that was constructed as the second stage of UBCV model development. The EMDF future condition model incorporates EMDF proposed facility conceptual design features to predict the long-term cell performance after disposal facility closure.

Thus construction of the disposal cell site-specific UBCV model consisted of the following steps:

1. <u>Establish model domain and dimensions.</u>

   The TMR method was used to develop the UBCV model from the calibrated BCV flow model (DOE 1997) by extracting boundary conditions, model layers, and model properties. A reduced grid cell size was used for the new model domain to improve accuracy.

2. <u>STAGE 1: Refine model domain and parameters to produce the current condition (2012) model.</u>

   To represent the detailed current site-specific features, the following refinements were made after the site-specific flow model domain was constructed.

   A. Refinement in the vertical direction was achieved by dividing the former Model Layer 1 into three separate layers and former Layer 2 into five separate layers to represent the current site conditions, to allow for future EMDF engineering features, and to support the risk/performance evaluation.

B. The refined and improved site-specific parameters used in extensive calibrated EMWMF models were incorporated into the UBCV model (e.g., ground water elevations).

C. Detailed adjustments were made to areas to smooth the transition along the model boundaries and parameter zones to represent the field conditions more precisely.

D. Parameters representing surface water features at the site (creeks and tributaries) were incorporated into the new model to represent the current condition model.

3. STAGE 2: Create the EMDF (future condition) model.

The future condition model was developed to provide required parameters for risk estimation and PreWAC development for the future on-site disposal facility.

A. EMDF design and post-closure topography for the EBCV site were incorporated into the future condition model to predict the flow conditions after disposal cell construction.

B. Parameters representing the construction/engineered features for the proposed EBCV site conceptual design were incorporated into the future condition model (e.g., the underdrain).

C. Future landfill performance parameters, such as HELP model-based long-term recharge rates through waste zone, were included.

4.2.1.1 UBCV Model Domain and Discretization

The UBCV model domain is the volume of earth represented mathematically by the model. The UBCV Model covers an area of 948 acres from east of the S-3 Ponds area at Y-12 to NT-6 (8,600 ft from east to west) and from the top of Chestnut Ridge to top of the Pine Ridge (4,800 ft from south to north). Figure H-5 shows the 2012 topography and UBCV (current condition) model domain. Figure H-6 shows the topography of the constructed EMDF that represents the future condition.

Model discretization refers to the assignment and alignment of the numerical cells in the model and the relationship of those cells to actual engineered and natural conditions. A uniform horizontal grid size of 10 ft × 10 ft is used for the model domain. There are a total of 4,540,800 cells in the UBCV Model, of which 3,572,049 are active in ground water flow.

The UBCV Model uses 11 model layers to reflect the vertical variation in the hydraulic properties at the site. The top of the model, Layer 1, reflects the topography for the current condition model (circa 2012) and proposed cell design topography around the EMDF for the future condition model. The first three model layers represent engineered design features, residuum saprolite and weathered bedrock zone. The top three model layers have variable thicknesses ranging from 15–25 ft. The bottom of Layer 3 corresponds approximately to the unweathered bedrock surface. Fractured bedrock is represented by Layers 4–8, each of which are 20 ft thick. Layers 9, 10, and 11 are 150 ft, 200 ft, and 300 ft thick, respectively, representing less fractured and less permeable deeper bedrock. Figure H-7 shows the vertical discretization for the future condition model along two cross sections that are shown in Figure H-6.

4.2.1.2 Model Boundary Conditions

The UBCV Model has a no-flow boundary at the top of Pine Ridge to the north of the proposed facility, at the top of Chestnut Ridge to the south, and at the ground water divide between BCV and Upper East Poplar Creek to the east (Figures H-5 and H-6). These boundaries approximate the natural ground water divide. The vertical base of the model is a no-flow boundary because minimal exchange of meteoric water with mineralized ground water (i.e., brine) occurs below this depth (see Section 2.3.3 in Appendix E). Constant head boundary conditions to the west were assumed based on a steady state simulation of the calibrated regional BCV ground water flow model. The model boundary was established at a sufficient distance from the EMDF site so as not to be affected by topographic alterations associated with disposal cell development.

The model incorporates Bear Creek and its tributaries, as well as site features for the EBCV concepttual design, such as ditches and channels, cut and filled areas, underdrain features, and French drains. The surface drainage features are represented in the model as drain cells (see Figure H-8). Drain cells allow ground water to discharge into a surface water body. Actual stream bottom elevations were assigned to the drain cells in the model.

As described in Section 6.2.2.4 of the RI/FS, landfill construction, operation, and long-term performance depend on maintaining the water table below the base of the landfill liner system. An underdrain is necessary for the EBCV site along the tributary channels and where there are springs and seeps within the facility footprint. The intent of this underdrain system is to provide a flow path for upwelling ground water immediately below the landfill and prevent ground water incursion into the liner system, since the tributaries are natural discharge areas for ground water. The conceptual layout plan for the underdrain is shown in Figure 6-12 of this RI/FS. The corresponding drain cell representation of the underdrain system in the UBCV model is shown in Figure H-8. In addition, a geomembrane-lined drainage ditch with underlying shallow French drain would be constructed along the upper (i.e., northern) side of the landfill to intercept and divert upgradient storm water and shallow subsurface storm flow away from the landfill. Further protection from ground water intrusion is provided by constructing the landfill base and geologic buffer above the seasonal high water table. Similar design considerations, including the need for engineered ground water drainage systems, will be necessary at the other BCV candidate sites.

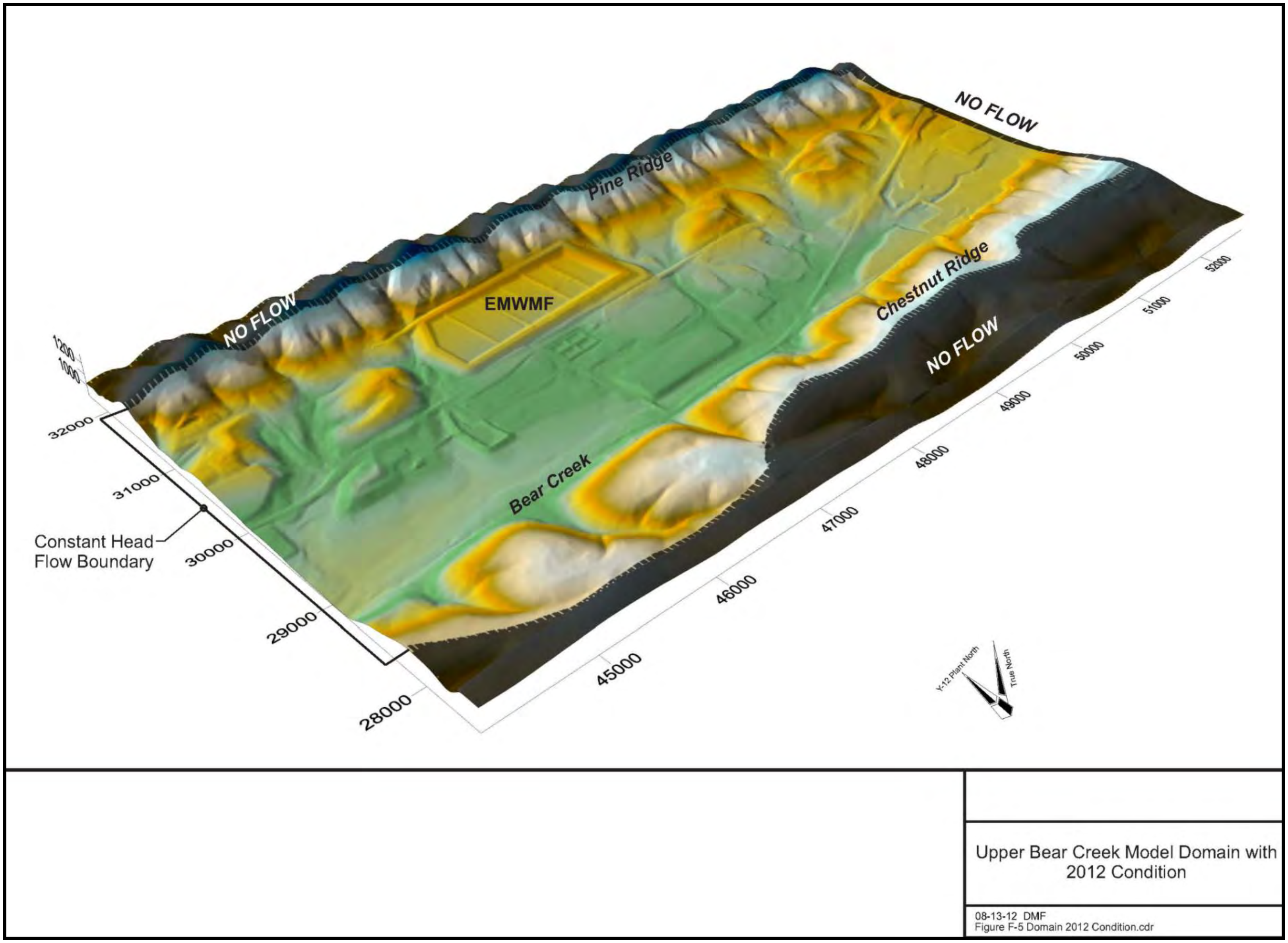


Figure H-5. Upper Bear Creek Valley Model Domain (Current 2012 Condition)

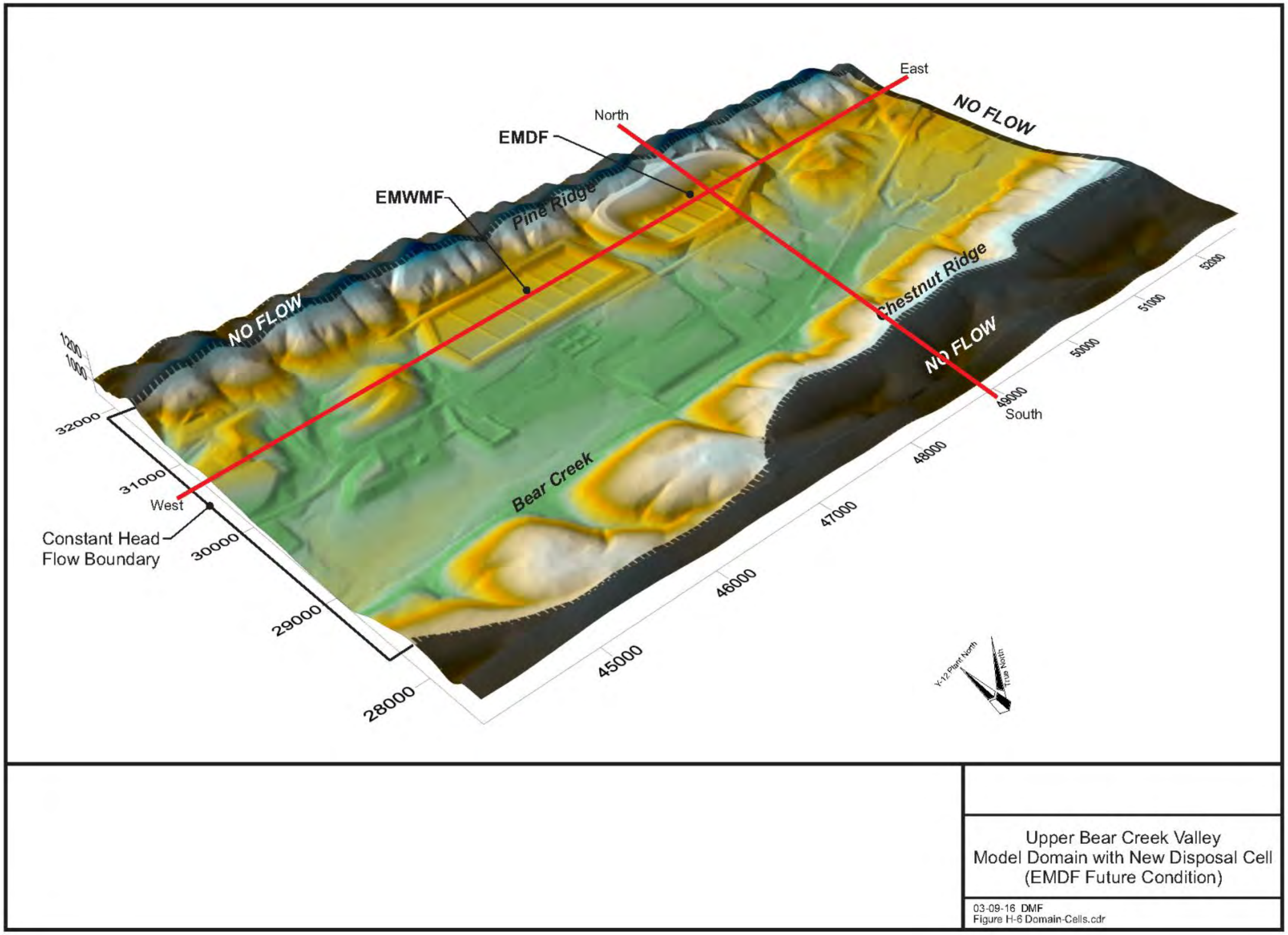


Figure H-6. Upper Bear Creek Valley Model Domain with New Disposal Cell (EMDF Future Condition)

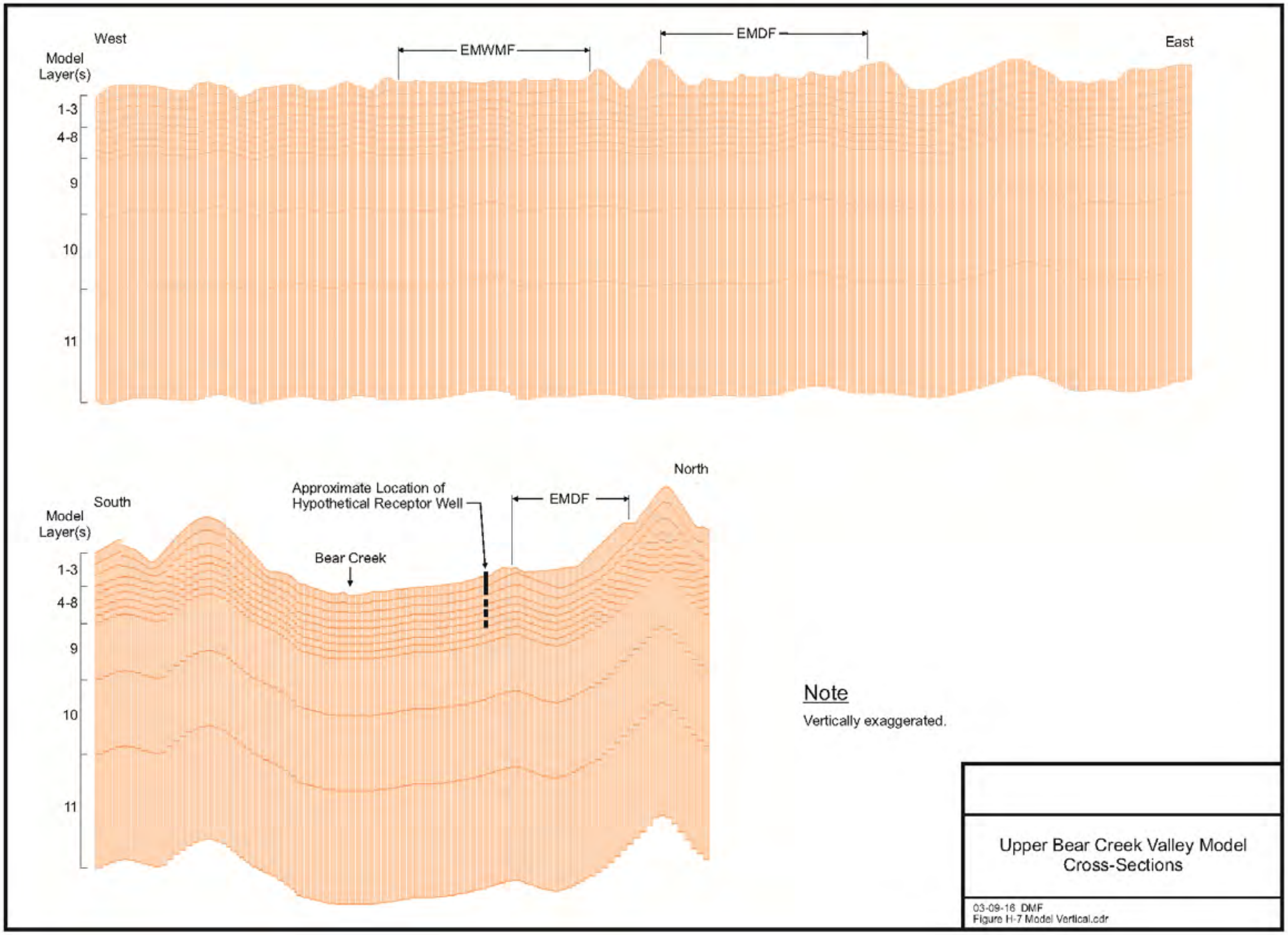


Figure H-7. Upper Bear Creek Valley Model Cross-Sections

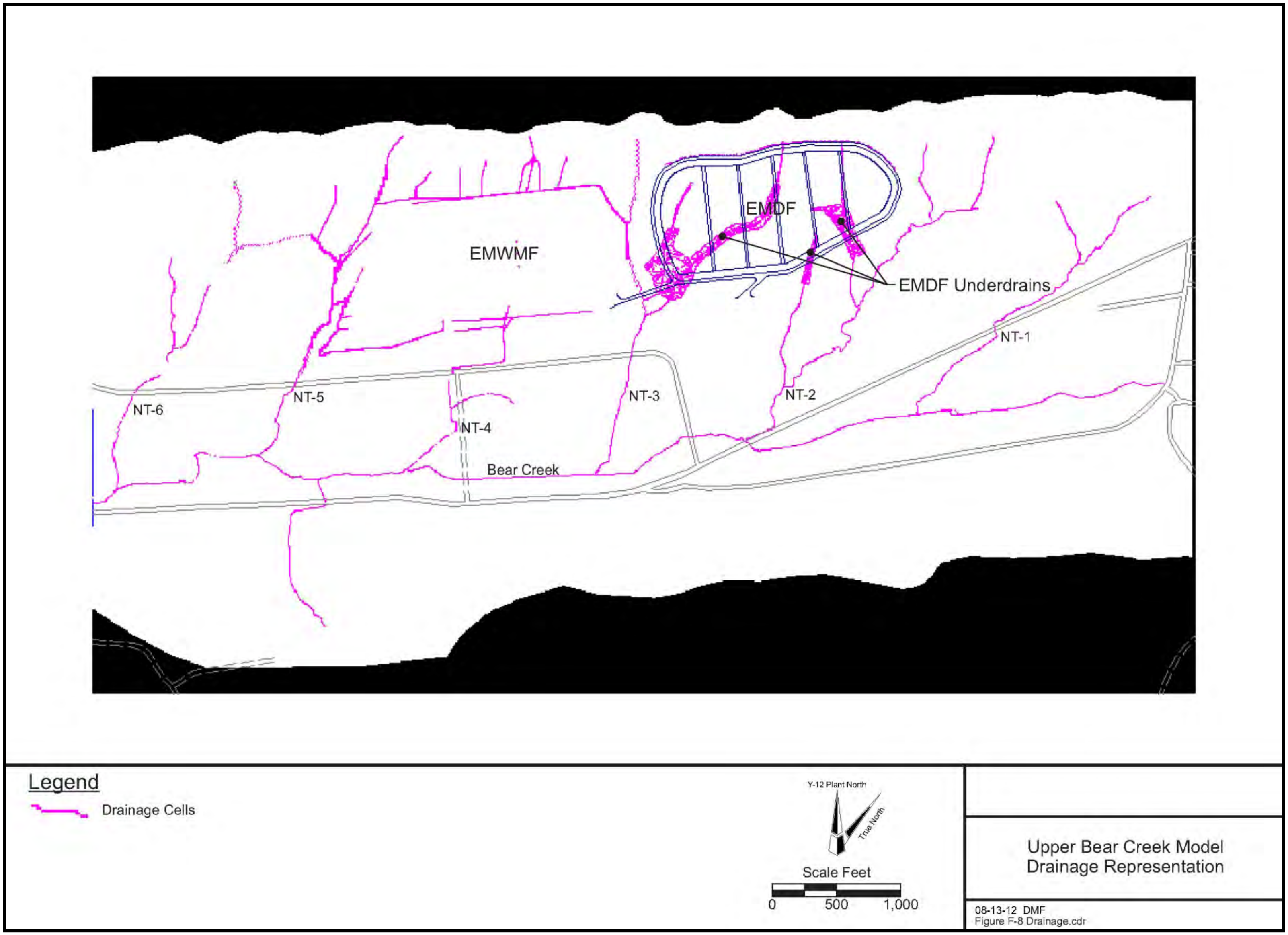


Figure H-8. Upper Bear Creek Valley MODFLOW Model Drainage Representation

Infiltration from precipitation is assumed to be the sole source of recharge to ground water for the site-specific UBCV Model, as the site is bounded on three sides by no-flow boundaries. Infiltration is precipitation minus runoff and evapotranspiration; and the recharge rate is a function of geologic media, surface slope, and vegetation. Several recharge rates were assigned in the model (see Figure H-9) corresponding to (1) natural recharge to the Maynardville Formation and Knox Group carbonates (2E-3 ft/day), (2) natural recharge to the Nolichucky shale (2E-3 ft/day), (3) natural recharge to the Conasauga Group shales and siltstones (1.6E-3 ft/day) and to Rome Formation sandstone (4.5E-3 ft/day), (4) reduced recharge through existing caps at former disposal sites (2.28E-4 ft/day), and (5) reduced recharge through the existing EMWMF in a future closed state (9E-5 ft/day). Recharge rates applied to the EBCV site footprint area vary over time per the assumed performance scenario and HELP model results. The four performance stages and corresponding recharge rates (see Table H-3) define four stress periods in the ground water model simulation. The constant recharge rate applied to the EMWMF footprint is also a HELP-predicted value, and corresponds to the performance stage 3 infiltration/recharge rate of 0.43 in. per year determined for the EBCV site conceptual design (Section 4.1.3).

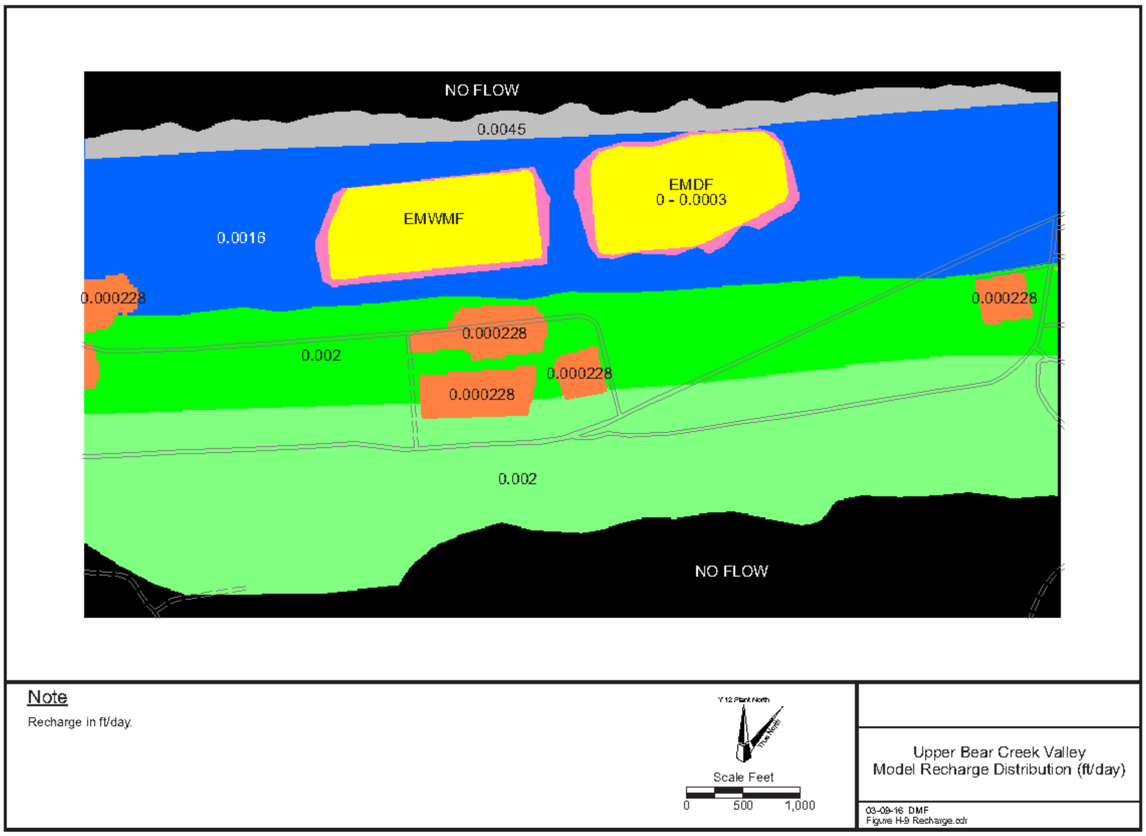


Figure H-9. Upper Bear Creek Valley Model Recharge Distribution (ft/day)

4.2.1.3 Hydraulic Conductivity Field

Six distinct hydraulic conductivity zones were used in the UBCV Model to represent the eight geologic units that exist in BCV (Knox Dolomite, Maynardville Limestone, Nolichucky Shale, Maryville-Rogersville-Rutledge formations, Pumpkin Valley shale, and Rome shale/sandstone).

Anisotropy ratios (Ky versus Kx [Kz]) of 5:1 (for weathered bedrock zone) and 10:1 (for fractured bedrock zone) were used to represent the preferred fracture/bedding orientation of the geologic units. In this case, Ky represents the conductivity parallel to strike, Kx is the horizontal conductivity perpendicular to strike, and Kz represents the vertical hydraulic conductivity. Both field data and previous modeling sensitivity analyses support the anisotropic ratios used in the model. Field data included analytical plume distribution and aquifer test data within BCV (Geraghty and Miller 1987, 1989; Law Engineering 1983; Lee, et al. 1992; Golder and Associates 1988). Extensive modeling sensitivity analyses were conducted during the Bear Creek model development reported in the Bear Creek Feasibility Study (FS) report (DOE 1997). A summary was also presented in a journal publication (Evans, et al. 1996). All these data indicated an anisotropic flow regime in the aquifer of BCV. A detailed summary of the aquifer test data is provided in the Bear Creek FS, Appendix F (DOE 1997).

Extensive modifications were made to the UBCV Model to represent future conditions and site-specific features associated with cell construction. Engineered features that were added include berms, underdrains, geologic buffer material, and the low permeability clay liner. All the engineered and reworked materials were modeled as isotropic units in the horizontal plane (i.e., hydraulic conductivity does not vary with direction).

In summary, the EBCV site is modeled as a single unconfined aquifer, with 11 vertical layers to simulate the changes in hydraulic parameters with depth, and the 45° average dip is represented by staggering hydrogeologic units with depth. Model Layers 1–3 represent the unconsolidated/weathered bedrock zone. Model Layers 4–8 represent the top bedrock interval between 50 and 150 ft. Model Layers 9–11 represent the intermediate/deep bedrock zone.

Figure H-10 shows the zones of hydraulic conductivities used to represent hydrogeologic units in Layer 1 of the UBCV Model. Figure H-11 shows the hydraulic conductivity field in a vertical south-north cross section, which illustrates the staggering of the hydrogeologic units with depth to simulate the 45° dip. Table H-4 provides a summary of model parameters for the future condition UBCV Model. All parameter values shown in Table H-4 are the same for the current condition (2012) model and the future condition model except the two parameters marked with an "*": the number of drain cells (shown under Model Boundary Conditions) and the EMDF recharge rate.

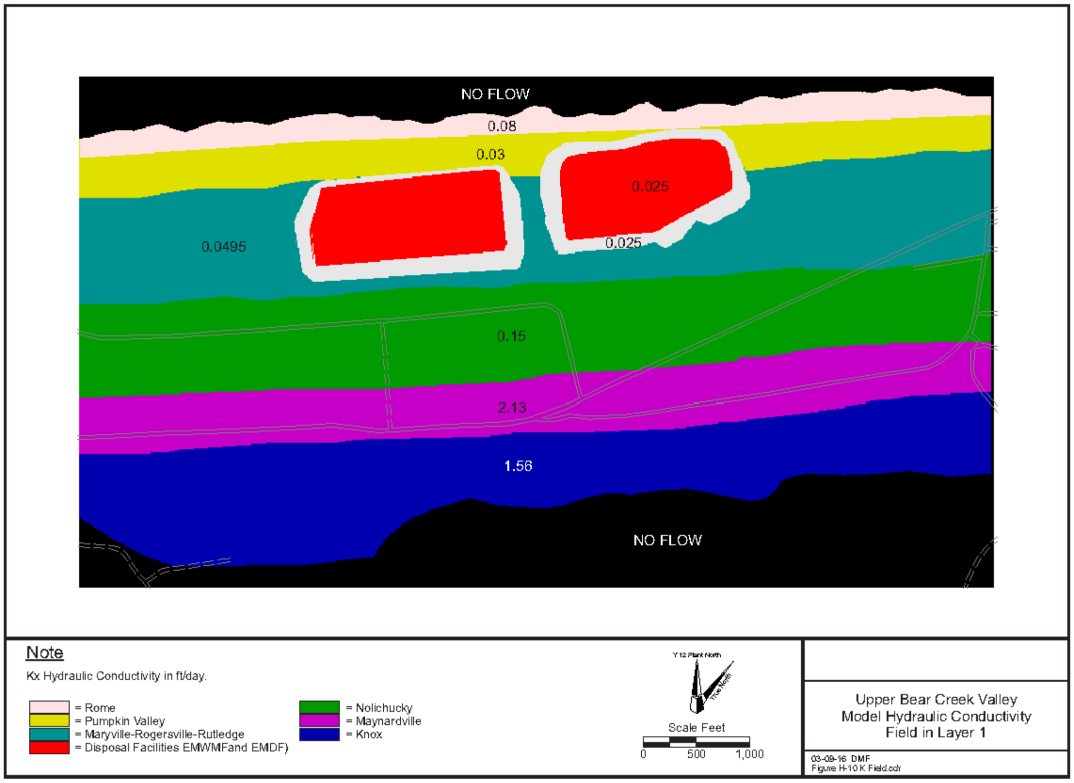


Figure H-10. Upper Bear Creek Valley Model Hydraulic Conductivity Field in Layer 1

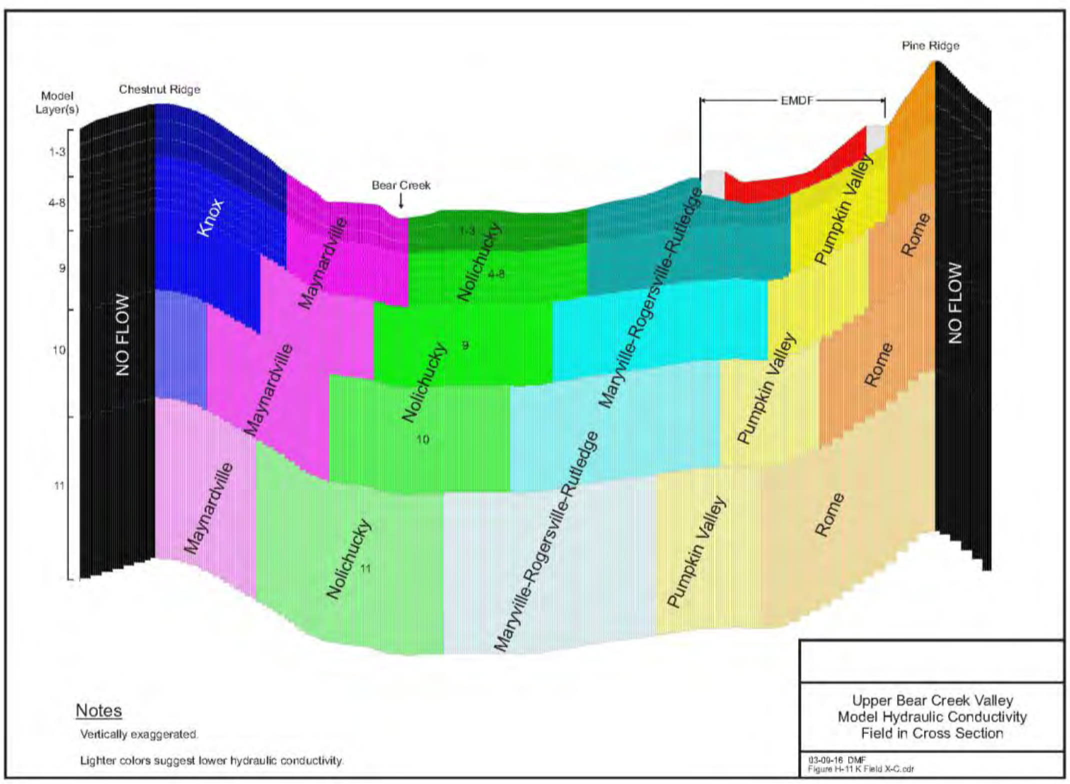


Figure H-11. Upper Bear Creek Valley Model Hydraulic Conductivity Field in Cross Section

Table H-4. UBCV MODFLOW Ground Water Model Parameter Summary (Future Condition)

<table>
<tr><th colspan="3">GRID INFORMATION</th></tr>
<tr><td>Number of Rows</td><td colspan="2">860</td></tr>
<tr><td>Number of Columns</td><td colspan="2">480</td></tr>
<tr><td>Number of Layers</td><td colspan="2">11</td></tr>
<tr><td>Total Cells</td><td colspan="2">4,540,800</td></tr>
<tr><td>Total Active Cells</td><td colspan="2">3,572,049</td></tr>
<tr><td>Percent Active Cells</td><td colspan="2">78.67%</td></tr>
<tr><th colspan="3">GRID DIMENSIONS</th></tr>
<tr><td>Row Spacing - Uniform Delta-Y</td><td>10</td><td rowspan="2">ft</td></tr>
<tr><td>Column Spacing - Uniform Delta-X</td><td>10</td></tr>
<tr><th colspan="3">Vertical Spacing</th></tr>
<tr><td>Layers 1–3</td><td>Variable (10 25)</td><td rowspan="5">ft</td></tr>
<tr><td>Layers 4–8</td><td>20 (each)</td></tr>
<tr><td>Layer 9</td><td>150</td></tr>
<tr><td>Layer 10</td><td>200</td></tr>
<tr><td>Layer 11</td><td>300</td></tr>
<tr><th colspan="3">COORDINATE TRANSFORMATION</th></tr>
<tr><td>X Offset (to Y-12 Coordinate System)</td><td>52723.33</td><td rowspan="2">ft</td></tr>
<tr><td>Y Offset (to Y-12 Coordinate System)</td><td>27510.47</td></tr>
<tr><td>Rotation</td><td>90.23</td><td>degree</td></tr>
<tr><th colspan="3">MODEL BOUNDARY CONDITIONS</th></tr>
<tr><td>Constant Heads</td><td>3,981</td><td rowspan="6"># of cells</td></tr>
<tr><td>Rivers</td><td>0</td></tr>
<tr><td>Drains*</td><td>126,126</td></tr>
<tr><td>General Heads</td><td>0</td></tr>
<tr><td>Wells</td><td>8</td></tr>
<tr><td>No Flow</td><td>968,751</td></tr>
<tr><th colspan="3">RECHARGE</th></tr>
<tr><th>Areas/Geologic Units</th><th>Recharge Rate (ft/day)</th><th>Recharge Rate (in/yr)</th></tr>
<tr><td>Closed Landfill/Paved Park Area</td><td>2.28E-04</td><td>9.74E-01</td></tr>
<tr><td>Rome</td><td>4.5E-03</td><td>19.7E+00</td></tr>
<tr><td>Maryville-Rogersville-Rutledge</td><td>1.6E-03</td><td>6.84E+00</td></tr>
<tr><td>Nolichucky</td><td>2E-03</td><td>8.54E+00</td></tr>
<tr><td>Knox</td><td>2E-03</td><td>8.54E+00</td></tr>
<tr><td>EMWMF</td><td>9.6E-05</td><td>4.10E-01</td></tr>
<tr><td>EMDF (Performance Stage 4)*</td><td>3.0E-04</td><td>1.32E+00</td></tr>
</table>

Table H-4. UBCV Ground Water Model Parameter Summary (Future Condition) (Continued)

HYDRAULIC CONDUCTIVITY[a]					
Material or Geologic Formation	**Model Layer(s)**	**Kx**	**Ky**	**Kz**	**Units**
Knox	1 3	1.56E+00	7.80E+00	1.56E+00	ft/day
Knox	8	9.18E-03	9.18E-02	9.18E-03	
Knox	9	2.54E-03	2.54E-02	2.54E-03	
Knox	10	1.16E-03	1.16E-02	1.16E-03	
Knox	11	3.60E-04	3.60E-03	3.60E-04	
Maynardville	1–3	2.13E+00	1.07E+01	2.13E+00	
Maynardville	8	1.21E-02	1.21E-01	1.21E-02	
Maynardville	9	3.34E-03	3.34E-02	3.34E-03	
Maynardville	10	1.52E-03	1.52E-02	1.52E-03	
Maynardville	11	4.80E-04	4.80E-03	4.80E-04	
Nolichucky	1 3	1.50E-01	7.50E-01	1.50E-01	
Nolichucky	4 8	6.81E-03	6.81E-02	6.81E-03	
Nolichucky	9	2.52E-03	2.52E-02	2.52E-03	
Nolichucky	10	6.10E-04	6.10E-03	6.10E-04	
Nolichucky	11	5.00E-05	5.00E-04	5.00E-05	
Maryville-Rogersville-Rutledge	1 3	4.95E-02	2.48E-01	4.95E-02	
Maryville-Rogersville-Rutledge	4 8	3.60E-03	3.60E-02	3.60E-03	
Maryville-Rogersville-Rutledge	9	1.35E-03	1.35E-02	1.35E-03	
Maryville-Rogersville-Rutledge	10	3.20E-04	3.20E-03	3.20E-04	
Maryville-Rogersville-Rutledge	11	4.50E-05	4.50E-04	4.50E-05	
Pumpkin Valley	1 3	3.00E-02	1.50E-01	3.00E-02	
Pumpkin Valley	4 8	4.72E-03	4.72E-02	4.72E-03	
Pumpkin Valley	9	1.75E-03	1.75E-02	1.75E-03	
Pumpkin Valley	10	4.20E-04	4.20E-03	4.20E-04	
Pumpkin Valley	11	5.60E-05	5.60E-04	5.60E-05	
Rome	1 3	8.00E-02	4.00E-01	8.00E-02	
Rome	4 8	5.00E-03	5.00E-02	5.00E-03	
Rome	9	2.00E-03	2.00E-02	2.00E-03	
Rome	10	5.00E-04	5.00E-03	5.00E-04	
Rome	11	8.00E-05	8.00E-04	8.00E-05	
compacted clay/underlying in-situ materials*	1	2.50E-02	1.25E-01	2.50E-02	
compacted clay berm/ underlying in-situ materials*	1	2.50E-02	1.25E-01	2.50E-02	

* Indicates the parameter shown for the future condition model is an addition to the current condition (2012) model parameter

[a] Hydraulic conductivities from references: DOE 1997, BJC 2003, DOE 1998b, and DOE 2010.

4.2.1.4 Model Calibration

Calibration of a ground water flow model refers to the process of adjusting model input parameters (e.g., hydraulic conductivity) and boundary conditions (e.g., precipitation recharge, stream and seep conductivity) to obtain a reasonable match between observed (actual ground water levels from monitoring wells) and simulated hydrogeologic conditions. In practice, this usually involves an iterative process of adjusting hydraulic properties and/or boundary conditions assigned in the model. At all stages of the model calibration process, parameter values and boundary conditions should be constrained by hydrogeologic data collected in the field and engineering design values.

The parameters that were used in the BCV regional model were validated previously in the BCV FS through extensive model calibration and sensitivity analysis (DOE 1997). The calibration was conducted using data from hundreds of ground water wells. Stream and seep discharge data collected by the USGS at hundreds of locations were used to constrain the model. Sensitivity analyses were run on the calibrated model to evaluate recharge rates and hydraulic conductivities (including anisotropy assumptions), which demonstrated that the most sensitive hydraulic conductivities were those in the upper layers of the model. These validated parameters and the BCV model, along with subsequent refinements for application to the EMWMF, are the basis of the future condition model presented in this RI/FS.

The UBCV model was constructed using the TMR approach based on the calibrated regional BCV model, and used extensive knowledge derived from EMWMF model development (BJC 2010). An advantage of the TMR approach is that a high resolution (small-scale) model can be developed that retains the regional flow characteristics. Because the parameters and boundary conditions associated with the refined model are derived from the regional ground water flow model, additional extensive calibration of the refined model is usually not necessary. New ground water monitoring wells installed under Phase I characterization efforts, within the proposed EMDF area, have been used in UBCV Model calibration. Increasing the assumed recharge rate for the Rome formation along the crest of Pine Ridge was found to improve the predicted ground water levels at the location of the uppermost Phase I monitoring well. After making this adjustment well head values were in general agreement with the model-predicted values.

As an additional validation procedure, predicted ground water discharge rates based on the calibrated current condition UBCV model were compared to BCV stream flow measurements. Ground water sinks (drains cells in the model) discharge to Bear Creek directly and to surface drainage features that also flow into Bear Creek eventually. The model predicted ground water discharge above the Bear Creek/NT-3 junction is 0.31 ft^3 per second (cfs). For comparison, the average flow rate measured at the junction location is 0.55 cfs (Appendix E, Section 2.4.3.1), which includes both base flow (ground water discharge) and surface water runoff. The comparison suggests that the UBCV Model provides very good discharge results, indicating that the hydraulic conductivity (K) values and recharge rates are properly represented in the model.

The net water balance error for the UBCV model domain was about 0.12% and is within the typically accepted limit of 1% (EPA 1996). This model-derived water balance is a quality assurance metric which shows that essentially all water has been mathematically accounted for, and that the MODFLOW simulation has correctly solved the governing flow equations.

4.2.2 MODFLOW/MODPATH Model Assumptions

Assumptions and code-supplied options used as a basis for executing the MODFLOW/MODPATH models are as follows:

- MODFLOW outputs are set as inputs to MODPATH.

- MODFLOW simulates ground water flow through a porous media using a 3D, block-centered finite-difference approach to solve the governing flow equation relating flow in the x, y, and z directions (Darcy's law), to sources, sinks, and storage.
- A porous media model is applicable since fractures are very small compared to the model domain (e.g., fracture spacings on the order of centimeters to meters) as compared to a model domain of 384 ha (948 acres).
- MODFLOW simulates effects of wells, recharge, rivers, drains, and "general-head boundaries." MODFLOW calculates head and flow rate within each grid cell.
- MODPATH uses a semi-analytical particle tracking scheme to obtain the particle flow path within each finite-difference grid cell from MODFLOW output. MODPATH simulates advection movement only.
- A heterogeneous and three-dimensional anisotropic medium is assumed.
- The model domain, grid, and layers are defined as described in Section 4.2.1.1.
- Boundary conditions are as described in Section 4.2.1.2. The model incorporates Bear Creek and its tributaries, as well as site features for the proposed EMDF such as ditches and channels, cut and filled areas, underdrain features, and French drains. The surface drainage features are represented in the model as drain cells as described in Section 4.2.1.2. Drain cells allow ground water to discharge into a surface water body. Actual stream bottom elevations were assigned in the model.
- Model hydraulic parameters (including hydraulic conductivities and recharge rates) are given in Section 4.2.1.3, and are based on those developed under the regional BCV model (DOE 1997).
- Assumed porosities are consistent with the vertical distribution of hydraulic conductivity: Model layer 1-3 = 20%, Model layer 4-8 = 5%, Model layer 9 = 3%, Model layer 10 = 2%, Model layer 11 = 1%. Effective porosity of the shallow aquifer (layers 1-3) for MODPATH average ground water velocity estimation is assumed to be 4%

4.2.3 MODFLOW/MODPATH Model Results

Figures H-12 and H-13 show the future condition, model-predicted shallow and intermediate depth hydraulic head contours, respectively, and associated flow direction and gradients predicted by MODPATH. Generally, the figures indicate that shallow ground water discharges into Bear Creek and its tributaries. However the tributaries exhibit a less pronounced influence on ground water flow in the intermediate bedrock ground water zone. Even though there is an upward gradient toward the NTs in the intermediate zone, the flow vectors indicate deeper ground water may underflow the NTs. The simulated ground water flow field is consistent with the site conceptual model, water level maps constructed based on monitoring data, and general understanding of the site presented in Appendix E.

Ground water flow paths and particle travel times from disposal cell locations to surface discharge locations are determined using the MODPATH model (Pollock 1989). Figure H-14 shows the ground water flow paths and discharge locations from various cell locations. The data are used to calculate the average flow velocity of the ground water, which is used in PATHRAE modeling. The MODPATH predicted particle path velocities are sensitive to the assumed porosity of the porous medium, which is 20% for MODFLOW/MODPATH model layers 1-3. However, a much smaller *effective* porosity that represents the ratio of modeled (Darcy) velocities to observed average linear ground water velocities is assumed for purposes of estimating the horizontal ground water velocity used as a PATHRAE input parameter. For the EBCV site future condition model, assuming 4% effective porosity, the predicted average ground water flow velocity is 69.9 ft/year (21.3 m/yr).

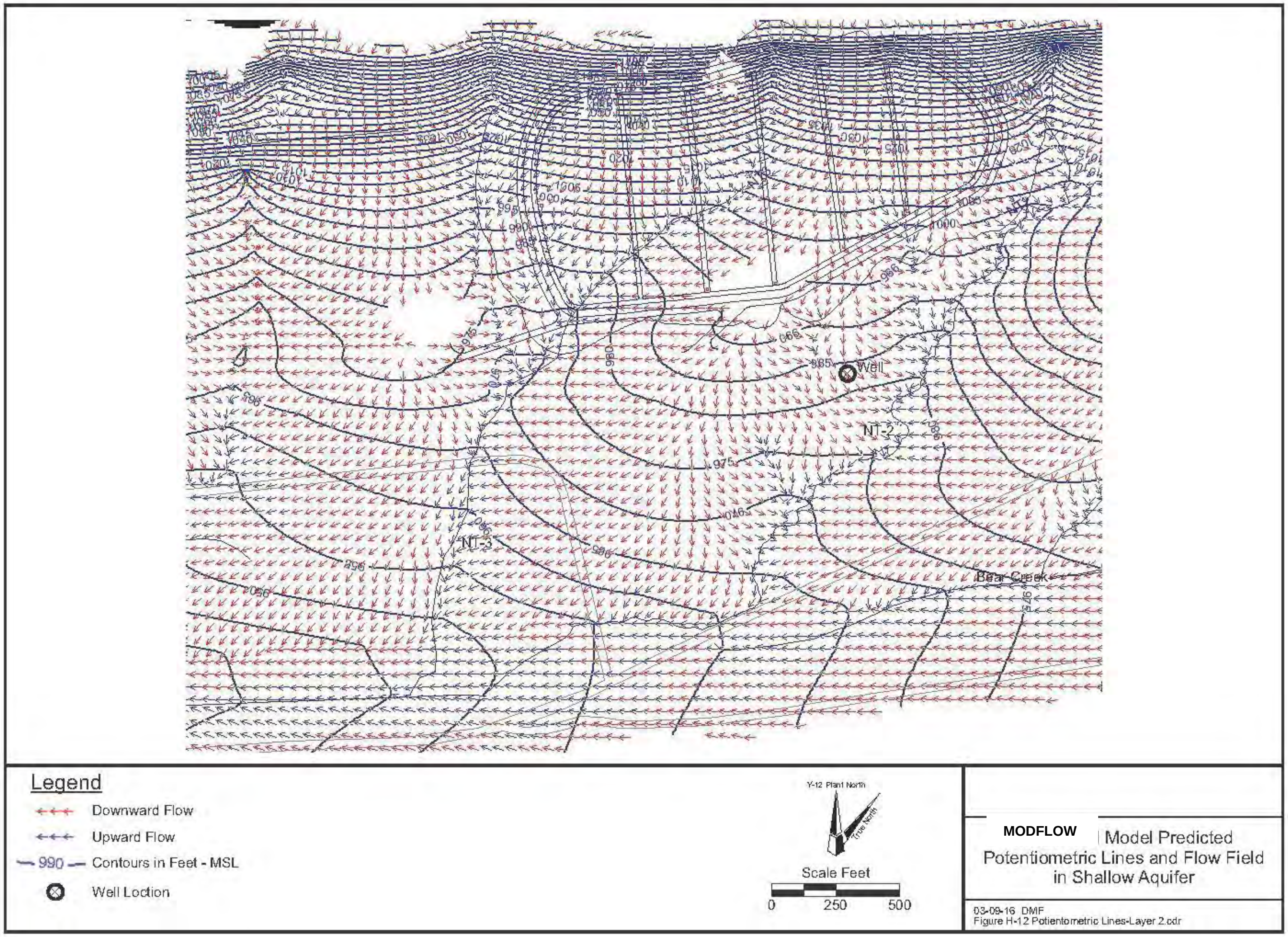


Figure H-12. MODFLOW Model Predicted Potentiometric Lines and Flow Field in the Shallow Aquifer

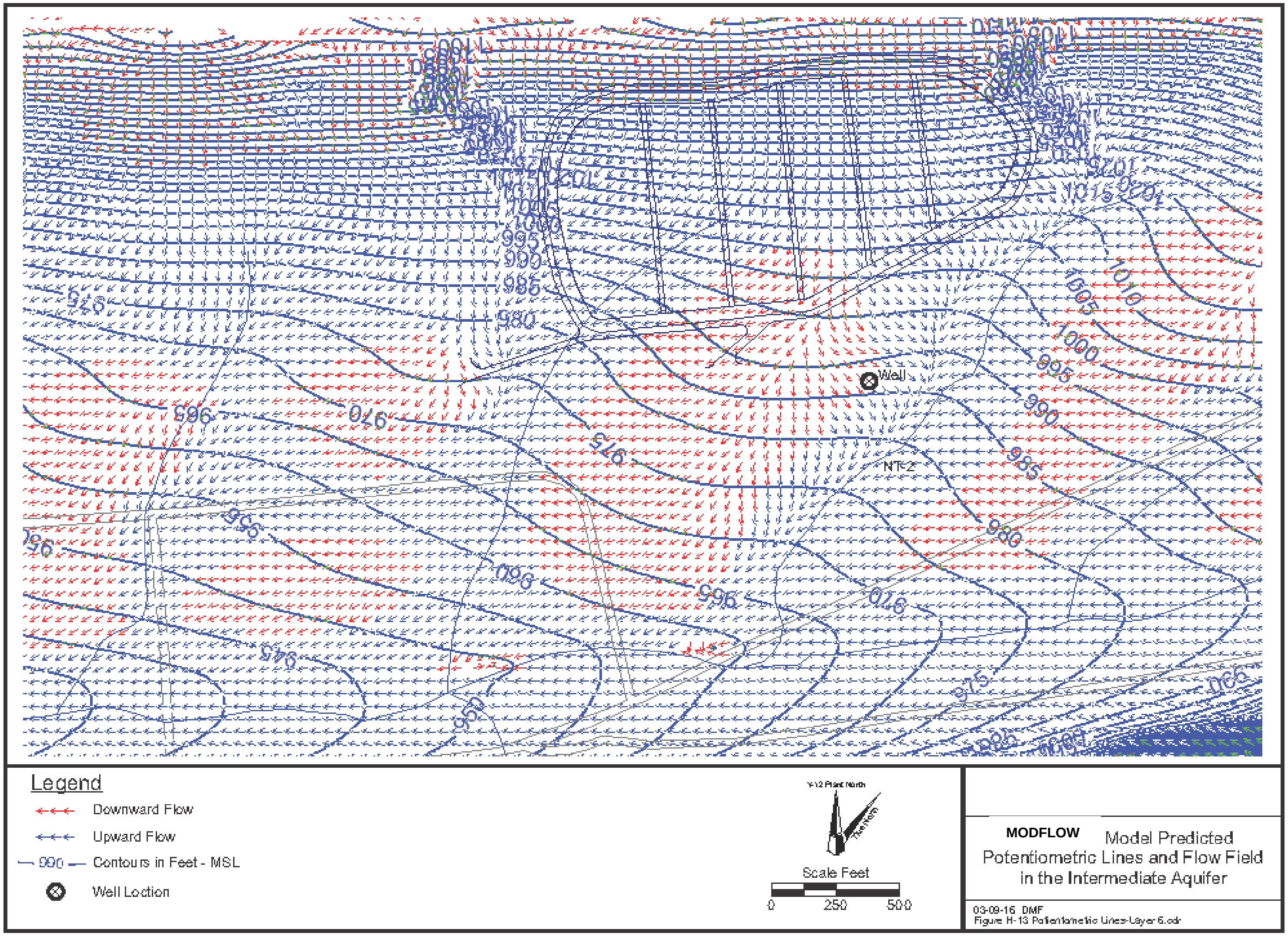


Figure H-13. MODFLOW Model Predicted Potentiometric Lines and Flow Field in the Intermediate Aquifer

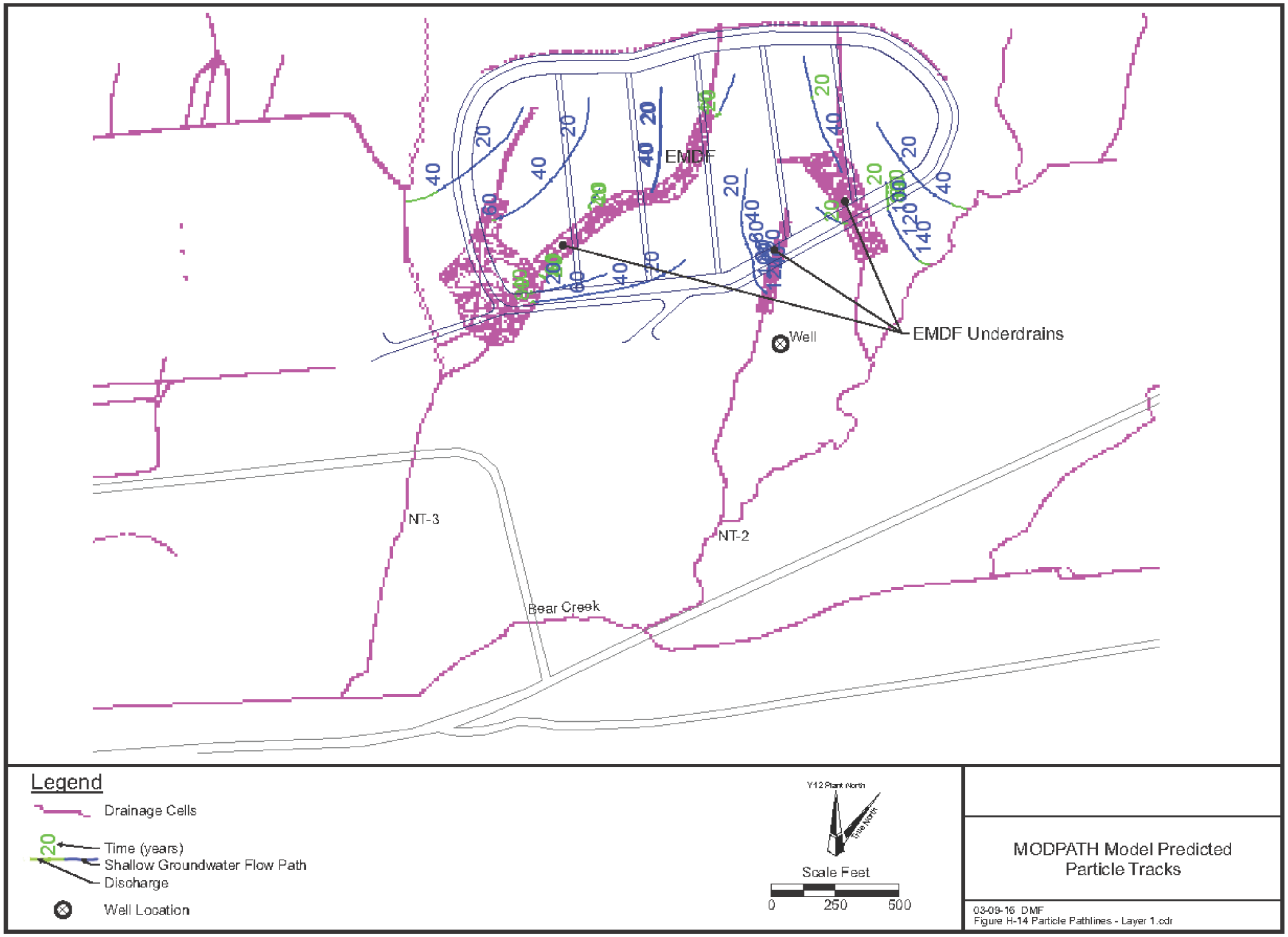


Figure H-14. MODPATH Predicted Particle Tracks

4.3 FATE-TRANSPORT (MT3D) MODEL APPLICATION

Advective transport of contaminants entering ground water from the waste cell was simulated by using MT3D (Version 1.0, Zheng, 1990), a fate-transport model code that is coupled to the ground water flow field results generated by MODFLOW.

4.3.1 Site-specific MT3D Model Development

Based on the results of the MODFLOW simulation for the future condition EBCV site, and assuming a unit leachate concentration for recharge beneath the waste cell (see Figure H-15), MT3D is used to predict a relative contaminant concentration distribution for the site. The simulation is dynamic, and incorporates the increase in recharge beneath the waste cell over time assumed in the facility performance scenario (i.e. it reflects the four stress periods applied in the MODFLOW simulation). The MT3D modeled three-dimensional contaminant plume (or ground water dilution field) is based solely on advective transport and contaminant mass conservation. No source depletion, hydrodynamic dispersion, contaminant retardation, or contaminant decay/degradation processes were included in the MT3D simulations. The MOC solution method was used for all the simulations to minimize the potential error from numerical dispersion.

The risk evaluation for the proposed EMDF assumes a scenario in which a hypothetical domestic ground water supply well is placed hydraulically down-gradient from the disposal cell. This receptor well (ground water point of exposure) is assumed to be located at the point of maximum ground water concentration predicted by MT3D at a distance of 100 m from the edge of waste in the cell.

The model analyses were carried out in the following steps:

1. An initial MT3D simulation is performed to identify the location of maximum predicted concentration for the receptor well at a distance of 100 m from the edge of waste. For locations relatively close to the waste cell, predicted concentrations reach steady state within approximately 2,000 years (1,000 years after the beginning of stress period/performance stage 4). Simulations are run to 4,000-years post-closure.
2. To account for the effects of ground water pumping on the local flow field and contaminant concentrations in the vicinity of the receptor well, a model well was added to the ground water model at the selected location. The model receptor well is screened to withdraw ground water from model Layers 3–6, and assumed to have a pumping rate of 240 gallons per day, adequate for a family of four. The MT3D simulation is repeated utilizing the flow model results that include the receptor well.
3. MT3D model output for all model layers at the well location were used to identify steady state relative concentrations (see Figure H-19) and to verify that the assumed well screen interval (corresponding to approximately 60 to 150 ft below ground surface at the well location) is conservative, based on the vertical distribution of relative concentration. The concentration of contaminants in water pumped for domestic use was calculated as a flow-weighted average of the steady-state concentrations predicted for model layers 3-6, based on the transmissivity (thickness multiplied by hydraulic conductivity) of each layer. This modeled-derived relative concentration is set as the well dilution factor (DF_{well}) for subsequent risk calculations and PreWAC development. Sensitivity of the MT3D simulated relative concentrations and the calculated DF_{well} to the assumed well screen interval was evaluated by simulating ground water withdrawal from alternative depth ranges. The senstiviity results are presented in Section 4.5 of this Appendix.

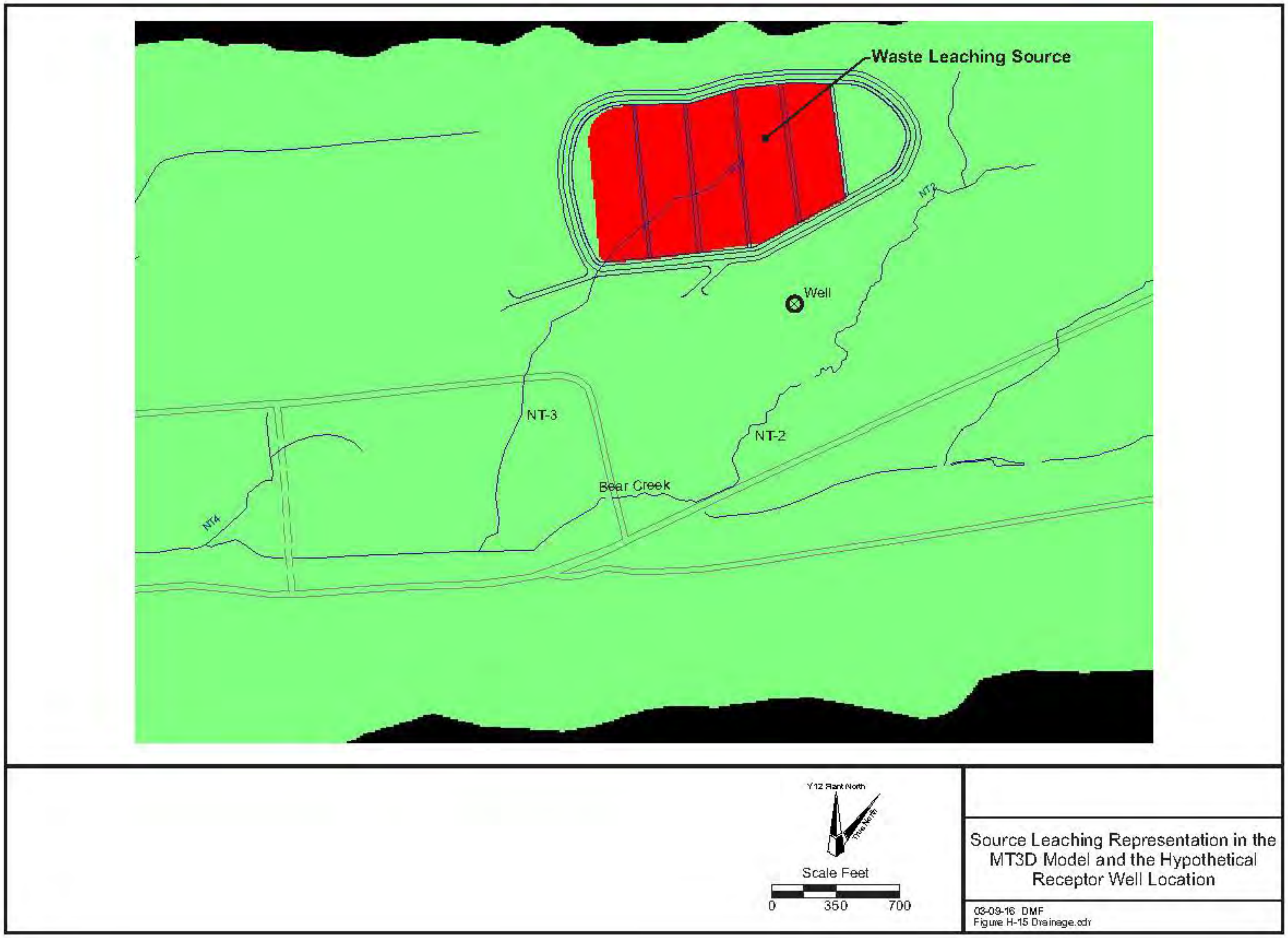


Figure H-15. Source Leaching Representation in the MT3D Model and the Hypothetical Receptor Well Location

4.3.2 MT3D Model Assumptions

Assumptions made in running the MT3D code are as follows:

1. Changes in the concentration field will not measurably affect the flow field.
2. Transport is modeled as three dimensional and transient.
3. Contaminant flux from the waste cell is based on a constant unit concentration leaching from a non-depleting contaminant source, and reflects the increasing infiltration/recharge rates assumed in the facility performance scenario.
4. Contaminant flux from a footprint corresponding to the 5-cell volume (2.2E+06 yd^3) is assumed (Figure H-15).
5. Only advection is considered; other processes (source depletion, dispersion, decay, and retardation) were not assumed.
6. The MOC solution method, best for advection only, was used for the simulation to minimize the potential error from numerical dispersion.
7. The receptor well (ground water point of exposure) is assumed to be located at the point of maximum ground water concentration predicted by MT3D at a distance of 100 m from the edge of waste in the cell.
8. The well pumping rate is 240 gallons/day, based on its use by a family of four.
9. Water is drawn from model Layers 3–6, corresponding to 57–147 ft below ground surface.

4.3.3 MT3D Model Results

Based on the UBCV flow simulations for the closed landfill scenario (i.e., permanent cover system in place) including the withdrawal of ground water from a supply well, the MT3D code was used to predict the contaminant concentration distribution in the site for the given well scenario. Figure H-16 shows the (relative, nonspecific) contaminant concentration plume representing the maximum value for all model layers at the end of the 4000 year MT3D simulation. The plume in Figure H-16 shows the modeled ground water concentration as fraction of the assumed unit leachate concentration at the source. As predicted by the site conceptual model, the MT3D results indicate that over 90% of the shallow plume discharges into surface water features (tributaries, NT-2,NT-3, and Bear Creek) upstream of the assumed surface water point of exposure.

Figure H-17 shows the relative concentration plume representing the average of model Layers 3–6, corresponding to the assumed screened interval at the hypothetical receptor well location. Figure H-18 shows the modeled contaminant distribution in a south-north cross section intersecting the receptor well. Model Layer 9 shows a thickened plume that is an artifact of the model layer thicknesses, and not representative of actual ground water conditions. As noted above, model Layers 1–8 are relatively thin, reflecting the fact that most ground water flow occurs in the shallow interval. Model Layers 9–11 were defined more coarsely because relatively little flow occurs in these layers. The thick contaminant plume in model Layer 9 should be interpreted as actually occurring in the upper part of the layer, not the entire layer thickness.

Ground water dilution factors for the receptor well location (DF_{well}) were calculated based on the MT3D model results. The DF_{well} values are based on the ratio of C_{well} (the model-predicted contaminant concentration in the continuously pumped well [240 gallons per day]) to C_L (the assumed unit contaminant concentration [leachate concentration] entering the ground water beneath the disposal facility). Figure H-19 shows the predicted relative concentrations in model layers at the hypothetical domestic ground water supply well location. The hypothetical receptor well is screened at depths corresponding to model Layers 3–6. The flow-weighted average relative concentration of water extracted from the assumed screened interval is defined as $DF_{well} = C_{well}/C_L$ (also shown in Figure H-19). The model output for the assumed well location reflects the assumed instantaneous increase in infiltration (by a factor of 3) at 1,000 years. The values of DF_{well} used for PreWAC development are based on model results at 1,000 years for those COPCs predicted by PATHRAE to peak before 1,000 years, and on the modeled steady state concentrations (predicted by MT3D after approximately 2,000 years) for those COPC's predicted to peak after 1,000 years. Calculations of exposure and risk incorporating these DF_{well} values are described in Section 4.4.3.

4.4 PATHRAE MODELING AND RISK/HAZARD ANALYSIS

The PreWAC development methodology used for the proposed EMDF is similar to the methodology used to develop the EMWMF WAC (DOE 1998a, 1998b). The PATHRAE model is used to estimate receptor exposure for the surface water pathway. Additional calculations using output from PATHRAE and MT3D determine the overall risk (or dose, for hazardous COPCs) for the hypothetical receptor from the combined effects of contaminated ground water ingestion (via a well) and contaminated surface water use. It is assumed under the hypothetical receptor scenario that a resident farmer consumes drinking water from a well and uses Bear Creek surface water for agricultural purposes resulting in ingestion of contaminated milk, meat, and vegetation. The conceptual exposure model annotated with modeling functions and domains is shown in Figure H-20.

Using input parameters generated from supporting hydrologeologic models, site-specific data, and conceptual design information, PATHRAE-RAD and PATHRAE-HAZ models are used to perform risk analysis. A single pathway (waste cell to ground water to surface water) in the PATHRAE RAD/HAZ model is used to predict exposure to the receptor from surface water usage. Exposure to the receptor via the ground water ingestion route is determined in calculations performed outside of the code (using the ground water flow model and MT3D results). PreWAC are then developed based on the combined exposure of the receptor via surface water and ground water.

The method involves assuming that a unit concentration (1 Ci/m^3 for radiological contaminants or 1 kg/m^3 for non-radiological constituents) of a single COPC in the waste occupies the entire disposal facility volume. The one-dimensional PATHRAE model requires the total inventory (for each modeled COPC) and waste cell dimensions as source term inputs, implicitly assuming a uniform distribution of contamiants within the landfill. The unit concentration assumption is necessary because the actual contaminant concentrations for various COPCs are uncertain. However, the calculated PreWAC do not depend on this assumption. The model-based peak ingestion of contaminants is used to determine the carcinogenic risk (ELCR), or hazardous chemical exposure (HI) corresponding to the assumed unit concentration source term. Based on the PATHRAE predicted time of peak surface water concentration, the appropriate target risk/HI criterion for each COPC (see Section 2.5 of this Appendix) is compared to the model-predicted risk/HI and used to rescale the assumed unit waste concentration to an allowable waste concentration (PreWAC) for each COPC. This calculation is explained in detail in Section 5 of this Appendix.

PATHRAE model development for the EMDF is described in Section 4.4.1; assumptions are given in Section 4.4.2. PATHRAE model output and risk/HI calculations are described in Section 4.4.3. Calculations of PreWAC are described in Chapter 5.

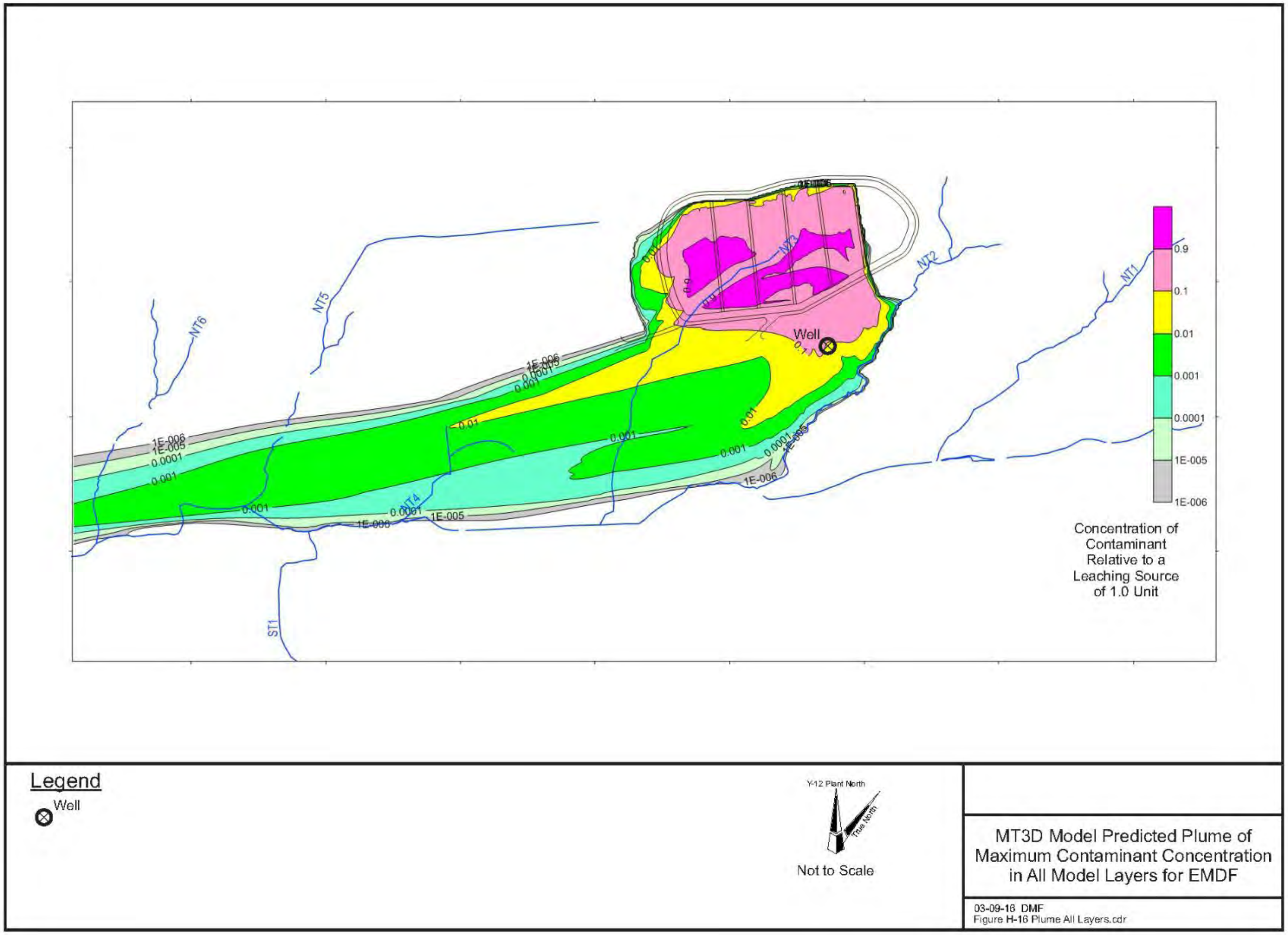


Figure H-16. MT3D Model Predicted Plume of Maximum Contaminant Concentration in All Model Layers for EMDF

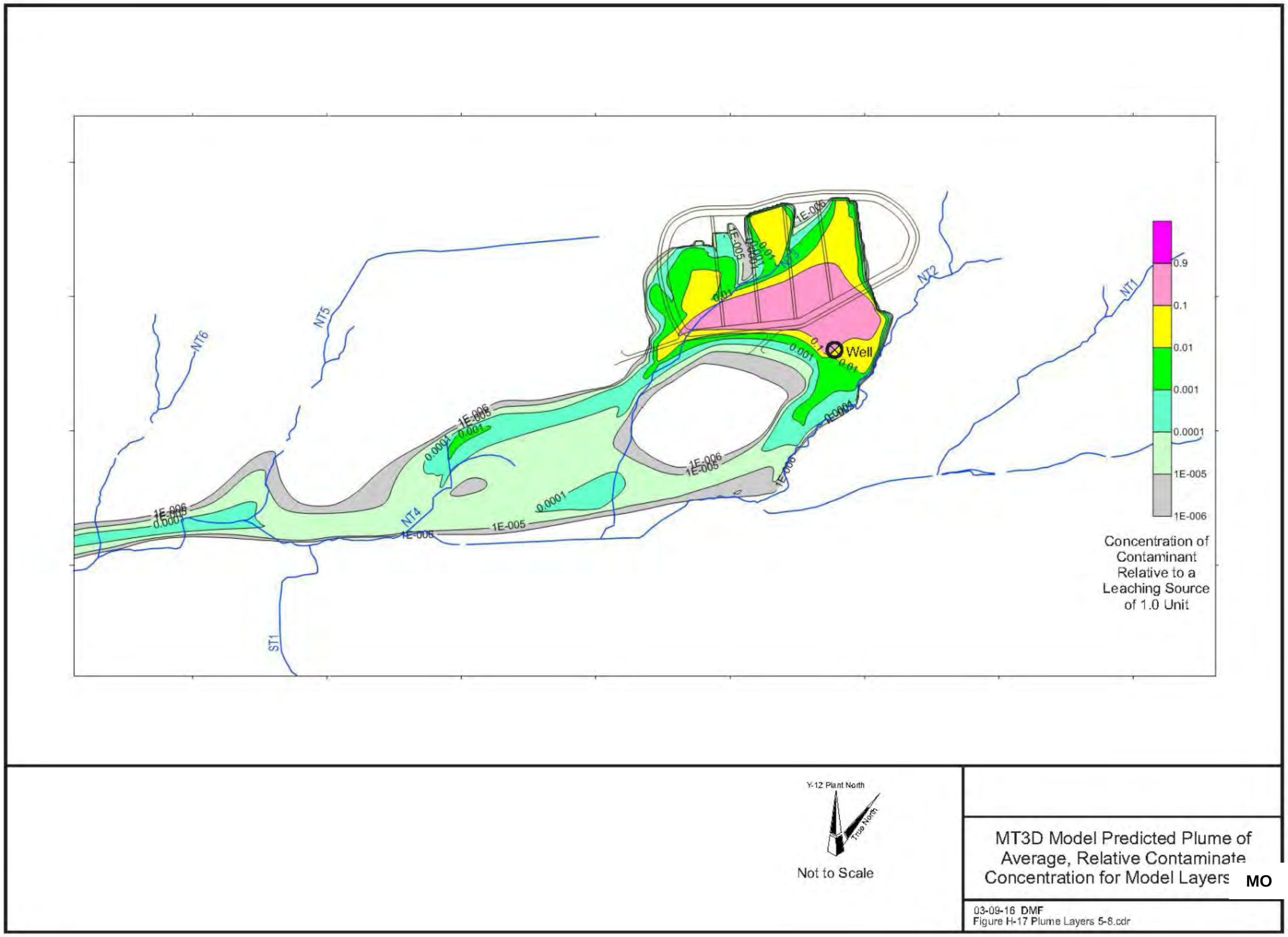


Figure H-17. MT3D Model Predicted Plume of Average, Relative Contaminant Concentration for Model Layers 53–86

Plume in figure is representative of well water concentration (flow-weighted average of model predicted concentrations for layers 3-6).

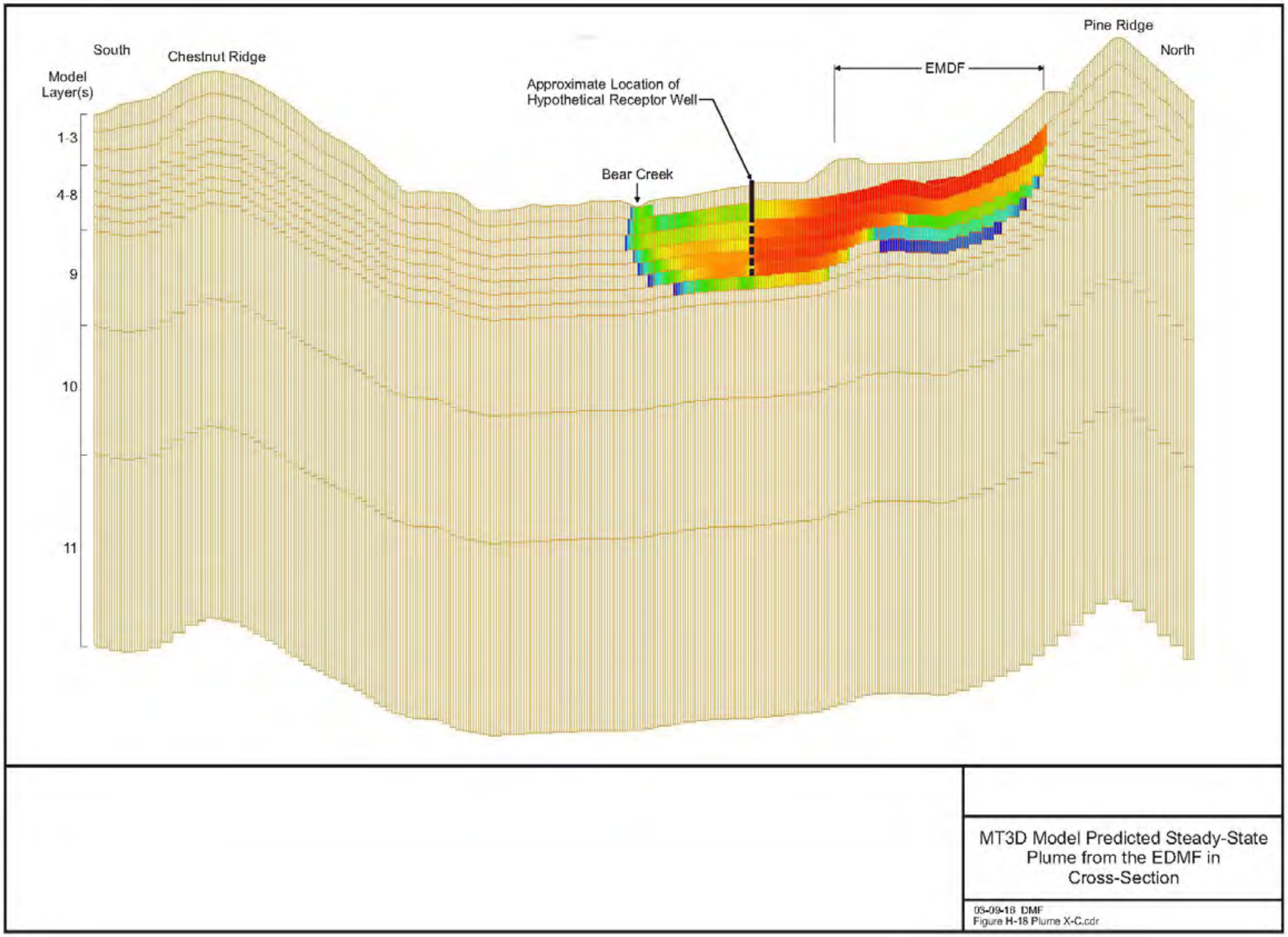
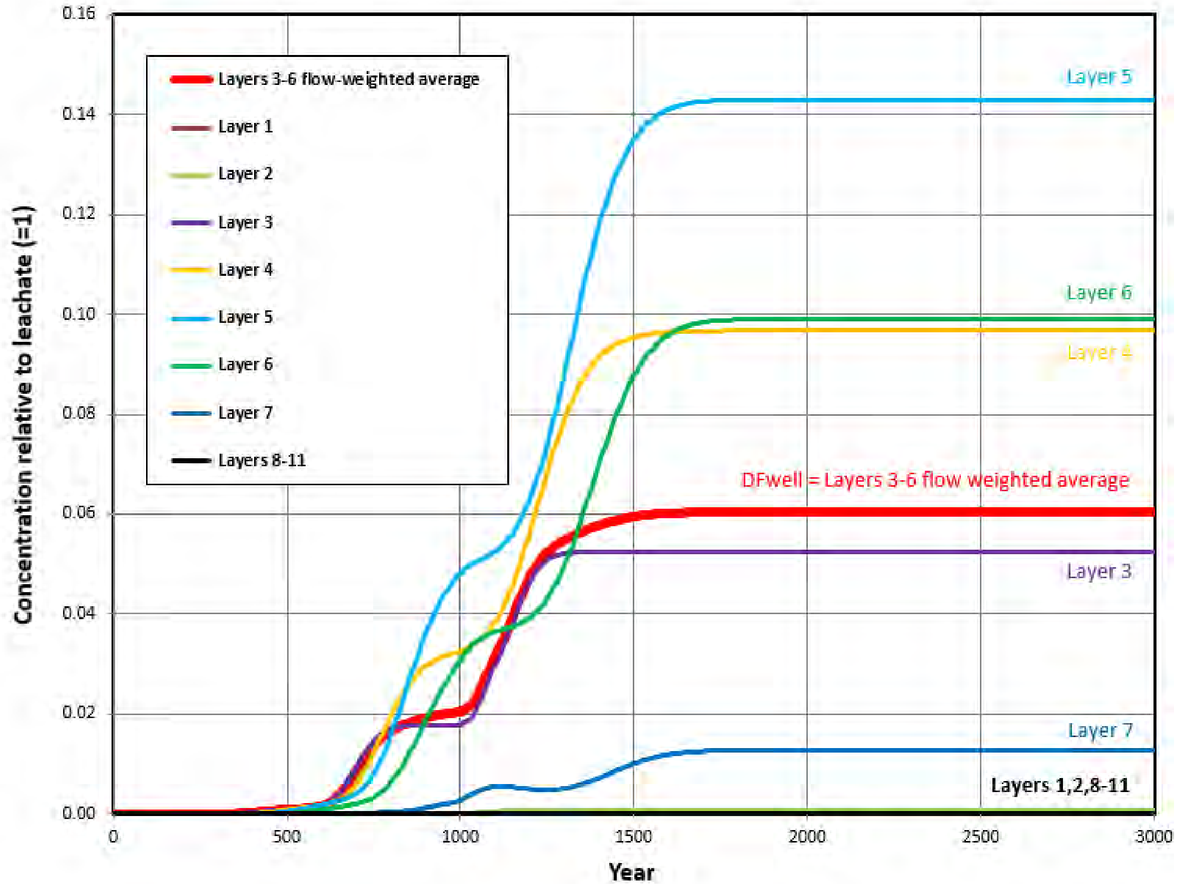


Figure H-18. MT3D Model Predicted Steady-state Plume from the EMDF in Cross-section



Legend

C_{well} - Well Concentration
C_L - Leachate Concentration

Model Predicted Groundwater Concentrations (Relative to Leachate) with Time

08-28-12 DMF
Figure F-19 Concentrations.cdr

Figure H-19. MT3D Model Predicted Ground Water Well Concentrations (Relative to Leachate) with Time

4.4.1 Site-specific PATHRAE Model Development

PATHRAE is a one-dimensional fate and transport model. The code simulates contaminant migration from a contained volume (landfill) of a single uniform COPC concentration, travel of the COPC vertically through the vadose zone (via advection by percolating precipitation/ infiltration), horizontal migration of the COPC through the saturated zone (via advection and dispersion in ground water) and discharge of the COPC at the surface water point of exposure. The waste mass itself is conceptualized as a rectangular box, with the single contaminant uniformly distributed throughout the cell. Based on the conceptual design of the EMDF (which dictates the volume of the facility, surface area of the facility, location with respect to well/surface water, and cover/waste thicknesses), and assuming a single contaminant occupies the landfill at a particular initial concentration level (set at 1 Ci/m^3 for radioactive species and 1 kg/m^3 for hazardous species), depletion of the source is modeled via two mechanisms: (1) radioactive decay, and (2) leaching via equilibrium solid-liquid partitioning. Migration of the COPC is assumed to occur from the entire base of the landfill throughout the simulation (or until the contaminant is completely depleted). Chemically retarded transport of contaminants is modeled assuming equilibrium solid-water partitioning in the vadose zone and dispersive horizontal transport in the saturated zone with limited chemical retardation (solid-water partition coefficients [K_ds] are decreased by a factor of 10 from the vadose zone values). No degradation of hazardous chemical compounds is assumed during the 1,000 year compliance period, whereas chemical compounds predicted to peak beyond 1,000 years are assumed to degrade completely within 1,000 years (USGS 2006).

Receptor (MEI) exposure to contaminants via discharge of ground water to surface water is calculated using environmental food chain analysis. The exposure results from the resident farmer receptor irrigating crops with contaminated surface water and ingesting them, eating livestock watered with contaminated surface water, and drinking milk from livestock watered with the contaminated surface water, all of which are considered in the food chain calculations (contaminant to vegetation/animal to receptor). Based on the food chain analysis, an equivalent surface water uptake (EU_{sw}) is determined by PATHRAE for each contaminant, which quantifies the equivalent annual amount of surface water the receptor would have to drink to equate to the uptake of the contaminant via the routes specified (e.g., eating crops/livestock watered with contaminated surface water). EU_{sw} values are calculated for both adult and child receptors; carcinogenic risk estimates assume an adult receptor, whereas a hypothetical resident child receptor is assumed for intake of hazardous, non-radiological contaminants.

The ground water ingestion pathway is analyzed outside of the PATHRAE code, but is based on results of the PATHRAE surface water pathway analyses and other ground water model results (see Section 4.4.3, which explains these calculations further).

4.4.2 PATHRAE Model Assumptions

PATHRAE-HAZ/RAD input values used for modeling the proposed EMDF site include code default numbers, generic numbers obtained from literature sources, contaminant-specific parameters (e.g. Kd, slope factors), EMDF conceptual design information, and measured site-specific data (such as stream flow rates). Some key input parameters are based on the HELP and MODFLOW/MODPATH models and site-specific information (e.g., water infiltration rates, ground water velocitiy). Key parameters used in the PATHRAE model are summarized in Table H-5.

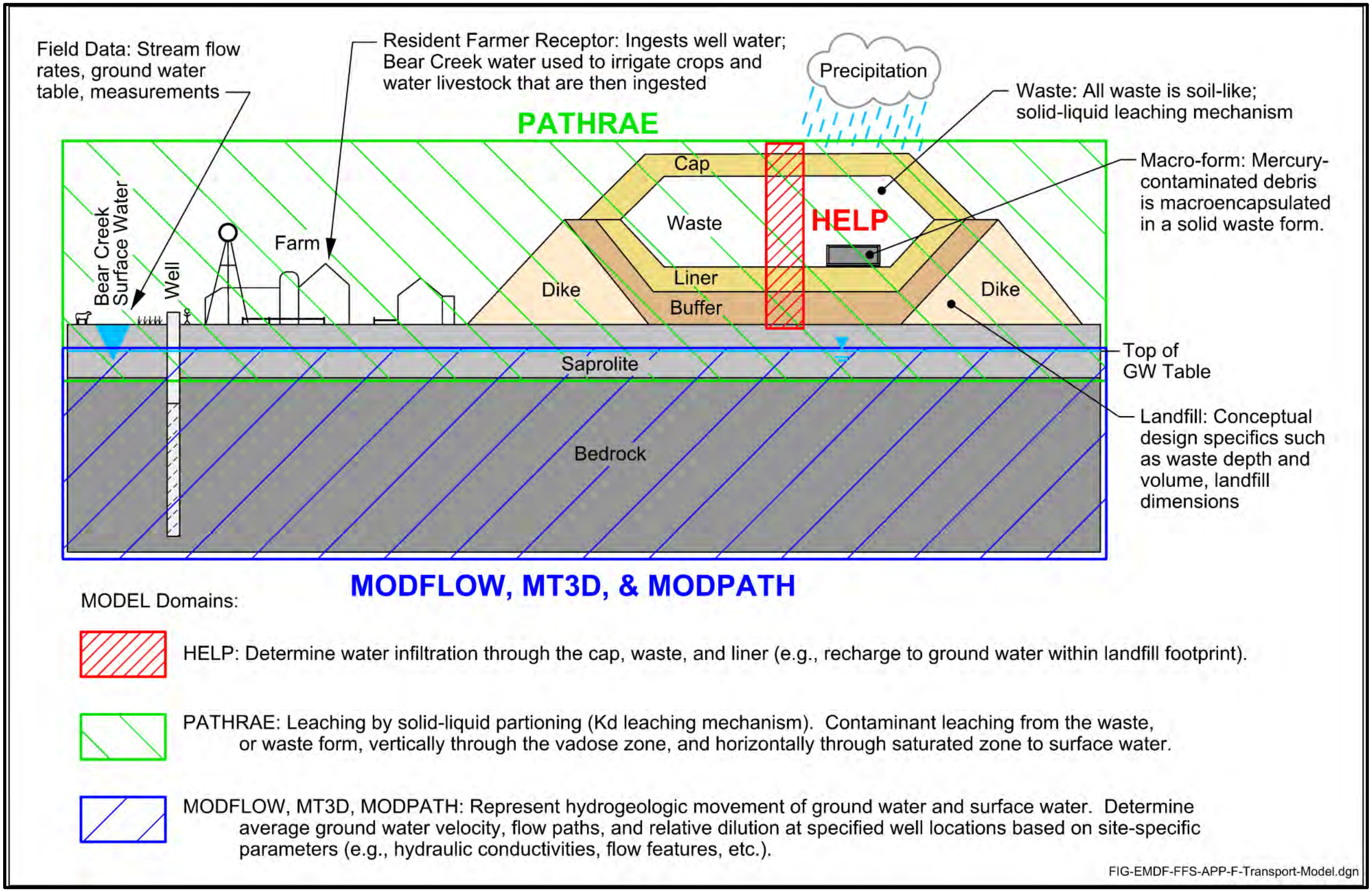


Figure H-20. Contaminant Leaching/Transport Analysis and Exposure Conceptual Model

Table H-5. Key Parameters for Use in PATHRAE Modeling and PreWAC Calculations

Zone	Parameter	Source of Data	Value	Unit
Waste Zone	Waste volume	Conceptual design	2,200,000	yd^3
	Width of waste cell (perpendicular to ground water flow path)	Conceptual design	1,401	ft
	Length of waste cell (along ground water flow path)	Conceptual design	798	ft
	Disposal cell surface area	Conceptual design	1,117,998	ft^2
	Waste thickness (average)	Conceptual design	53	ft
	Waste density	Assumption	1,600	kg/m^3
	Canister life (cover system longevity)	Facility performance scenario	200	yr
	Recharge to ground water from waste zone	HELP Model results	0.43, 1.32	in./yr
	Amount of water percolating through the waste cell	Calculated using HELP results & conceptual design	0.00127, 0.00390	cfs
Vadose Zone	Vadose zone thickness (depth to ground water from bottom of waste)	Model predicted water table & conceptual design	22	ft
	Vadose bulk density	Assumption	1,800	kg/m^3
	Vadose porosity	Derived from HELP-specified material characteristics and conceptual design	0.44	vol/vol
	Vadose saturated hydraulic conductivity		1.00E-06	cm/s
	Vadose water content		0.38	vol/vol
Ground Water	Aquifer material density	Assumption	1,800	kg/m^3
	Aquifer material porosity (effective)	Assumption	0.04	vol/vol
	Longitudinal dispersivity in bedrock aquifer	10% of ground water path length	47.6	meter
	Transverse dispersivity in bedrock aquifer	Assumption	0	m^2/yr
	Average horizontal ground water velocity	MODPATH model result (effective porosity = 0.04)	69.9	ft/yr
Surface Water	Bear Creek flow rate at SW point of exposure (Junction NT-3 and Bear Creek)	BCK 11.54 field data	0.82	cfs
	Surface water dilution factor (DF_{creek})	Calculated, volumetric flow through waste/volumetric flow at SW point of exposure	0.00154, 0.00473	unitless
	Distance to surface water point of exposure (ground water path length)	Surface water exposure scenario assumption	1,561 (476)	ft (m)
Ground Water Well	Distance from nearest edge of waste to ground water well location	Ground water exposure scenario assumption	328 (100)	ft (m)
	Ground water well DF at specified location	MT3D Model results at given well location	0.019, 0.076	unitless

For each COPC, based on a given set of input parameter values, PATHRAE-HAZ/RAD predicts the peak surface water concentration (ground water to surface water pathway), the time of peak concentration, and equivalent surface water uptake (EU_{sw}). Because PATHRAE does not permit a time-varying rate of infiltration through the waste cell, a simplified performance scenario that approximates the scenario used for ground water modeling is assumed:

- Zero infiltration for first 200 years (PATHRAE *canister life* parameter = 200 years)
- Infiltration after 200 years = 0. 3 "/yr for COPCs that peak during the 1,000-year compliance period
- Infiltration after 200 years = 1.32"/yr for COPCs that peak after the 1,000-year compliance period

PATHRAE was run utilizing the lower annual infiltration/recharge rate (0. 3") to identify COPCs that peak within the 1,000 year compliance period. This is equivalent to (conservatively) assuming that all critical cover and liner system components fail at 200 years post closure, 300 years earlier than the facility performance scenario assumes. PATHRAE was run a second time utilizing the higher annual infiltration/recharge rate (1.32") for COPCs predicted to peak after 1,000 years. This is equivalent to (conservatively) assuming that all critical cover and liner system components have degraded by 200 years post closure, 800 years earlier than the facility performance scenario assumes. This approach is conservative for radionuclides, because it results in higher modeled peak surface concentrations and higher estimated risk, yielding more restrictive (lower) PreWAC values.

Vadose zone contaminant transport is modeled assuming steady, non-dipersive vadose fluid flow within uniform unsaturated materials and contaminant retardation via equilibrium sorption. Vadose zone parameters are based on HELP model output and EMDF conceptual design specifications. The HELP specified material profile below the waste, consisting of liner system layers and 7 ft of structural fill (an average thickness for the conceptual design), was the basis for the calculated layered-equivalent (thickness-weighted average) vadose parameter values for input to PATHRAE (see Table H-5). The 22 ft thickness of the vadose zone is based on the assumed thickness of the liner system and geobuffer layer (15 ft) plus the average 7 ft thickness of structural fill in the conceptual design (Figure H-21). This assumed vadose thickness is supported by the ground water model results for the future (post-closure) condition. The MODFLOW-predicted thickness of the unsaturated zone (depth to the water table) below the geologic buffer layer is 10-35 ft (Figure H-22), 3-28 ft greater than the assumed 7 ft thickness of structural fill included in the PATHRAE-modeled vadose zone. The MODFLOW-predicted average total vadose zone thickness for the waste cell floor area (inside the heavy dashed boundary in Figure H-22) is 34.6 ft, suggesting that the assumed thickness of 22 ft for PATHRAE modeling is conservative.

Assumed values for exposure factors utilized in the PATHRAE environmental food chain analysis and post-PATHRAE risk/HI evaluation are based on EPA guidance (EPA 1991, 2008). Table H-6 lists the assumed ingestion rates for both adult and child receptors used in these risk evaluations. Contaminant-specific uptake efficiency factors assumed in the food chain analysis to calculate EU_{sw} are tabulated in the PATHRAE output files included in Attachment B to this Appendix.

4.4.2.1 Contaminants of Potential Concern

Potential contaminants disposed in the facility will consist of radioactive and hazardous constituents. All COPCs are considered, and an exhaustive list of radioactive contaminants was initially developed (see Attachment A of this Appendix). Isotopes that have a half-life of less than five years were not modeled under the assumption that the final cover will fully perform for 200 years following closure, and the isotopes will have decayed over 40 half-lives, thus their concentrations may be considered insignificant by the time they reach the receptor. A total of 265 isotopes were considered; 203 were not modeled for the reasons stated in Attachment A, and the remaining 62isotopes were modeled. Likewise, an exhaustive list of hazardous contaminants was considered (see Attachment A). Data pertinent to each contaminant (e.g., slope factors, specific activities, reference doses, etc.) are given in the Attachment.

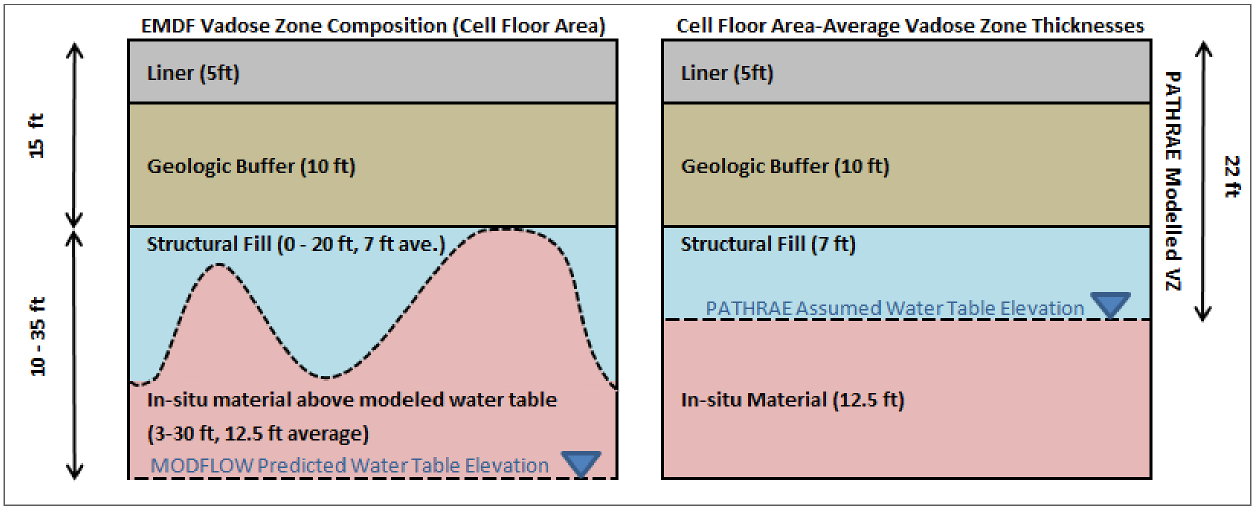


Figure H-21. EMDF Conceptual Design Vadose Zone Thickness

Table H-6. Exposure Factor Values Assumed for PATHRAE Food Chain Calculations

Exposure Factor	Adult Value	Child Value
Body mass (kg)	70	16
Exposure Duration (yr)	30	6
Ingestion of drinking water (L/yr)	730	365
Ingestion of leafy vegetation (kg/yr)	14	3
Ingestion of produce (kg/yr)	176	82
Ingestion of cow milk (L/yr)	110	169
Ingestion of goat milk (L/yr)	0	0
Ingestion of meat (kg/yr)	95	52
Ingestion of fish (kg/yr)	0	0

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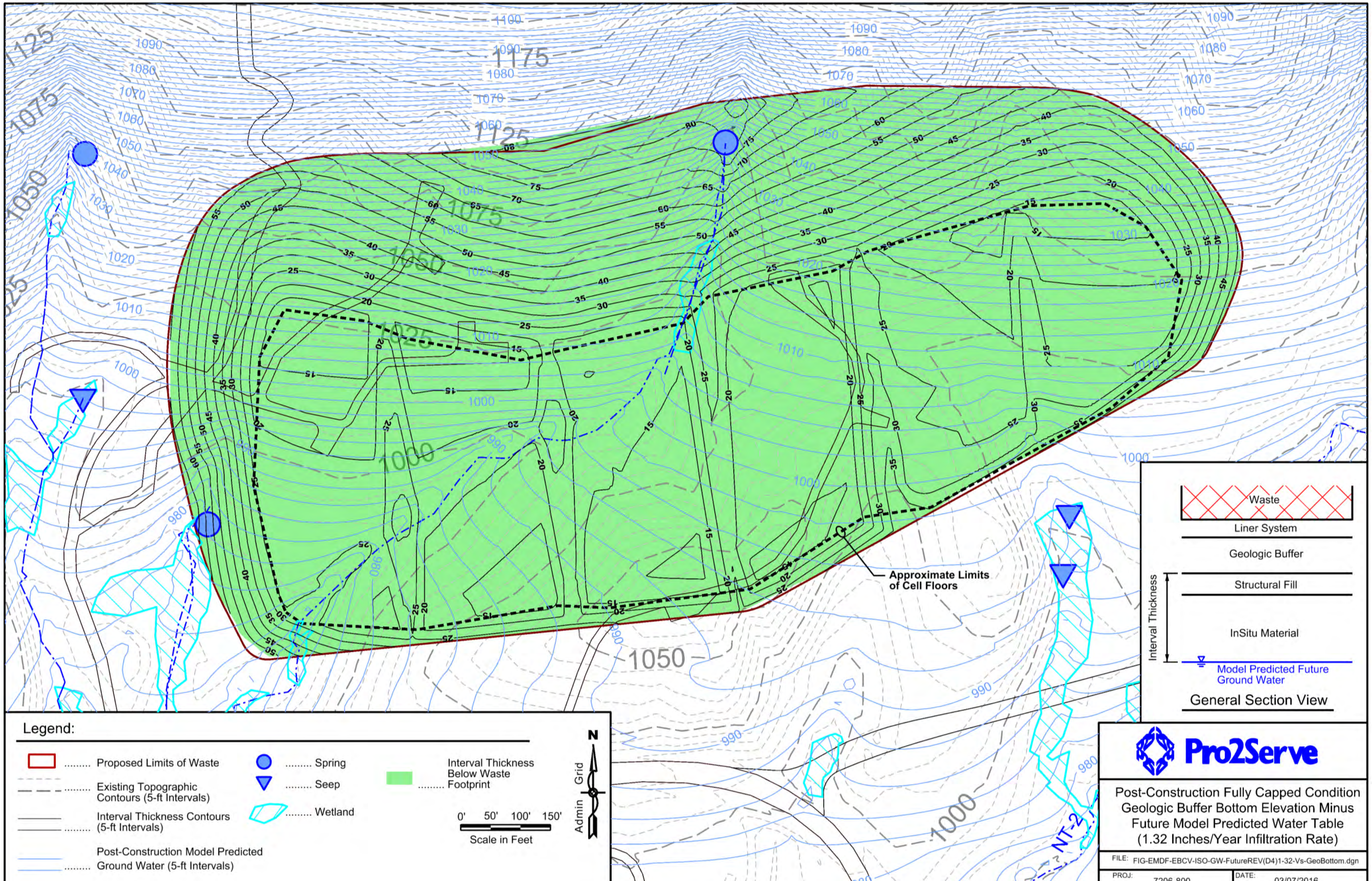

Figure H-22. MODFLOW predicted post construction water table elevations and depth to the water table below the geologic buffer layer.

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4.4.2.2 Partition Coefficients

Contaminant-specific K_d are key parameters in determining the leaching and transport of that contaminant in the environment, and ultimately, to the receptor. The assumed waste contaminant leaching process uses a simple K_d release mechanism. The K_d values that are used to develop the PreWAC are summarized in Attachment A. A discussion of K_d is also included in the Attachment, and references for the K_ds used are presented. All waste being modeled (debris as well as soil) is assumed to be soil-like. Based on EMWMF leachate data (UCOR 2015) and Bear Creek soil data (NRCS 2013; DOE 1993), near slightly acidic to near neutral pH conditions are expected for the future EMDF, and solid-liquid K_ds determined in near neutral pH conditions would apply. The majority of projected waste to be generated is debris; however, as shown in Fig. 2-3 in Chapter 2 of this RI/FS, the volume of clean fill and waste fill that would actually occupy the proposed 2.2 M yd^3 facility is roughly twice the volume of debris; therefore, a soil-like assumption is considered valid. Debris would be surrounded in the landfill by clean and waste soil fill to meet void and operational fill requirements, including a layer of soil that underlies all waste disposed in the facility to protect the liner from waste placement activities. Therefore, soil-like material characteristics (including K_d) are the most representative for the overall waste since the waste cell is modeled as a single unit source.

The K_d values tabulated in Attachment A of this Appendix are applied to the waste zone for leaching from the waste cell and to the transport in the vadose zone. For contaminant retardation within the saturated zone, where relatively rapid, dispersive transport via fractures may limit retardation by sorption processes (i.e. equilibrium solid-water partitioning may not be attained), the tablulated Kd values are decreased by a factor of 10.

4.4.2.3 Other PATHRAE Input Parameters

A notable difference in PATHRAE modeling and risk calculation for the proposed EMDF vs. the EMWMF WAC is the Reference Dose and Slope Factor parameters based on updated values in EPA risk guidance (EPA 2014), which are used to calculate risk/HI from ground water and surface water pathways. The Reference Dose and Slope Factors for all COPCs are given in Attachment A. Also, site-specific parameters for the proposed EMDF conceptual design and conditions are used to arrive at PreWAC. (Refer back to Table H-5, which summarized the input parameters used to conduct PATHRAE analysis.)

4.4.2.4 Summary of PATHRAE Assumptions

A listing of assumptions for the PATHRAE code execution and risk assessment for PreWAC development follows:

- A resident farmer (MEI) conceptual scenario, as described in Sections 4.4 and 4.4.1.
- Adult MEI is a 70 kg person, a 30-year exposure is assumed (Child MEI is 15 kg, 6 years).
- Adult MEI drinks water from a well, at a rate of 2 L/day (730 L/year); Child MEI assumption is 365 L/year.
- MEI waters livestock and irrigates crops using surface water available at the main trunk of BCV, the closest main Bear Creek (surface water) location to the landfill.
- Attachment A contains a list of COPCs, and their associated parameters (e.g., K_d, slope factors, etc). Isotopes with half-lives less than five years are not modeled as they decay a minimum of 40 half-lives prior to assumed cap failure and infiltration (from precipitation) into the landfill.
- Conceptual design parameters are listed in Table H-5.
- Material properties are listed in Table H-5.
- Site properties are listed in Table H-5.
- Inputs from other models (HELP, MODFLOW/MODPATH, MT3D) as listed in Table H-5.

- Waste is modeled as soil-like. Soil K_ds are assumed to represent the release mechanism in the waste and leaching mechanism in the vadose and saturated zones. The saturated zone K_d is conservatively assumed to be $1/10^{th}$ of the vadose zone K_d.
- An average vadose zone thickness of 22 ft is based on results of ground water modeling of the long-term future condition, and corresponds to 5 ft of liner material, 10 ft of hydrogeologic buffer soil, and another 7 ft of structural fill above the water table.
- Near neutral pH conditions exist in the waste zone based on EMWMF data.
- The complex ground water flow field cannot be adequately modeled by PATHRAE simple one-dimensional flow assumptions and contaminant movement is instead modeled using MODFLOW/MODPATH and the MT3D code. PATHRAE simple one-dimensional flow is adequate to model ground water flow discharge to surface water only.
- All of the modeled mass flux from the cell, reduced by radioactive decay for radionuclides, is discharged via ground water to surface water at a single location on Bear Creek (i.e., no portion of the flux of contaminated ground water from the waste cell bypasses the surface water point of exposure).
- The EMDF is conceptualized as one large rectangular waste cell containing a uniform unit concentration of a single contaminant at the initiation of the simulation, 1 Ci/m^3 for radioactive COPCs and 1 kg/m^3 for hazardous COPCs, which leach from the "base" of the landfill.
- A single radioisotope source is assumed to occupy the landfill in PATHRAE-RAD analysis; decay of that isotope is accounted for, as is leaching from the landfill thus resulting in a depleting source. Isotopes are modeled to peak concentration in surface water.
- A single hazardous contaminant source is assumed to occupy the landfill in PATHRAE-HAZ analysis; hazardous contaminants are modeled to peak concentration in surface water. No degredation o is assumed for hazardous contaminants that are predicted to peak within the 1,000 year compliance period (chemical compounds) Chemical compounds predicted to peak beyond 1,000 years (assuming no degradation) are assumed to degrade completely within 1,000 years and are not carried forward for PreWAC development.
- No isotopic in-growth is accounted for; this is because only a single contaminant is examined at one time, and only in terms of calculating a PreWAC limit for that radioactive species in the landfill as a whole. The source of the isotope (whether it is present due to decay or placed in the landfill during operations) need not be considered. Nuclide in-growth is, however, considered outside of the model, and analytic PreWAC have been adjusted as necessary to account for daughter product in-growth (see Section 5.1.1.2).
- Advection, retardation, and dispersion in the shallow aquifer are considered in PATHRAE analysis. No vadose zone dispersion is incorporated in PATHRAE fate and transport simulation.
- COPCs predicted to peak in surface water beyond 1,000,000 years post-closure are not carried forward for PreWAC development.

4.4.3 PATHRAE Model Results

PATHRAE-RAD and PATHRAE-HAZ, which model, respectively, radioactive and hazardous constituent fate and transport, are used to calculate the peak time of arrival and peak concentration of each COPC at the surface water receptor location. For each contaminant that peaks within a 1,000,000 year timeframe, the peak concentration of the contaminant in the creek is determined. COPCs that are not predicted to peak within 1,000,000 years post closure are not carried forward in the analysis.

The PATHRAE model also determines the equivalent annual surface water consumption per year (EU_{sw}) for each nuclide based on the surface water exposure routes (via crops and livestock), as stated in Section 2.3. As a reminder of the definition given in Section 4.4.1, EU_{sw} is the total equivalent annual surface water consumption in liters that would give the same annual nuclide uptake as would occur from the assumed consumption of contaminated vegetation, meat, and milk. Thus, the specific routes by which contaminants are ingested and the quantities of the contaminated foods ingested are accounted for in the EU_{sw} factor.

The input and output text files for the PATHRAE model runs (PATHRAE-RAD and PATHRAE-HAZ) are included in Attachment B to this Appendix. The input files contain all the input parameters in tabulated form, many of which are also summarized in Attachment A.

The calculated dilution factors for the creek (surface water source) and residential well (see Section 4.3.3) were used for scaling the constituent concentrations in the creek to corresponding well concentrations. The two dilution factors each have two different values corresponding to the different waste cell infiltration rates for performance stages 3 and 4.The DF calculations are as follows:

- DF_{well}: The well (ground water) dilution factor (DF_{well}) is the steady state well concentration (C_{well}) obtained while pumping, as a fraction of the unit leachate concentration assumed for MT3D simulation: $DF_{well} = C_{well}/C_L = C_{well}/1.$. For those COPCs predicted by PATHRAE to peak before 1,000 years (prior to the assumed cover clay degradation and increased infiltration), the value $DF_{well} = 0.020$ predicted at 1,000 years is used for PreWAC development. For those COPC's predicted to peak after 1,000 years, the modeled steady state concentrations predicted by MT3D ($DF_{well} = 0.064$ beginning around 2,000-years post-closure) is used as the basis for PreWAC development.
- DF_{creek}: The creek (surface water) dilution factor, DF_{creek}, is defined as the volumetric water flux from the disposal cell (volumetric infiltration/recharge rate) divided by the average creek water volumetric flow rate. The creek flow is measured at a weir location on Bear Creek (BCK- 11.54) near the hypothetical farmer's surface water irrigation intake at the junction NT-3. The PATHRAE-predicted peak surface water concentration (C_{creek}) divided by DF_{creek} is equal to the concentration of contaminated ground water leaving the waste cell, so that DF_{creek} may also be expressed in terms of concentrations, $DF_{creek}=C_{creek}/C_L$. For radionuclides having a short half life relative to retarded travel time (proportional to K_d) in the aquifer, the ratio C_{creek}/DF_{creek} will underestimate C_L due to radioactive decay that occurs in ground water between the waste cell and the surface discharge location. For most radioisotopes the magnitude of this error is small.

To derive a relation between the PATHRAE predicted surface water concentration and the corresponding ground water concentration at the receptor well, C_{creek}/DF_{creek} is substituted for C_L in the expression for DF_{well}, replacing the unit leachate concentration assumption with the PATHRAE-derived C_L. Solving the resulting equation for C_{well} yields $C_{well} = (DF_{well}/DF_{creek}) \times C_{creek}$, where the surface and ground water concentrations correspond to the assumed unit waste concentration the PATHRAE model runs.

Risk is determined as a function of pathway (ground water/well and surface water/creek), then summed to get the peak effective risk:

$$PReff = PRwell + PRcreek$$

- PR_{eff} = Peak effective risk (total risk from all pathways)
- PR_{well} = Peak risk from ground water pathway (ingesting well water)
- PR_{creek} = Peak risk from surface water pathway (ingesting crops and livestock/milk that were irrigated/watered with surface water from creek)

4.4.3.1 PATHRAE-RAD Results

The peak risk due to surface water pathway and the peak risk due to the ground water pathway defined above must be calculated. Equations are written for these two risks:

$$PR_{creek} = C_{creek} \cdot EU_{sw} \cdot SF \cdot 30$$

C_{creek} = Peak concentration in the surface water given by PATHRAE-RAD, [pCi/L]
EU_{sw} = Equivalent uptake of surface water given by PATHRAE-RAD, [L/yr]
SF = Slope factor (isotope specific, from ORNL 2015), [ELCR/pCi]
30 = Exposure duration, [yr]

and

$$PR_{well} = C_{well} \cdot 730 \cdot SF \cdot 30$$

C_{well} = Peak concentration in the pumped well water, [pCi/L]
730 = Volume of well water ingested, [L/yr]

Combining the above risks to get the peak effective risk ($PR_{eff} = PR_{well} + PR_{creek}$), and substituting $C_{well} = (DF_{well}/DF_{creek}) \times C_{creek}$ gives:

$$PR_{eff} = C_{creek} \cdot [730 \cdot \frac{DF_{well}}{DF_{creek}} + EU_{sw}] \cdot SF \cdot 30$$

Thus, the peak effective risk or ELCR is determined, for each radioisotope considered, based on the assumed hypothetical exposure scenario. For radioisotopes predicted to peak after 2,000-years post-closure, preliminary administrative limits based on modeling exposures at 100 m have been assigned, considering DOE, International Commission on Radiological Protection, and proposed Nuclear Regulatory Commission exposure limit guidelines. As preliminary limits, these values are subject to modification prior to finalization in the WAC Attainment (Compliance) Plan.

The predicted peak surface water concentrations and peak times, calculated EU_{sw} values, and peak effective risks calculated using the PATHRAE-RAD parameter assumptions for the EBCV site and equations listed above for EMDF, based on a COPC initial source of 1 Ci/m^3, are given in Attachment B, Table 1 for the radioactive COPCs.

4.4.3.2 PATHRAE-HAZ Results

Similar calculations are carried out for hazardous COPCs that are also considered carcinogenic, and modeled using PATHRAE-HAZ. The variables are marked with a prime to indicate hazardous contaminants as opposed to radioactive contaminants. The most significant differences are the SFs, units, and conversion factors.

The peak risk due to the surface water pathway (creek) and the peak risk due to the ground water pathway (well) must be calculated. Equations are written for these two risks:

$$PR'_{creek} = C'_{creek} \cdot EU'_{sw} \cdot SF' \cdot \frac{30}{1{,}788{,}500}$$

C'_{creek} = Peak concentration in the surface water given by PATHRAE-HAZ, [mg/L]
EU'_{sw} = Equivalent uptake of surface water given by PATHRAE-HAZ, [L/yr]
SF' = Slope factor (contaminant specific, from EPA 2012), [ELCR/(mg/kg-d)]
30 = Exposure duration, [yr]
1,788,500 = 70 kg adult human receptor × 365 day/yr × 70 yr life, [kg-d]

and

$$PR'_{well} = C'_{well} \cdot 730 \cdot SF' \cdot \frac{30}{1{,}788{,}500}$$

C'_{well} = Peak concentration in the pumped well water, [mg/L]
730 = Volume of well water ingested, [L/yr]

Combining the above risks to get the peak effective risk, and substituting $C'_{well} = (DF_{well}/DF_{creek}) \times C'_{creek}$ gives:

$$PR'_{eff} = C'_{creek} \cdot [730 \cdot \frac{DF_{well}}{DF_{creek}} + EU'_{sw}] \cdot SF' \cdot \frac{30}{1{,}788{,}500}$$

Thus the peak effective carcinogenic risk or ELCR is determined, for each hazardous COPC, for the assumed hypothetical exposure scenario. For these carcinogenic risks associated with non-radiological COPCs, assuming an adult receptor is conservative because a smaller EU'_{sw} (based on the child-specific ingestion rates) and much shorter exposure duration yields a smaller ELCR for all hazardous COPC's.

The peak creek dose (PD'_{creek}, [mg/kg-day]) of hazardous COPCs for non-carcinogenic effects is calculated in much the same way, conservatively assuming a child receptor:

$$PD'_{eff} = \frac{C'_{creek} \cdot \left[365 \frac{L}{yr} \cdot \frac{DF_{well}}{DF_{creek}} + EU'_{sw}\right]}{15\ kg \cdot 365 \frac{day}{yr}}$$

In this case the drinking water ingestion and body mass are the child receptor values given in Table H-6, and EU'_{sw} is a child-specific value calculated by PATHRAE assuming the child-specific ingestion rates (EPA 2008). The peak surface water concentrations and peak times, calculated EU_{sw} values, and peak effective risks and doses for the hazardous COPCs, based on unit source terms and calculated using the PATHRAE-HAZ results and equations listed above, are given in Attachment B Table 2. As these results (Attachment B Table 1) and the results for radioactive COPCs (Attachment B Table 2) are based on a single contaminant with an initial unit source term concentration in the landfill, they must be scaled to the appropriate RAO risk/HI limits to determine PreWAC limits. Those calculations and PreWAC results are discussed in Chapter 5.

4.5 EVALUATION OF MODEL SENSITIVITY AND PATHRAE LIMITATIONS

Uncertainty in model parameter assumptions and model results is an important consideration in evaluating the overall conservatism of the modeling approach for PreWAC development. Sensitivity of key MODFLOW parameters for the UBCV model including hydraulic conductivities and recharge rates have been presented in recent reports and are briefly summarized in Section 4.5.1. Sensitivity evaluations were performed for key parameters in the HELP and PATHRAE models (Sections 4.5.2 and 4.5.3). Sensitivity evaluation for MODPATH and MT3D was limited to the impact of the assumed aquifer porosity (Section 4.5.4). Section 4.5.5 presents the result of supplemental modeling performed to evaluate PATHRAE limitations and the conservatism of PATHRAE approximations and assumptions.

4.5.1 MODFLOW, MODPATH and MT3D sensitivity

Since the development of the BCV regional ground water model for the BCV RI/FS (DOE 1997), there has been continued refinement and application of this MODFLOW model to specific areas at higher model resolution, including the existing EMWMF and the proposed EMDF at the EBCV site (BJC 2010). Early and subsequent sensitivity evaluations indicated that the model is most sensitive to hydraulic conductivity, particularly the degree of anisotropy, and assumed recharge rates. Based on observed water table elevations near the upslope boundary of the proposed EMDF, the assumed recharge rate on the Rome formation (Figure H-9) was increased to ensure UBCV current condition model results corresponded to these actual measured conditions.

Sensitivity of modeled underdrain function to assumptions was evaluated by replacing the blanket drain portions of the model with porous media cells and assigned K values. The resulting impact on the predicted elevation of the water table beneath the cell floors was negligible, even for a conservatively low K values representative of silty sediment. Additional refinements to underdrain performance modeling and sensitivity analyses are beyond the scope of this RI/FS, and will be undertaken in future detailed design efforts once a final CERCLA waste disposition Record of Decision has been issued.

Sensitivity of MODPATH and MT3D model simulations to the assumed aquifer porosity of model layers 1-3 was also evaluated. The predicted ground water velocities (MODPATH) and the rate of simulated contaminant plume development and time to steady state concentrations (MT3D) vary in direct proportion to the assumed porosity. The MODPATH ground water velocity used for PATHRAE model runs was based on a conservative porosity of 0.04 (base case porosity for MODFLOW layers 1-3 is 0.20). The PreWAC derivation utilizes the steady state relative concentrations predicted my MT3D. Because only the time to steady state is sensitive to the porosity assumption, rather than the predicted concentration, this sensitivity does not affect the PreWAC results.

A final MT3D sensitivity evaluation was performed for the assumption of well screen interval. For the base case simulation used to derive the well dilution factor DF_{well}, model layers 3-6 were assumed to supply well water. Layers 3-6 were the four highest predicted relative concentrations in the initial simulation. Incorporating ground water pumping from these layers and taking the transmissivity-weighted average predicted relative concentration resulted in DF_{well} = 0.064 for the long term steady state condition. Two additional MT3D simulations were performed assuming model layers 1-3 (representing the upper saprolitic zone) and 5-8 (representing a deeper fractured bedrock interval) supply the water to the well head. Pumping from layers 1-3 resulted in a much smaller (less conservative) DF_{well} = 0.037. Pumping from model layers 5-8 resulted in DF_{well} = 0.067, slightly higher than for the layers 3-6 assumption. This result reflects the combined effects of pumping-induced changes in the simulated steady state concentrations for various layers and the fact that layer three has a much higher transmissivity and relatively low concentration for the base case simulation. (Figure H-19)

4.5.2 HELP model sensitivity

Sensitivity evaluations of the HELP model simulations focused on uncertainty in future climate conditions and the potential for more severe degradation of critical cover system components (clay layers) than was assumed in the baseline facility performance scenario. Some of the results are used to inform the PATHRAE sensitivity evaluations.

4.5.2.1 HELP sensitivity to climate assumptions

The EMDF facility performance scenario assumes no significant change in future climatic conditions. Increased precipitation in future centuries is likely for the East Tennessee region, given current global and regional climate change forecasts. Four HELP sensitivity runs were performed to evaluate the impact of increased precipitation, increased temperature and precipitation, and increased temperature, precipitation and length of the growing season. The increases in these parameters evaluated were as follows:

HELP Sensitivity 1:	**Precipitation Increases 25% from base case assumption**
HELP Sensitivity 2:	**Precipitation Increases 50%**
HELP Sensitivity 3:	**Precipitation Increases 25%, Temperature Increases 10%**
HELP Sensitivity 4:	**Precipitation Increases 25%, Temperature Increases 10%, Length of Growing Season Increases 10%**

The results of HELP sensitivity runs 1 to 4 are given in Table H-7, which includes the components of the surface hydrologic budget for each scenario, as well as the baseline results for facility performance stage 4 (>1,000 years). HELP sensitivity runs 1 to 4 assume the same reduced performance of the cover clay barrier that is assumed for performance stage 4. The last row of Table H-7 is the HELP predicted infiltration into the waste zone in inches/year. The precipitation increases evaluated are quite large compared to recent climate model forecasts, which suggest increases of 10-20% under a range of greenhouse gas scenarios (IPCC 2013). The HELP predicted infiltration is much more sensitive to increased precipitation (HELP sensitivity 1 and 2) than to increased temperature and length of growing season (HELP sensitivity 3 and 4). The proportional impact of the precipitation increase, relative to stage 4 base case infiltration, is 13% and 24% for HELP sensitivity 1 and 2 respectively. Increases in average temperature and length of growing season (HELP sensitivity 3 and 4) have relatively little impact on infiltration relative to the HELP sensitivity case 1, which has the same assumed increase in precipitation.

4.5.2.2 HELP sensitivity to clay barrier layer performance assumptions

The EMDF facility performance scenario assumes degradation of cover clay layer performance, reduced cover drainage efficiency, and 50% erosion of the surface layer beginning at 1,000 years post closure (performance stage 4). Three HELP sensitivity runs were performed to evaluate the impact of more severe clay barrier degradation, reduction in cover drainage, and surface erosion of the cover system. The changes in these parameters are as follows:

HELP Sensitivity 5:	**Increase of amended clay hydraulic conductivity from K=7.0E-08 cm/s to 3.5E-07 cm/s**
HELP Sensitivity 6:	**Increase of amended clay hydraulic conductivity from K=7.0E-08 cm/s to 3.5E-07 cm/s Decrease of lateral drainage layer hydraulic conductivity from K=3.0E-03 cm/s to 3.0E-04 cm/s**
HELP Sensitivity 7:	**Decrease in thickness of protective cover layer to 1ft (75% erosion)**

Table H-7. HELP Modeling Sensitivity Analysis Results Runs 1 to 4

HELP Mass Balance Component	Base Case Stage 4 (>1,000 yr)		HELP Sensitivity 1 P x 1.25		HELP Sensitivity 2 P x 1.5		HELP Sensitivity 3 P x 1.25, T x 1.1		HELP Sensitivity 4 P x 1.25, T&LGS x 1.1	
	(in/yr)	%	(in/yr)	%	(in/yr)	%	(in/yr)	%	(in/yr)	%
Precipitation	54.39	100%	68.01	100%	81.60	100%	68.01	100%	68.01	100%
Runoff	0.69	1.3%	1.05	1.5%	1.56	1.9%	0.08	0.1%	0.08	0.1%
Evapotranspiration	30.90	57%	33.12	49%	34.54	42%	35.77	53%	35.73	53%
Cover Drain Collection	21.48	39%	32.32	48%	43.86	54%	30.69	45%	30.74	45%
Flux through Cover Clay Layers	**1.32**	**2.4%**	**1.49**	**2.2%**	**1.64**	**2.0%**	**1.46**	**2.1%**	**1.46**	**2.1%**

Table H-8. HELP Modeling Sensitivity Analysis Results Runs 5 to 7

HELP Mass Balance Component	D4 Base Case (>1,000 yr)		HELP Sensitivity 5 Cover Clay K x 2		HELP Sensitivity 6 Clay K x 2 and Drain K/10		HELP Sensitivity 7 Cover Erosion 75%	
	(in/yr)	%	(in/yr)	%	(in/yr)	%	(in/yr)	%
Precipitation	54.39	100%	54.39	100%	54.39	100%	54.39	100%
Runoff	0.69	1.3%	0.69	1.3%	0.69	1.3%	0.68	1.3%
Evapotranspiration	30.90	57%	30.90	57%	30.90	57%	30.75	57%
Cover Drain Collection	21.48	39%	16.85	31%	14.38	26%	21.63	40%
Flux through Cover Clay Layers	**1.32**	**2.4%**	**5.96**	**11.0%**	**8.41**	**15.5%**	**1.32**	**2.4%**

The results of HELP sensitivity runs 5 to 7 are given in Table H-8, which includes the components of the surface hydrologic budget for each scenario, as well as the baseline results for facility performance stage 4 (>1,000 years). The HELP predicted infiltration rate is highly sensitive to the hydraulic conductivity assumptions for the cover system amended clay layer and lateral drainage layer (HELP sensitivity 5 and 6). The predicted infiltration rate is insensitive to the assumption regarding cover erosion (HELP sensitivity 7).

4.5.3 PATHRAE model sensitivity

Sensitivity evaluations of the PATHRAE model included all of the key parameter assumptions (seeTable H-5), including cover system performance (infiltration and leaching), partition coefficients (K_d values), waste volume uncertainty, vadose zone and saturated zone parameters, and assumptions on the location of the surface water point of exposure and Bear Creek flow rate. Sensitivity evaluations were limited to PATHRAE-RAD because simulations for hazardous COPCs did not include degradation processes and thus are much less complex than for the radioisotope model runs.

Table H-9 summarizes the results of 12 PATHRAE-RAD sensitivity cases in terms of radioisotope releases (number and timing of predicted peaks), and the magnitude of changes in the predicted time to peak and peak surface water concentration. Model sensitivity was evaluated relative to PATHRAE predictions for the performance stage 3 infiltration rate (0. 3"/yr). The stage 3 base case assumed parameter values and the change in the parameter value evaluated for each sensitivity case are listed in the second and third columns of table H-9, respectively. Radioisotopes predicted to peak within the 1,000-year compliance period are identified in the fourth column. Numbers of isotopes predicted to peak in the range of 1,000 - 2,000 years, and total number of predicted peaks within 1,000,000 years are given in columns five and six, respectively. Columns seven through ten summarize the magnitude of impacts on PATHRAE surface water predictions for each sensitivity case.

The model predictions are most sensitive to the assumed infiltration rate through the cover and into the waste zone (sensitivity cases 1 and 2). Sensitivity case 2 infiltration (3.5"/yr) results in C-14 and Tc-99 peaking within 1,000 years, whereas these two radioisotopes peak between 1,000 and 2,000-years post-closure under sensitivity case 1 infiltration (1.3"/yr). Case 1 infiltration is similar to the performance stage 4 assumption for model-based PreWAC development (Table H-3). Case 2 infiltration also results in six additional isotopes predicted to peak within 1,000,000 years.

Sensitivity of PATHRAE predicted peak timing and concentrations is given for two groups of radioisotopes distinguished on the basis of the ratio between half life and retarded travel time. Retarded travel times were calculated based on the the K_d values and the stage 3 base case infiltration rate and vadose and aquifer parameter assumptions. In general, peak concentrations for isotopes having half life > retarded travel time are less sensitive to parameter assumptions than for isotopes having short half lives relative to retarded travel time. However, in most cases predicted peak concentrations for these more sensitive isotopes are less than 0.1 pCi/L, so that increases in concentrations by many orders of magnitude are still relatively small in absolute terms.

Increased infiltration in sensitivity cases 1 and 2 result in increased concentrations by a factor of 3 or greater, depending on the ratio half life:retarded travel time (HL/RT). The large relative increases (> 10 x higher) indicated for case 2 infiltration and HL/RT < 1 are primarily associated with very low predicted peak concentrations (<< 0.001 pCi/L). Increased infiltration also results in earlier peak times, averaging around 50% earlier than base case predicted times, with relatively little difference between HL/RT>1 and HL/RT<1 isotopes (Table H-9, columns seven – ten).

PATHRAE predictions are also sensitive to K_d assumptions. Sensitivity case 3 assumes a factor of two reduction in K_d values in the waste, vadose and saturated zones, which results in a factor of 2 increase in predicted concentrations and earlier peak arrival times for isotopes having HL/RT>1. Concentration

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Table H-9. Summary of PATHRAE Model Sensitivity Evaluation

Sensitivity Case Number Model Parameter Evaluated	Model Parameter Values		Impacts at Surface Water Compliance Point						
			Number and Timing of Peaks			Peak Surface Water Concentration and Time of Peak			
			Radiouclides that peak within 1,000 yrs (Base Case: Cl-36, H-3)	Number of radiouclides that peak between 1,000 and 2,000 yrs (Base Case =0)	Total number of radionuclides that peak before 1,000,000 yrs (Base Case =29)	Peak Time	Peak Concentration	Peak Time	Peak Concentration
	Base Case (Stage 3)	Sensitvity Case				Half Life > Travel Time		Half Life < Travel Time	
(1) Infiltration Rate (m/yr)	0.0109 (0.43")	0.034 (3 X Base) (1.3")	Cl-36, H-3	2	31	40-50% Earlier	3X Higher	55-65% Earlier	>3 X Higher
(2) Infiltration Rate (m/yr)	0.0109 (0.43")	0.0889 (8.2 X Base) (3.5")	Cl-36, H-3, C-14, Tc-99	0	37	65-75% Eariler	8-10 X Higher	70-85% Eariler	>10 X Higher
(3) Partition Coefficient (Kd, mL/g)	Contaminant Specific	0.5 X Base	Cl-36, H-3	2	30	50% Earlier	2 X Higher	50% Earlier	>3 X Higher
(4) Waste volume (M yd^3)	2.2	2.5 (6 cell volume)	Cl-36, H-3	0	29	No Change	1.14X higher	No Change	1.14X higher
(5) HDPE Liner Life (yr)	200	100 (0.5 X Base)	Cl-36, H-3	0	29	90-150 yr earlier	No Change	100 yr earlier	No Change*
(6) Vadoze Zone Thickness (m)	6.7	4.572 (0.65 X Base) (Liner and geobuffer only)	Cl-36, H-3	1	30	20-25% Earlier	0-10% Higher	25-30% Earlier	1.25 - 10 X Higher
(7) Vadoze Zone Porosity (vol/vol)	0.44	0.22 (0.5 X Base)	Cl-36, H-3	1	29	110-170 yr Earlier	No Change**	115 yr earlier	No Change
(8) Aquifer Flow Velocity (m/yr)	21.3	85.2 (4 X Base)	Cl-36, H-3	1	30	15-20% Earlier	0-5% Higher	10-15% Earlier	1.2 -3 X Higher
(9) Aquifer Porosity (vol/vol)	0.04	0.3 (1.5 X Base)	Cl-36, H-3	1	30	15-25% Earlier	0-5% Higher	10-15% Earlier	1.2-3 x Higher
(10) Aquifer Dispersivity (m)	47.6	95.2 (2 X Base)	Cl-36, H-3	1	29	4-20% Later	No Change	No Change	0-5% Lower
(11) Bear Creek Flow Rate (m^3/yr)	736,000	368,000 (0.5 X Base)	Cl-36, H-3	0	29	No Change	2X higher	No Change	2X higher
(12) Distance to Surface Water Point of Exposure (Aquifer path length, m)	476	100 (0.21 X Base)	Cl-36, H-3	1	30	10% Earlier - 2% Later	0-3% Higher	5-8% Earlier	1.1-2 X Higher

* H-3 predicted concentration is sensitive

** C-14, Cl-36, T-99 predicted concentrations are sensitive (>10% higher)

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increases by a factor of 3 or more for isotopes having HL/RT<1. As for infiltration sensitivity cases, the more extreme concentration sensitivity is associated with very low model predicted concentrations.

Sensitivity to changes in other model parameters (cases 4-12) is less than for infiltration and K_d assumptions. Predicted peak concentrations for some isotopes having HL/RT<1 are sensitive to vadose zone thickness (case 6), aquifer flow velocity (case 8) and aquifer porosity (case 9). Changes in the assumed (Bear Creek) flow rate at the surface water point of exposure (case 11) results in directly proportional changes in predicted peak concentrations, which is a simple dilution effect.

4.5.4 Supplemental modeling to evaluate PATHRAE limitations

This section summarizes a set of supplemental analyses to evaluate the effect of several simplifications used in the PATHRAE code. The focus is on dispersion in the vadose zone, which is neglected in PATHRAE. Neglect of dispersion in the vadose zone is clearly not conservative in some situations. In particular, when the radionuclide half life is short compared with retarded travel time, dispersion may cause an increase in peak breakthrough because some fraction of the mass may arrive before having time to decay. However, the conditions for which this is expected correspond to the conditions where the radionuclide discharge is highly attenuated in the subsurface. In addition, there are several other conservative assumptions in PATHRAE, which will partially or fully compensate for the non-conservative neglect of vadose zone dispersion.

4.5.4.1 Method of analyses

The analyses uses the same pathway conceptualization as PATHRAE's ground water transport to surface water pathway. Specifically, radionuclide leaching from the source zone, transport in the vadose and saturated zones, and dilution by surface water are represented. However, the method of analyses used here is more flexible than PATHRAE and accommodates dispersion in the vadose zone, transient flow velocities, and matrix diffusion effects.

The leach rate from the source zone and surface water dilution is modeled identically to PATHRAE. Vadose zone transport is represented by solving the advection dispersion equation with equilibrium sorption so that dispersion in the vadose zone and transient infiltration effects can be accommodated. Transport in the saturated aquifer is evaluated with the advection dispersion equation coupled to a matrix diffusion system. Details are provided in Painter, 2016.

4.5.4.2 Effect of neglecting dispersion in the vadose zone

Several sets of simulations were undertaken to identify combinations of half life and Kd for which PATHRAE's neglect of dispersion in the vadose zone is not conservative. When the radionuclide half life is short compared with retarded travel time, dispersion may cause an increase in peak breakthrough because some fraction of the mass may arrive before having time to decay. However, the conditions for which this is expected correspond to the conditions where the radionuclide discharge is highly attenuated in the subsurface.

The simulations considered transient infiltration with two dispersivity values in the vadose zone (1 cm and 67 cm). Three values of Kd in the vadose zone were considered. A range of half lives was used for each value of Kd. The assumed infiltration rates and time periods over which the rates were applied correspond to the assumed EMDF facility performance scenario, except that stage 3 infiltration (0.43 in./year) begins at 200-years post closure (stage 2 is eliminated). This assumption corresponds to the infiltration rates applied in the application of PATHRAE models for PreWAC development, but explicitly incorporates the infiltration increase at 1,000 years, which PATHRAE does not (i.e. PATHRAE assumes steady infiltration at either the higher or the lower rate).

The supplemental modeling results suggest that a for a given Kd value, a relatively narrow range of half lives exists for which neglect of vadose zone dispersion leads to significant under-prediction (by a factor of 2 or more) of peak concentrations that are also high enough to be of concern, based on the associated risk. For (longer) half lives beyond this critical range, the magnitude of the error in neglecting vadose dispersion becomes negligible. For half lives shorter than the critical range, the predicted surface water peak concentration (accounting for vadose dispersion) becomes negligible. Based on model simulations that assume the flow rates and travel times used for the RI/FS exposure scenario, the critical half-life range is approximately 50 to 75 years for Kd of 1 mL/g, 75 to 150 years for Kd of 2 mL/g, 80 to 200 years for Kd of 3 mL/g, and 180 to 1,000 years for Kd of 10 mL/g.

4.5.4.3 Compensating effect of transient vadose zone velocity

The simulations to evaluate accounting for vadose dispersion were obtained with transient infiltration rates, which affected both the leach rate from the source zone and the vadose zone velocity. Transient velocities are not accommodated by PATHRAE. Thus, in the reference case PATHRAE simulations, the higher vadose zone velocity of 0.088 m/yr was applied to the entire simulation period. The impact of the steady infiltration assumption was evaluated for two combinations of K_d and half life (2 mL/g, 100 years and 10 mL/g, 200 years). Simulations assuming transient infiltration with and without vadose dispersion were compared to the reference case (the PATHRAE approximation, steady infiltration without vadose dispersion). The results suggest that for smaller K_d values, the effect of neglecting both vadose dispersion and transient infiltration can be conservative (predicted peaks are smaller than the reference case both with and without vadose dispersion). However, for larger K_d values, the impact of neglecting vadose dispersion is significant even accounting for transient infiltration (i.e. the steady infiltration reference case significantly underpredicts the peak concentration relative to the transient infiltration simulation including vadose dispersion).

4.5.4.4 Compensating effect of matrix diffusion

Matrix diffusion is not represented directly in PATHRAE. Instead, the parameters appearing in the equilibrium sorption model (K_d and aquifer porosity) are selected to bound the peak breakthrough from the saturated zone. The degree of conservatism inherent in that approach was evaluated with simulations using a computer code (MARFA) that can represent matrix diffusion in the saturated zone.The saturated zone parameters were modified from the PATHRAE reference case for the MARFA runs. This adjustment is required because of differences in the two model conceptualizations. In particular, the matrix diffusion model in MARFA provides a more realistic representation of transport in the fractured material in the saturated zone, and thus requires fewer conservative bounding-type approximations.

The fracture parameters assumed are based on previous modeling work at Oak Ridge National Laboratory. A fracture spacing of 10 cm and a fracture aperture of 0.12 mm were used. This corresponds to a fracture porosity of 0.0012. This value of fracture porosity was then used to scale the saturated zone travel time from the value used in the PATHRAE reference case. The resulting travel time is 0.67 years. In addition, the Kd in the saturated zone was not reduced from the vadose zone value, as opposed to the PATHRAE reference case, which used a saturated zone Kd that is 10% of the vadose zone value. The basis for these changes from the PATHRAE reference case is that use the PATHRAE equilibrium sorption model does not distinguish between primary and secondary porosity and does not represent mass transfer limitations between flow zones (fractures) and sorption sites that are located in the matrix. Thus, the PATHRAE reference case reduced K_d in the saturated zone compared to the vadose zone and used an effective porosity that is intermediate between the fracture and matrix values. Because MARFA represents primary and secondary porosity directly and has an explicit representation of mass transfer limitations through the matrix diffusion model, those conservative assumptions were not needed. For effective matrix diffusivity, Stafford et al. (1998) estimate a value of 1.89e-3 m2/yr. Given the uncertainty in this number a value of 1.89e-4 m2/yr was assumed.

The impact of the neglecting matrix diffusion was evaluated for the same two combinations of K_d and half life examined for the transient infiltration analysis (Similar results were obtained for 3 ml/g and 1 ml/g K_d values) As suggested in Section 4.5.4.2, dispersion in the vadose zone is non-conservative from a risk perspective for a limited range of half lives. However, incorporating both vadose dispersion and matrix diffusion (based on the parameter assumptions given above) significantly decreases the predicted peak concentrations relative to the equilibrium sorption + vadose dispersion case. The MARFA simulations incorporating matrix diffusion suggest that other conservatisms in the PATHRAE reference case – specifically the way equilibrium sorption is used to represent matrix diffusion – compensates for the non-conservative neglect of dispersion in the vadose zone for combinations of half life and mobility (K_d) for that limition of the PATHRAE approximation.

4.5.4.5 Summary of Results

Three simplifying assumptions in the PATHRAE reference case were relaxed in this analysis, using the same pathway conceptualization but with more flexible modeling tools. Neglect of vadose-zone dispersion was found to be conservative or non-conservative, depending on the retarded travel time and the half life. For a given K_d, a relatively narrow range of half life was identified for which neglect of vadose zone transport is non-conservative and radionuclide discharge into surface water is non-negligible. That range of half lives increases with increasing K_d. However, there are two additional conservative simplifications in the PATHRAE reference case that compensate for the non-conservative effect of neglecting vadose zone dispersion: the use of a steady infiltration rate and vadose zone velocity, and the way equilibrium sorption is used to represent transport in the fractured material of the saturated aquifer. With more realistic representations of all three processes, the PATHRAE reference case was found to be pessimistic (conservative) for all parameter combinations considered.

5. ANALYTIC PRELIMINARY WASTE ACCEPTANCE CRITERIA

Analytic PreWAC are determined for a future on-site facility based on meeting the RAOs (see Section 2.5) within the 1,000-year post-closure compliance period:

1. Prevent exposure of human receptors to CERCLA waste (or contaminants released from the waste into the environment) that exceeds a human health risk of 10^{-4} to 10^{-6} ELCR or HI of 1.
2. Prevent adverse impacts to water resources or unacceptable exposure to ecological receptors from CERCLA waste contaminants through meeting chemical-, location- and action-specific ARARs, including RCRA waste disposal and management requirements, Clean Water Act AWQC for surface water in Bear Creek, and Safe Drinking Water Act MCLs in waters that are a current or potential source of drinking water.

The RAOs set carcinogenic risk goals and non-carcinogenic HI goals for direct protection of human health. Additionally, water resource protection is accomplished within the 1,000 year compliance period, as specified in the RAOs, through compliance with ARARs, including MCLs for water used as drinking water (well water). RAO attainment for both radiological and conventional contaminants is also supported by limiting the concentration of waste that can be disposed in the facility. These PreWAC waste concentration limits are determined based on demonstrating the following goals are met during the 1,000 year compliance period:

- 10^{-5} ELCR and HI of 1 based on a human receptor's (direct) ingestion of ground water from a drinking water well and (indirect) uptake of surface water for the compliance period (to 1,000 years) using a resident farmer scenario
- Appropriate AWQC for chemicals (risk-based discharge levels for radionuclides in Bear Creek and tributary surface water are per the Integrated Water Management Focused Feasibility Study, UCOR 2016)
- MCLs in ground water present in the drinking water well of the resident farmer scenario

The calculations and discussions that follow derive PreWAC that meet these objectives.

5.1 CARCINOGENIC PREWAC CALCULATIONS

PreWAC limits are calculated for carcinogenic contaminants (all radioactive COPCs and hazardous COPCs that are carcinogenic) based on the results of PATHRAE-RAD/HAZ modeling. HI PreWAC for hazardous COPCs are calculated by using PATHRAE-HAZ results, and are discussed in Section 5.2.

5.1.1 Carcinogenic Preliminary Waste Acceptance Criteria for Radioactive Contaminants of Potential Concern

The model runs are based on an assumed uniform unit concentration of a single contaminant completely filling the landfill (e.g., 1 Ci/m^3). The calculated PR_{eff} (total effective risk due to this single radioactive COPC) thus represents risk at this assumed concentration. A ratio is set up to scale this assumed concentration and corresponding risk to the appropriate carcinogenic risk goal (set as 10^{-5} for contaminants that peak < 1,000 years post-closure, and as 10^{-4} for those COPCs predicted to peak between 1,000 and 2,000 years, see Table H-1), which allows calculation of the PreWAC limit for each radioactive COPC. For radioisotopes predicted to peak after 2,000-years post-closure, preliminary administrative limits based on modeling exposures at 100 m have been assigned, considering DOE, International Commission on Radiological Protection, and proposed Nuclear Regulatory Commission exposure limit guidelines. As preliminary limits, these values are subject to modification prior to finalization in the WAC Attainment (Compliance) Plan.

An example calculation for Tc-99 is given here with PR_{eff} equal to 1.29E+00. "X" would be the calculated PreWAC limit based on 10^{-4} ELCR since Tc-99 surface water concentration peaks between 1,000 years and 2,000 years (see Attachment B, Table 1):

$$\frac{1\,\frac{Ci}{m^3}}{1.29\,ELCR} = \frac{X\,\frac{Ci}{m^3}}{10^{-4}\,ELCR}$$

X requires conversion to the typical units of pCi/g using an assumed in-place waste density. For this example, X is determined to be 7.75E-05 Ci/m^3. Converting based on an in-place waste density of 1,600 kg/m^3 along with other unit conversions, the Tc-99 PreWAC limit is calculated as 4.87E+01 pCi/g. PreWAC limits for radionuclide COPCs calculated by this method, based on PATHRAE results provided in Attachment B, are given in Table H-10.

5.1.1.1 Adjustments to PreWAC Based on MCLs and Specific Activity Limits

For those radioisotopes predicted to peak within the 1,000-year compliance period, predicted ground water (well water) peak concentrations are compared to MCLs to ensure that all RAOs and PreWAC goals are met. MCLs are given in 40 CFR 141.66. For radionuclides without a promulgated MCL, MCL surrogates are calculated based on DOE Standard-1196-2011 Derived Concentration Standards (DOE 2011). These MCL surrogate values correspond to a 4 mrem/yr dose to the receptor for each radioisotope. For the EBCV site conceptual design and exposure scenario modeled for PreWAC development, only two radioisotopes, H-3 and Cl-36, peak within the 1,000year compliance period, and neither required a reduction of the model-derived PreWAC to meet MCLs. PreWAC values must be compared to the specific activity (SA) of the COPC, because contaminant concentration cannot physically exceed the SA. If the SA is exceeded, the PreWAC limit is set to the SA. Four of 62 radioisotopes considered had model-derived PreWAC that exceeded the SA and were therefore assigned an SA limit (Table H-10)

5.1.1.2 Adjustments to PreWAC Based on Isotopic Decay

Radioactive decay chains in which decay products (daughters) have PreWAC limits were analyzed for cases where the parent isotope may require either establishment of a PreWAC limit (if no limit was determined by the fate-transport modeling of that isotope), or a more stringent limit (if the isotope has an initial fate-transport calculated PreWAC limit). The analysis thus assures that decay of a parent will not result in a daughter concentration exceeding its PreWAC limit. Several decay paths were determined to require this analysis including the following parent → daughter pairs:

- Am-241 → Np-237
- Cm-248 → Pu-244
- Pu-240 → U-236
- Pu-239 → U-235
- Cf-249 →Cm-245
- Cm-244→ Pu-240
- Pu-241 → Am-241
- Pu-238 → U-234
- Pu-242 → U-238
- U-238 → U-234

Table H-10. EMDF Analytic PreWAC for Radionuclides

Nuclide COPC	Carcinogenic PreWAC (pCi/g)			Nuclide COPC	Carcinogenic PreWAC (pCi/g)		
	Peak Time (Years)	PreWAC	Adjusted PreWAC*		Peak Time (Years)	PreWAC	Adjusted PreWAC*
Ac-227				Ni-63			
Ag-108m				Np-237	29,882	1.05E+03	
Al-26				Pa-231	191,613	1.31E+05	
Am-241[2]	16,297	1.46E+15	5.13E+06	Pb-210			
Am-243	20,822	4.74E+03		Pd-107			
Ba-133				Pu-238[2]			3.28E+03
Bi-207				Pu-239	22,827	9.27E+02	
C-14	1,037	6.89E+01		Pu-240	20,620	4.87E+03	
Cd-133m				Pu-241[2]			5.13E+06
Cf-249[2]	16,046	3.30E+17	8.53E+04	Pu-242	27,254	5.04E+02	
Cf-250				Pu-244	35,416	4.78E+02	
Cf-251	17,322	7.21E+08		Ra-226			
Cl-36	944	3.49E+00		Ra-228			
Cm-243				Re-187[1]	8,451	8.61E+06	4.62E+04
Cm-244[2]			4.95E+03	Se-79	156,297	1.79E+06	
Cm-245	21,062	3.48E+03		Si-32[1]	12,623	2.64E+14	1.10E+14
Cm-246	20,055	1.32E+04		Sm-151			
Cm-247	33,203	6.05E+02		Sn-121m			
Cm-248	27,116	1.58E+02		Sn-126	58,726	9.37E+04	
Co-60				Sr-90			
Cs-135				Tc-99	1,537	4.56E+01	
Cs-137				Th-229			
Eu-150				Th-230			
Eu-152				Th-232			
Eu-154				U-232			
H-3[1]	694	3.80E+19	9.70E+15	U-233	31,886	3.25E+03	
I-129	4,069	1.10E+02		U-234	32,748	3.23E+03	
K-40	30,047	1.37E+04		U-235	49,639	3.04E+03	
Nb-93m				U-236	41,366	3.05E+03	
Nb-94	51,998	1.14E+06		U-238	52,397	3.17E+03	
Ni-59[1]	892,141	7.34E+11	8.00E+10	Zr-93	36,195	1.32E+05	

* PreWAC in this column are corrected if necessary by (1) setting PreWAC to the SA, if SA was exceeded; (2) to meet MCLs in well water at the hypothetical receptor location through a reduction in the risk goal by a factor of 10; or (3) to account for in-growth of daughter isotopes (isotopic decay).
** Little to no migration of the radionuclide into surface water either because the COPC exhibits a high K_d (e.g., does not leach from soil) or because the half-life is short (e.g., less than 50 years).
[1] These COPCs original PreWAC exceeded the SA. Therefore, the adjusted PreWAC was set equal to the SA.
[2] These COPCs have adjusted PreWAC limits that account for isotopic decay.

Table H-11 is a summary of data required for the analysis, and calculated limits to be compared to the parent isotope fate-transport PreWAC limit. The analysis is based on calculating a parent concentration limit assuming 100% of the parent decays to the daughter isotope, if the parent decays a minimum of seven half-lives within 1E+06 years (fractional decay was taken into account if less than seven half-lives pass). If the calculated limit is less than the existing (or unlimited) PreWAC for that parent isotope, the calculated limit is set as the isotope's PreWAC limit. If the calculated limit exceeds the parent isotope's fate-transport PreWAC limit, no further adjustments are necessary.

As a result of these calculations, five isotopes were identified that originally had no PreWAC limit, but, once decayed, challenge the daughter PreWAC limits. Therefore, the parent isotope is assigned an adjusted PreWAC limit. Table H-11 shows the results of these calculations, and the adjusted PreWAC limits are highlighted. These values were also given in Table H-10.

Table H-11. Isotopic Decay Pairs Considered for Further Adjustments to PreWAC

Decay Path Considered	Parent Initial PreWAC (pCi/g)	Daughter PreWAC Limit (pCi/g)	Daughter Specific Activity (Ci/g)	Parent Specific Activity (Ci/g)	Adjusted PreWAC for Parent (pCi/g)
Am-241 decays to Np-237	no limit	1.12E+03	7.10E-04	3.40E+00	5.47E+06
Cm-248* decays to Pu-244	1.68E+02	5.10E+02	1.80E-05	4.20E-03	1.38E+05
Pu-240 decays to U-236	5.20E+03	3.25E+03	6.50E-05	2.30E-01	1.17E+07
Pu-239 decays to U-235	9.89E+02	3.25E+03	2.20E-06	6.20E-02	9.30E+07
Cf-249 decays to Cm-245	no limit	3.71E+03	1.70E-01	4.10E+00	9.10E+04
Cm-244 decays to Pu-240	no limit	5.20E+03	2.30E-01	8.10E+01	5.28E+03
Pu-241 decays to Am-241	no limit	1.56E+15	3.40E+00	1.00E+02	5.47E+06
Pu-238 decays to U-234	no limit	3.44E+03	6.20E-03	1.70E+01	3.50E+03
Pu-242* decays to U-238	5.37E+02	3.38E+03	3.40E-07	3.90E-03	3.93E+03
U-238* decays to U-234	3.38E+03	3.44E+03	6.20E-03	3.40E-07	no limit

*Parent isotope does not decay more than seven half-lives in the time frame considered (1E+06 year). This is taken into account in calculations.

5.1.2 Carcinogenic PreWAC for Hazardous COPCs

PreWAC limits for carcinogenic hazardous COPCs are calculated in the same manner as described above for radioactive COPCs limits. However, in this case X' requires conversion to the typical units of mg/kg for a non-radioactive COPC, using the in-place waste density. Acrylonitrile is used as an example (see Attachment B, Table 2) where the ELCR for this contaminant is listed):

$$\frac{1\,\frac{kg}{m^3}}{2.82 \times 10^{-1}\;ELCR} = \frac{X'\;\frac{kg}{m^3}}{10^{-5}\;ELCR}$$

Carcinogenic hazardous chemical compounds are assumed to either peak within the 1,000-year compliance period, or to have degraded completely within that timeframe, so the appropriate target ELCR is 10^{-5}. *X'* requires conversion to the typical units of mg/kg using an assumed in-place waste density and unit conversions. For this example, *X'* is determined to be 3.55E-05 kg/m^3, and converting based on an in-place waste density of 1,600 kg/m^3 along with other unit conversions, the acrylonitrile carcinogenic PreWAC limit is calculated as 0.022 mg/kg. Carcinogenic hazardous elements are all predicted to peak after 1,000-year post-closure, so meeting RCRA LDRs ensures protection of human health and the environment (see Table H-1), rather than model-derived carcinogenic PreWAC.

Carcinogenic PreWAC limits for hazardous COPCs calculated by this method, based on PATHRAE results, are given in Table H-12. As with radionuclide PreWAC, hazardous COPC carcinogenic PreWAC are compared to physical limits (e.g., cannot physically exceed 1E+6 mg/kg), and predicted ground water (well) concentrations may not exceed MCLs. For the 9 carcinigenic organic chemical compounds predicted to peak with the 1,000-year compliance period, none required carcinogenic PreWAC reductions to meet MCLs.

5.2 HAZARDOUS (HAZARD INDEX) PRELIMINARY WASTE ACCEPTANCE CRITERIA CALCULATIONS

Toxicological effects of hazardous COPCs (HI) are quantified based on allowable daily intake limits. The goal for protecting human health is an HI of 1 for contaminants that peak prior to 1,000 years. Hazardous chemical compounds are assumed to either peak within the 1,000-year compliance period, or to have degraded completely within that timeframe. Hazardous elements are all predicted to peak after 1,000 years, so compliance with RCRA LDRs ensures protection of human health and the environment (see Table H-1), rather than model-derived HI-based PreWAC. An exception exists for uranium, a COPC for which there is no LDR limit but which does have an established daily intake limit. An HI of 3 is adopted as the target for development of HI-based uranium PreWAC. HI PreWAC are determined on this basis, using the same relationships as are setup for carcinogenic PreWAC calculations. Using acrylonitrile as an example, PD'_{eff} = 5.69 mg/kg-day (see Appendix B Table 2). Dividing by the reference dose for acrylonitrile (5.4E-01 mg/kg-day, given in Attachment A) this corresponds to an HI of 10.5. Using this model-derived HI value based on an assumed contaminant concentration of 1.0 kg/m^{3,} and setting up a ratio to calculate the HI PreWAC based on meeting an HI of 3:

$$\frac{1\,\frac{kg}{m^3}}{10.5\,HI} = \frac{X'\,\frac{kg}{m^3}}{1\,HI}$$

where X´ requires conversion to the typical units of mg/kg using an assumed in-place waste density. For this example, the acrylonitrile HI PreWAC is calculated as 4.39 mg/kg. Table H-12 lists the HI PreWAC for all hazardous COPCs. As with radionuclide PreWAC, HI-based PreWAC are compared to physical limits (e.g., cannot physically exceed 1E+6 mg/kg), and predicted ground water (well) concentrations for hazardous chemical compounds may not exceed MCLs or established AWQCs. Model-derived, HI-based PreWAC for chemical compounds that result in well water exceeding MCLs or surface water exceeding AWQCs are decreased as necessary to meet the most limiting requirement for protection of water resources. The adjusted HI PreWAC are provided in the table.

In this way, the carcinogenic (Section 5.2.1) and HI PreWAC that meet target risk goals are calculated for each hazardous contaminant in EMDF based on the PATHRAE-HAZ simulations under the assumption that a single contaminant at an assumed unit concentration occupies the landfill. For hazardous COPCs predicted to peack within the 1,000-year compliance period (hazardous chemical compounds), the MCLs are met in the ground water (well water), and this drives the back-calculation of adjusted PreWAC in cases where those MCLs are exceeded. Similar PreWAC adjustments are maded to ensure compliance with established AWQCs at the surface water point of exposure for chemical compounds. Note that, for those cases that require adjustments to PreWAC to meet MCLs, the adjusted carcinogenic and HI PreWAC for the COPC are the same.

Table H-12. EMDF Analytic PreWAC for Hazardous Constituents

COPC	Carcinogenic and HI PreWAC*		
	Carcinogenic (mg/kg)	HI (mg/kg)	Adjusted PreWAC (mg/kg)
Hazardous Elements (HI =3)			
U-233		6.05E+01	6.05E+01
U-234		5.76E+01	5.76E+01
U-235		5.22E+01	5.22E+01
U-236		5.23E+01	5.23E+01
U-238		5.22E+01	5.22E+01
Hazardous Chemical Compounds (ELCR = 10-4, HI = 1)			
2,4-D		3.44E+00	3.21E+00
2,4,5-T[Silvex]		9.38E+00	7.82E+00
Acenaphthene			
Acenaphthylene			
Acetone		1.07E+02	
Acetonitrile		6.19E-01	
Acetophenone		1.37E+01	
Acrolein		5.19E-02	
Acrylonitrile	2.10E-02	4.17E+00	4.52E-01
Aldrin			
Aroclor-1221			
Aroclor-1232			
Benzene	**		
Benzoic acid		4.13E+02	
Benzyl alcohol		1.15E+01	
Benzidine	**		
alpha-BHC	**		
beta-BHC	**		
delta-BHC	**		
Bromodichloromethane	1.88E-01	2.14E+00	1.14E+00
Bromoform	**		
Bromomethane		1.58E-01	
Butylbenzene	**		
Carbazole	**		
Carbon disulfide		1.99E+01	
Carbon tetrachloride	**		
Chlordane			
Chlorobenzene	**		
Chloroform	**		
Chloromethane [Methyl chloride]	9.51E-01		
o-Chlorotoluene	**		
m-Cresol		6.92E+00	
o-Cresol	**		
p-Cresol		1.37E+01	
Cumene [Isopropylbenzene]	**		
Cyanide	**		
DDD			
DDE	**		
Di-n-butylphthalate		1.02E+01	
Dibenz(a,h)anthracene			
Yellow shading for Adjusted PreWAC: MCL-based			
Orange shading for Adjusted PreWAC: AWQC-based			

Table H-12. EMDF Analytic PreWAC for Hazardous Constituents (Continued)

COPC	Carcinogenic and HI PreWAC*		
	Carcinogenic (mg/kg)	HI (mg/kg)	Adjusted PreWAC (mg/kg)
Hazardous Chemical Compounds, continued (ELCR = 10-4, HI = 1)			
Dibenzofuran			
Dibromochloromethane	2.02E-01	3.11E+00	1.66E+00
1,2-Dichlorobenzene	**		
1,3-Dichlorobenzene			
1,4-Dichlorobenzene	**		
1,2,-cis-Dichloroethylene	**		
1,2-trans-Dichloroethylene		2.63E+00	1.75E+00
Dichlorodifluoromethane		1.68E+02	
1,2-Dichloropropane	4.17E-01	1.24E+01	9.19E-02
Dieldrin			
Diethylphthalate	**		
1,2-Dimethylbenzene	**		
2,4-Dimethylphenol	**		
Dimethylphthalate		1.30E+03	4.51E+02
2,4 Dinitrotoluene	3.06E-01	1.74E+00	
2,6 Dinitrotoluene	4.84E-02	2.67E+00	
Endosulfan plus metabolites	**		
Endrin			
Endrin aldehyde			
Endrin ketone			
Ethylbenzene	**		
Ethylchloride			
Heptachlor			
Heptachlor epoxide			
Hexachlorobenzene			
Hexachloroethane	**		
n-Hexane	**		
1-Hexanol		4.50E+00	
2-Hexanone		5.62E-01	
Isophorone	**		
Lindane	**		
Methanol		2.07E+02	
Methylene Chloride			
Methylcyclohexane		1.01E+03	
Methyl Isobutyl Ketone		8.35E+00	
Methyl Methacrylate		1.54E+02	
1-Methyl-4-(1-methylethyl)-benzene	**		
2-Methylnapthalene	**		
(1-Methylpropyl)benzene	**		
Naphthalene			
4-Nitrobenzenamine[4-Nitroaniline]	**		
Nitrobenzene		3.02E-01	
2-Nitrophenol	**		
4-Nitrophenol	**		
N-nitroso-di-n-propylamine	**		
N-Nitrosodiphenylamine	**		
Yellow shading for Adjusted PreWAC: MCL-based			
Orange shading for Adjusted PreWAC: AWQC-based			

Table H-12. EMDF Analytic PreWAC for Hazardous Constituents (Continued)

COPC	Carcinogenic and HI PreWAC*		
	Carcinogenic (mg/kg)	HI (mg/kg)	Adjusted PreWAC (mg/kg)
Hazardous Chemical Compounds, continued (ELCR = 10-4, HI = 1)			
Phenol	**		
Propylbenzene	**		
Propylene glycol		2.07E+03	
Pyridine		1.08E-01	
Styrene	**		
1,1,1,2-Tetrachloroethane	**		
1,1,2,2-Tetrachloroethane	8.81E-02	3.24E+00	8.41E-01
Tetrachloroethene	**		
2,3,4,6-Tetrachlorophenol			
Toluene	**		
1,2,4-Trichlorobenzene	**		
Trichloroethene	**		
Trichlorofluoromethane	**		
2,4,6-Trichlorophenol	**		
1,2,3-Trichloropropane	5.92E-04	6.53E-01	
Trimethylbenzene [isomer mix]	**		
1,2,4-Trimethylbenzene	**		
1,3,5-Trimethylbenzene	**		
Vinyl Chloride	**		
Xylene [mixture of isomers]	**		
Yellow shading for Adjusted PreWAC: MCL-based			
Orange shading for Adjusted PreWAC: AWQC-based			

5.3 DISCUSSION OF PREWAC RESULTS

Analytic WAC limits represent the maximum allowable concentration of a single contaminant within the landfill as a whole. The PreWAC are developed based on individual contaminants occupying the landfill, and therefore wastes that have multiple contaminants must have the sum of fractions (SOF) rule applied to determine their acceptability. The application of the SOF to individual waste streams or the landfill as a whole is beyond the scope of the RI/FS, but will be addressed in a future primary document, the WAC Attainment Plan. For purposes of this RI/FS, the application of the PreWAC is to the total volume of waste upon facility closure. The final analytic WAC, along with other physical, administrative, and safety basis-derived WAC (see RI/FS Chapter 6, Figure 6-26), will dictate the acceptance of waste into the landfill. Based on this preliminary analysis of only the analytic PreWAC, the on-site disposal facility can accept a majority of the anticipated waste without resulting in unacceptable risk.

A 1,000 year compliance period is modeled, based on requirements in DOE M 435.1 (DOE 1999b). This time is selected to encompass the processes and migration of radionuclides most likely to contribute to the risk/hazard to a receptor. Longer timeframes are not used to assess compliance because of the inherently large uncertainties in extrapolating such calculations over long time frames. However, risk-based PreWAC for radioisotopes predicted to peak between 1,000 and 2,000 years are developed to assist in meeting performance goals, per the criteria in Table H-1. In demonstrating compliance with risk goals, CERCLA does not specify a period of compliance to be adhered to, so the 1,000 year period is adopted for hazardous COPCs as well. Hazardous compounds are not modeled past 1,000 years, due to their expected degradation in the environment well within that 1,000-year time frame. Hazardous elements (e.g., silver, mercury) are all predicted to peak after 1,000 years, so compliance with RCRA LDRs is assumed to ensure protection of human health and the environment (see Table H-1), within the 1,000-year period, rather than model-derived HI-based PreWAC. An exception exists for uranium, for which model-derived HI PreWAC are calculated assuming a HI of 3.

An original extensive list of radionuclides (see Attachment A) was considered as COPCs, and those isotopes with half-lives under five years were removed from consideration since during the course of landfill operation and shortly after closure they would undergo decay and result in insignificant risk to a receptor; these isotopes were not modeled. Several other isotopes were removed from consideration because there is no information that indicates a source of that isotope in the future waste. This left a list of 62 isotopes to be modeled. Modeling resulted in the following conclusions:

- Isotopes with half-lives up to about 500 years, regardless of the K_d [mL/g], result in insignificant concentrations at receptor locations, as demonstrated by modeling results. This group of isotopes includes, most notably, Sr-90 and Cs-137 (expected to be present in future EMDF waste), among 24 others. See Figures H-23 and H-24 that show the relative contaminant decrease in concentration in the landfill itself, due largely to radioactive decay of the contaminants as opposed to their leaching/mobility. Figure H-22 also shows decay-only curves for isotopes illustrated, showing the relatively large decrease in the landfill due to decay, and relatively small decrease due to leaching. The Sr-90 decay-only curve is illustrated in Figure H-23 as well.
- A number of isotopes that did not result in significant risk to the receptor (e.g., did not display a peak concentration in the time frame up to 1,000,000 years) included those with significantly high K_ds (e.g., above 2,000 mL/g) and relatively long half-lives; eight isotopes fit this category (see Figure H-25). Figure H-26 illustrates that a high Kd results in very limited mobility; reduction of the COPC in the landfill (in this case, Ni-59) is due mostly to the radioactive decay of the contaminant.

- The remaining 26 isotopes include highly mobile COPCs with longer half-lives or moderately mobile COPCs with shorter to moderate half-lives. These COPCs were determined to pose a risk to the receptor such that analytical PreWAC limits were defined (as given in Table H-10). Figure H-27 illustrates the difference in the decay-only curve versus relative concentration in the landfill due to decay and leaching for Tc-99, which is indicative of COPCs with PreWAC.

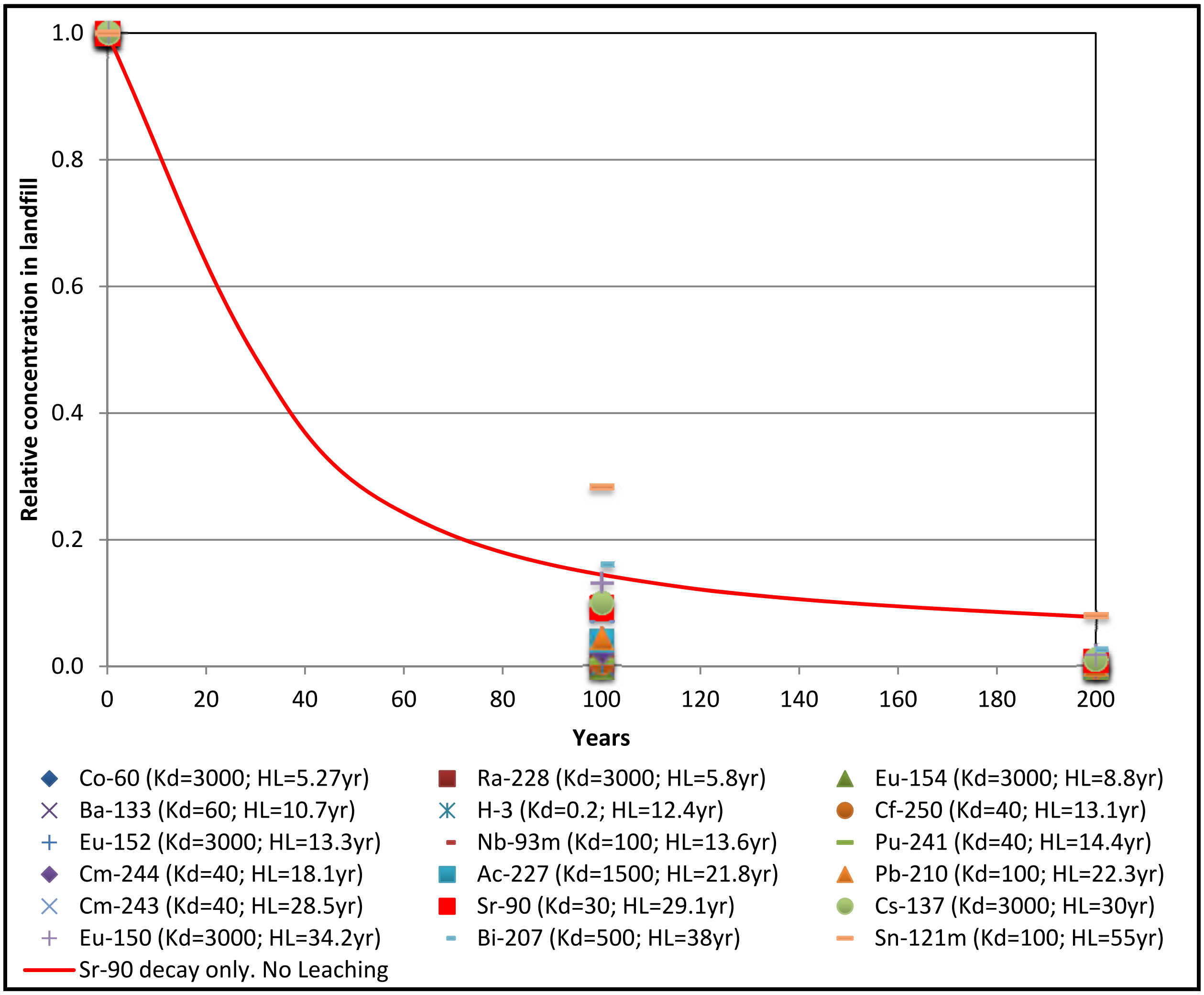

Figure H-23. Relative Concentration in Landfill of Radioactive COPCs with Half-lives under 55 Years

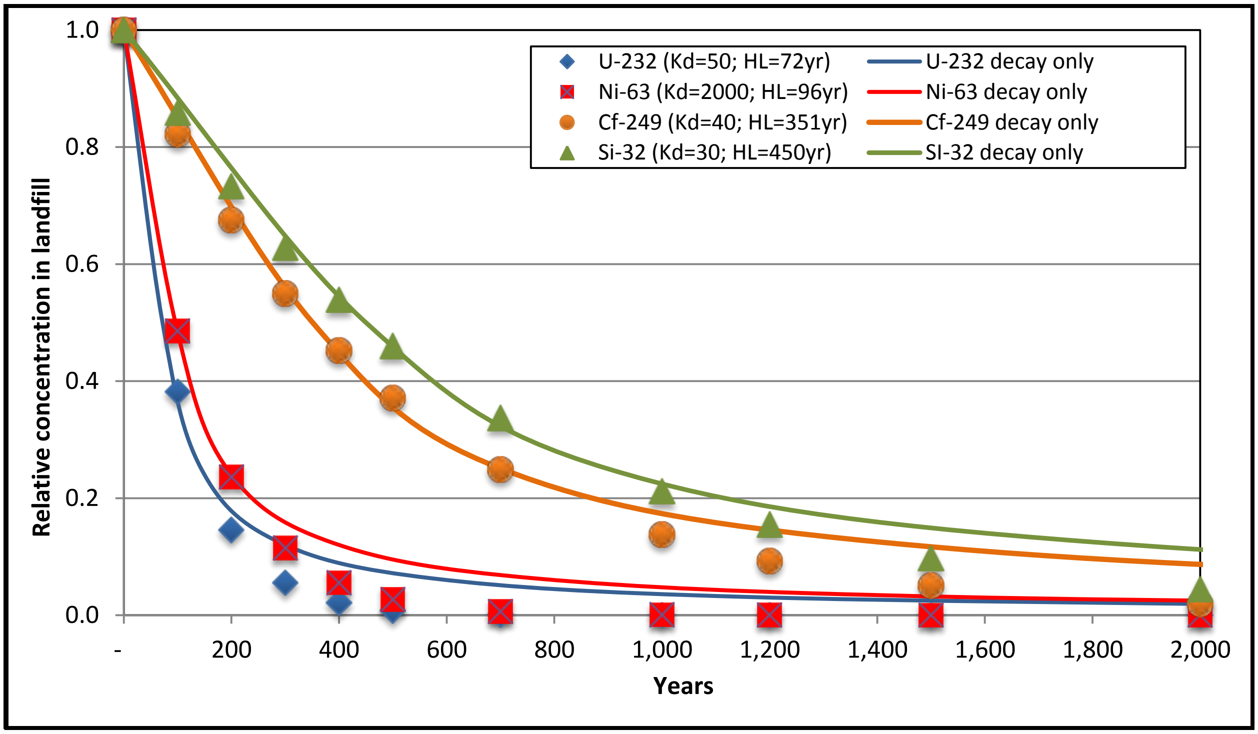

Figure H-24. Relative Concentration in Landfill of Radioactive COPCs with Half-lives under 500 Years

Differences in isotope decay curves vs data points, which represent decay and leaching of isotope, illustrate how these shorter half-lives account for the majority of the decrease of isotope concentration in the landfill.

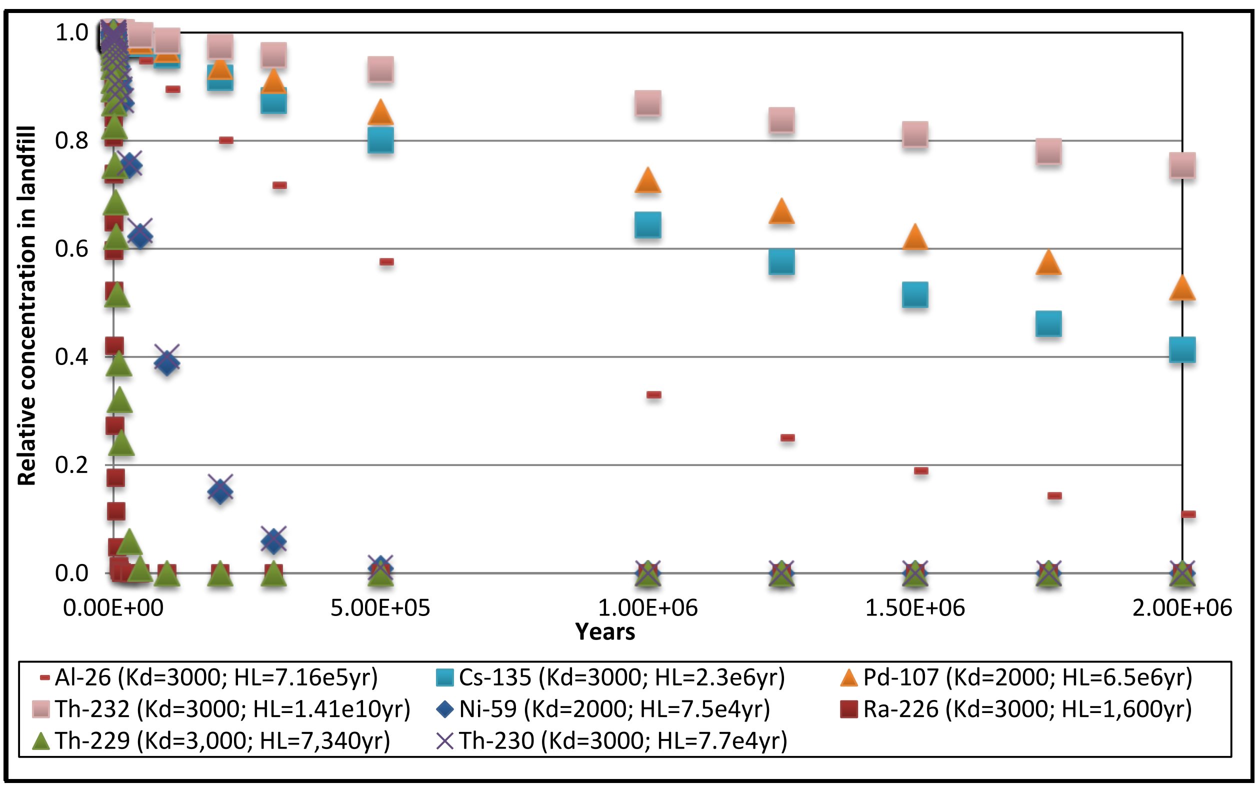

Figure H-25. Relative Concentration in Landfill of Radioactive COPCs with High Partition Coefficients

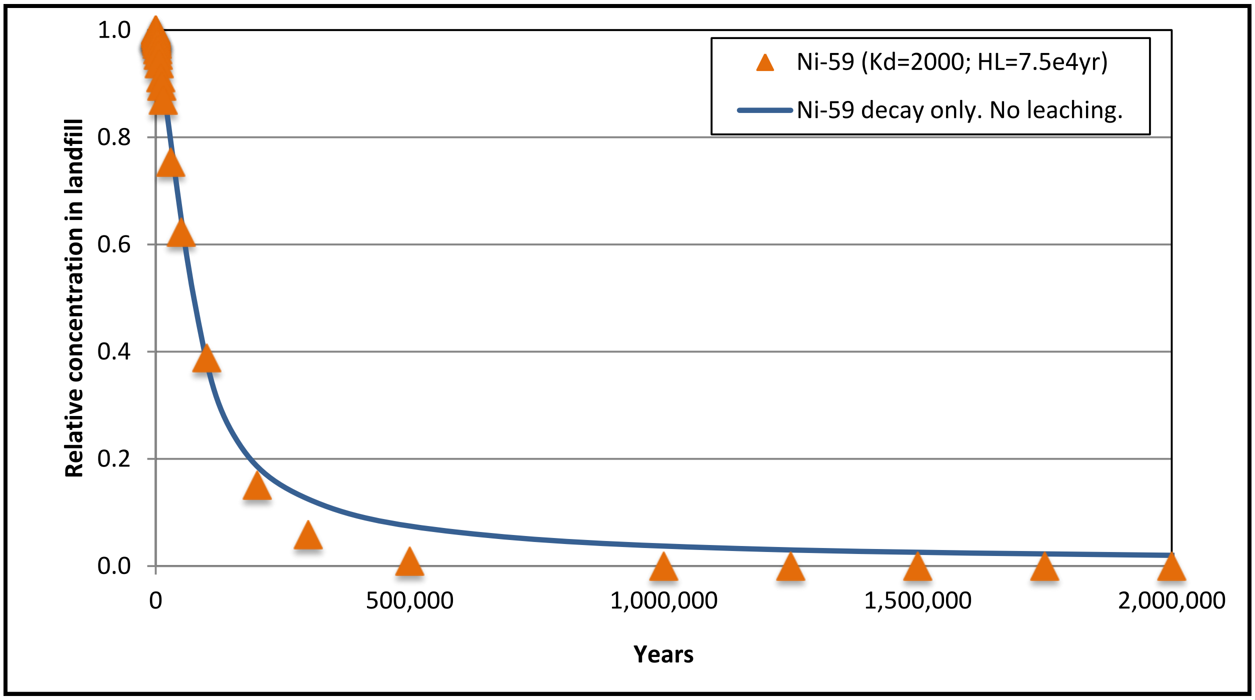

Figure H-26. Relative Concentration of Ni-59 in Landfill due to Decay+Leaching versus Decay Only

Difference in curve vs data points accounts for leaching of Ni-59 from the landfill. This illustrates how relatively little leaching is seen for a COPC with a high K_d.

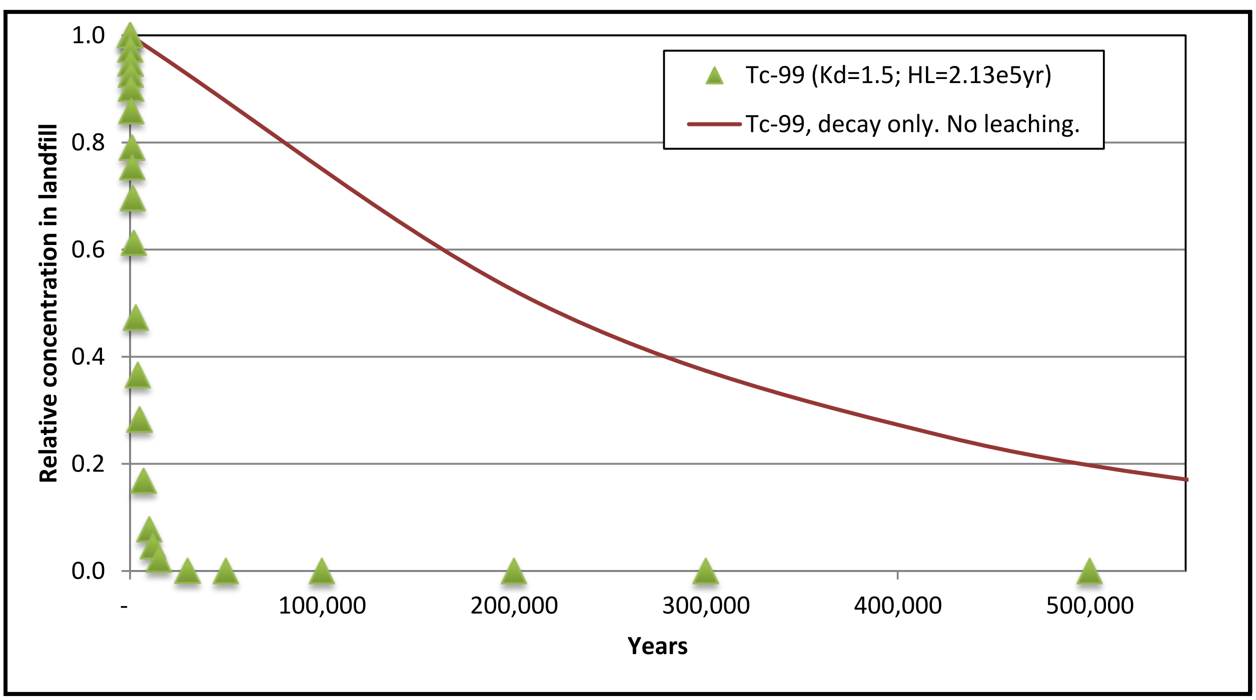

Figure H-27. Relative Concentration of Tc-99 in Landfill due to Decay+Leaching versus Decay Only

The analytic PreWAC limits calculated for radioactive constituents were given in Table H-10. Many radionuclides modeled, as noted in the table, did not result in significant risk and thus have no defined limit, either because of their lack of mobility in the environment (a result of relatively high K_d), and/or because of their rapid decay (a result of a short half-life). Beyond the fate and transport modeling for individual COPCs that set PreWAC limits, further analyses, including comparison to SAs, MCLs, AWQC and growth of radioactive progeny (through isotopic decay) were carried out that resulted in adjustments to many PreWAC limits (to result in limit reductions only), as explained in Sections 5.1.1.1 and 5.1.1.2.

Several conservative assumptions were made for PreWAC development. Those conservative assumptions provide a defense-in-depth approach in the modeling, and are summarized here:

- Isotopes are modeled to peak. Modeling is not truncated at 1,000 years. Many isotopes' peak time of arrival at the receptor are tens of thousands of years out.
- Cap and liner geosynthetics are assumed to fully function for only 200 years. This is conservative according to literature sources (Rowe, et al. 2009, Rowe, 2005), which indicate lifetimes over 500 years may be expected for comparable environments (e.g., thickness of protective layers).
- A constant, average and unchanging footprint is assumed for the landfill in fate and transport modeling with a uniform depleting source (note this is different from the constant leaching source assumed for the ground water modeling). Realistically, the contaminant-contributing footprint of the landfill will shrink over time, as the outer edges of the landfill (source) become depleted more quickly (less source due to shape of landfill) resulting in a decreasing footprint available for leaching.
- Partition coefficients in the saturated zone are assumed to be a factor of 10 lower than the partition coefficients in the vadose and waste zones. This is a highly conservative assumption, based on the results of supplemental modeling performed to evaluate PATHRAE model limitations (see Section 4.5).
- All waste is assumed to be soil or a soil-like matrix with one K_d value for each radiological and chemical constituent within the waste (see Section 5.1). For concrete and process equipment, the effective leach rate that the material actually exhibits can be lower than indicated by the K_d value since contaminant release occurs only at the surface by direct contact with percolating water due to the lack of porosity of the waste form. Use of a soil-like waste form to represent all waste forms is a conservative assumption in that it assumes all the waste is uniformly distributed and available to leaching as soon as cell performance evaluation begins.

There are uncertainties in the PreWAC analysis due to data gaps in site-specific information and the conceptual stage of the disposal facility design at the proposed EMDF site; however, the numerous conservative assumptions off-set these uncertainties. Furthermore, simplifying assumptions such as the use of a porous ground water flow model, introduce uncertainty. It is recognized that the scale of the model allows this simplification, due to the overall dimensions of the modeled area. Phase I characterization has allowed confirmation of the assumed high ground water tables used in the conceptual design. However, as the site selection and design process proceeds, additional site-specific data obtained through further site investigation and hydrogeological/ geotechnical analyses, as well as engineering design changes (e.g., disposal facility location, excavation depth, configuration, depth to water from the bottom of the waste, and waste thickness) can be used to optimize the disposal facility design for the actual site conditions, better define input parameters, and reduce uncertainties. Similar to the EMWMF design process, any additional data and design changes that could significantly impact the PreWAC analyses would be re-evaluated to confirm that the EMDF WAC is still protective for radionuclide and chemical constituents.

5.4 COMPARISON TO ENVIORNMENTAL MANAGEMENT WASTE MANAGEMENT FACILITY ANALYTIC WASTE ACCEPTANCE CRITERIA

Table H-13 compares the analytic PreWAC developed for the EMDF at the EBCV site with the EMWMF analytic WAC. The analytic PreWAC for EMDF are generally similar to or more restrictive than the analytic WAC for EMWMF. However, many more isotopes are assigned PreWAC for the proposed EMDF compared to the EMWMF analytic WAC.

The differences between analytic PreWAC for the EMDF and EMWMF WAC are largely due to the difference inthe distance from the disposal cell to the receptor well location and the different approach to (Pre WAC development for COPCs predicted to peak after 1,000 years. Minor differences in conceptual design, site-specific data (water table depth, creek flow rates), and contaminant constants (e.g., slope factors) also contribute to differences in EMDF PreWAC compared to EMWMF analytic WAC.

The EMWMF analytic WAC was developed using a DF_{well} of 0.0027, compared to values of 0.02 and 0.064 for the EMDF PreWAC developed for peaks before and after 1,000 years, respectively. As shown in Section 5.2, the well concentration (C_{well}) is directly proportional to DF_{well} and indirectly proportional to the analytic PreWAC value. As a result, a higher DF_{well} results in a higher C_{well} and a lower analytic PreWAC value. For radioisotopes predicted to peak after 2,000-years post-closure, preliminary administrative limits based on modeling exposures at 100 m have been assigned, considering DOE, International Commission on Radiological Protection, and proposed Nuclear Regulatory Commission exposure limit guidelines. As preliminary limits, these values are subject to modification prior to finalization in the WAC Attainment (Compliance) Plan.

The analysis completed in this RI/FS demonstrates that an analytic PreWAC for the EMDF would meet applicable risk criteria and be protective. Based on these results, it can be concluded that most future CERCLA waste to be generated after EMWMF reaches maximum capacity would be able to be disposed at the proposed EMDF. It is acknowledged that the analytic PreWAC identified in this RI/FS are a preliminary data set provided to show viability of land disposal at the proposed site, and is subject to change based on final design and further analyses. If on-site disposal is part of the selected remedy as determined by the CERCLA process, final WAC (administrative, analytic, auditable safety analysis-derived, and physical) for a new facility will require approval by all Federal Facility Agreement parties and will be documented in the future primary document, WAC Attainment Plan.

Table H-13. Proposed EMDF Analytic PreWAC Comparison with EMWMF Analytic WAC

COPC	Carcinogenic (pCi/g or mg/mg)		HI PreWAC (pCi/g or mg/kg)	
	EMWMF WAC	Proposed EMDF PreWAC	EMWMF WAC	Proposed EMDF PreWAC
RADIONUCLIDES, [pCi/g]				
Ac-227			Not applicable	
Ag-108m				
Al-26				
Am-241	2.00E+21	1.46E+15		
Am-243		4.74E+03		
Ba-133				
Bi-207				
C-14	1.65E+02	6.89E+01		
Cd-113m				
Cf-249		3.30E+17		
Cf-250				
Cf-251		7.21E+08		
Cl-36		3.49E+00		
Cm-243				
Cm-244				
Cm-245		3.48E+03		
Cm-246		1.32E+04		
Cm-247		6.05E+02		
Cm-248		1.58E+02		
Co-60				
Cs-135				
Cs-137				
Eu-150				
Eu-152				
Eu-154				
H-3	1.50E+05	3.80E+19		
I-129	1.30E+01	1.10E+02		
K-40		1.37E+04		
Nb-93m				
Nb-94		1.14E+06		
Ni-59		7.34E+11		
Ni-63				
Np-237	3.20E+02	1.05E+03		
Pa-231		1.31E+05		
Pb-210				
Pd-107				
Pu-238				
Pu-239	7.20E+02	9.27E+02		

Table H-13. Proposed EMDF Analytic PreWAC Comparison with EMWMF Analytic WAC (Continued)

COPC	Carcinogenic (pCi/g - rads or mg/mg - haz)		HI PreWAC (pCi/g - rads or mg/kg - haz)	
	EMWMF WAC	Proposed EMDF PreWAC	EMWMF WAC	Proposed EMDF PreWAC
RADIONUCLIDES (continued), [pCi/g]				
Pu-240	5.80E+03	4.87E+03	Not applicable	
Pu-241				
Pu-242		5.04E+02		
Pu-244		4.78E+02		
Ra-226				
Ra-228				
Re-187		8.61E+06		
Se-79		1.79E+06		
Si-32		2.64E+14		
Sm-151				
Sn-121m				
Sn-126		9.37E+04		
Sr-90				
Tc-99	1.72E+02	4.56E+01		
Th-229				
Th-230				
Th-232				
U-232				
U-233	1.70E+03	3.25E+03	4.50E+07	6.05E+01
U-234	1.70E+03	3.23E+03	2.80E+07	5.76E+01
U-235	1.50E+03	3.04E+03	9.50E+03	5.22E+01
U-236	1.70E+03	3.05E+03	2.80E+05	5.23E+01
U-238	1.20E+03	3.17E+03	1.50E+03	5.22E+01
Zr-93		1.32E+05		
INORGANICS – ELEMENTS, [mg/kg]				
Antimony			1.60E+02	
Arsenic				
Barium			1.50E+05	
Beryllium				
Boron				
Cadmium				
Chromium VI				
Chromium III				
Chromium (Total)			1.40E+05	
Copper				
Lead			1.50E+03	
Manganese				
Mercury				
Molybdenum				

Table H-13. Proposed EMDF Analytic PreWAC Comparison with EMWMF Analytic WAC (Continued)

COPC	Carcinogenic (pCi/g - rads or mg/mg - haz)		HI PreWAC (pCi/g - rads or mg/kg - haz)	
	EMWMF WAC	Proposed EMDF PreWAC	EMWMF WAC	Proposed EMDF PreWAC
INORGANICS – ELEMENTS (continued), [mg/kg]				
Nickel				
Selenium			1.60E+03	
Silver				
Strontium			3.00E+05	
Tin			2.20E+03	
Vanadium			2.50E+04	
Zinc				
ORGANICS, [mg/kg]				
2,4-D				3.21E+00
2,4,5-T[Silvex]				7.82E+00
Acenaphthene			3.90E+05	
Acenaphthylene				
Acetone			2.70E+02	1.07E+02
Acetonitrile				6.19E-01
Acetophenone				1.37E+01
Acrolein				5.19E-02
Acrylonitrile		2.10E-02		4.52E-01
Aldrin				
Aroclor-1221				
Aroclor-1232				
Benzene	2.00E+02	**		
Benzoic Acid				4.13E+02
Benzyl Alcohol				1.15E+01
Benzidine		**		
alpha-BHC		**		
beta-BHC		**		
delta-BHC		**		
Bromodichloromethane		1.88E-01		1.14E+00
Bromoform		**		
Bromomethane				1.58E-01
Butylbenzene		**		
Carbazole		**		
Carbon disulfide				1.99E+01
Carbon tetrachloride	5.60E+01	**	6.60E+01	
Chlordane				
Chlorobenzene		**		
Chloroform	4.00E+01	**	1.00E+02	
Chloromethane [Methyl Chloride]		9.51E-01		
o-Chlorotoluene		**		
m-Cresol				6.92E+00
o-Cresol		**		

Table H-13. Proposed EMDF Analytic PreWAC Comparison with EMWMF Analytic WAC (Continued)

COPC	Carcinogenic (pCi/g - rads or mg/mg - haz)		HI PreWAC (pCi/g - rads or mg/kg - haz)	
	EMWMF WAC	Proposed EMDF PreWAC	EMWMF WAC	Proposed EMDF PreWAC
ORGANICS (continued), [mg/kg]				
p-Cresol				1.37E+01
Cumene [Isopropylbenzene]		**		
Cyanide		**		
DDD				
DDE		**		
Di-n-butylphthalate			1.90E+02	1.02E+01
Dibenz(a,h)anthracene				
Dibenzofuran				
Dibromochloromethane		2.02E-01		1.66E+00
1,2-Dichlorobenzene		**		
1,3-Dichlorobenzene				
1,4-Dichlorobenzene		**		
1,2,-cis-Dichloroethylene		**		
1,2-trans-Dichloroethylene				1.75E+00
Dichlorodifluoromethane				1.68E+02
1,2-Dichloropropane		4.17E-01		9.19E-02
Dieldrin	7.10E+00		6.00E+01	
Diethylphthalate		**		
1,2-Dimethylbenzene		**		
2,4-Dimethylphenol		**		
Dimethylphthalate				4.51E+02
2,4 Dinitrotoluene		3.06E-01		1.74E+00
2,6 Dinitrotoluene		4.84E-02		2.67E+00
Endosulfan plus metabolites		**		
Endrin				
Endrin Aldehyde				
Endrin Ketone				
Ethylbenzene		**		
Ethylchloride				
Heptachlor				
Heptachlor epoxide				
Hexachlorobenzene				
Hexachloroethane		**		
n-Hexane		**		
1-Hexanol				4.50E+00
2-Hexanone				5.62E-01
Isophorone	6.10E+03	**	1.50E+04	
Lindane		**		
Methanol				2.07E+02
Methylene Chloride				
Methylcyclohexane				1.01E+03
Methyl Isobutyl Ketone				8.35E+00

Table H-13. Proposed EMDF Analytic PreWAC Comparison with EMWMF Analytic WAC (Continued)

COPC	Carcinogenic (pCi/g - rads or mg/mg - haz)		HI PreWAC (pCi/g - rads or mg/kg - haz)	
	EMWMF WAC	Proposed EMDF PreWAC	EMWMF WAC	Proposed EMDF PreWAC
ORGANICS (continued), [mg/kg]				
Methyl Methacrylate				1.54E+02
1-Methyl-4-(1-methylethyl)-benzene		**		
2-Methylnapthalene		**		
(1-Methylpropyl)benzene		**		
Naphthalene				
4-Nitrobenzenamine [4-Nitroaniline]		**		
Nitrobenzene				3.02E-01
2-Nitrophenol		**		
4-Nitrophenol		**		
N-nitroso-di-n-propylamine		**		
N-Nitrosodiphenylamine		**		
Phenol		**		
Propylbenzene		**		
Propylene glycol				2.07E+03
Pyridine				1.08E-01
Styrene		**		
1,1,1,2-Tetrachloroethane		**		
1,1,2,2-Tetrachloroethane		8.81E-02		8.41E-01
Tetrachloroethylene	4.40E+02	**	2.90E+03	
2,3,4,6-Tetrachlorophenol				
Toluene		**	4.90E+04	
1,2,4-Trichlorobenzene		**		
Trichloroethylene	7.80E+02	**		
Trichlorofluoromethane		**		
2,4,6-Trichlorophenol		**		
1,2,3-Trichloropropane		5.92E-04		6.53E-01
Trimethylbenzene [mixture of isomers]		**		
1,2,4-Trimethylbenzene		**		
1,3,5-Trimethylbenzene		**		
Vinyl Chloride		**		
Total Xylenes [mixture of isomers]		**		

Yellow shading for EMDF PreWAC: MCL-based | Orange shading for EMDF PreWAC: AWQC-based

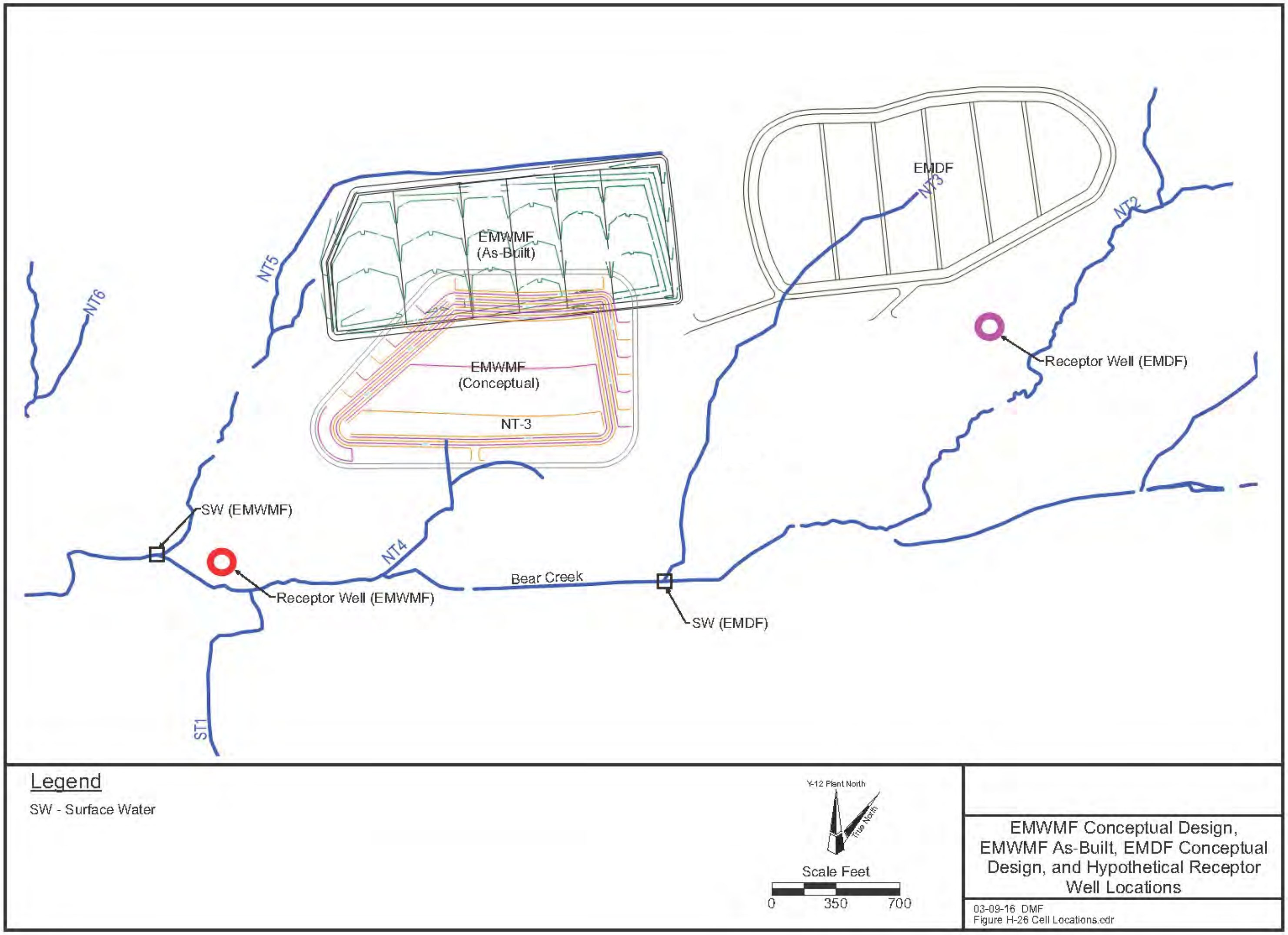

Figure H-28. EMWMF Conceptual Design, EMWMF As-built, EMDF Conceptual Design, and Hypothetical Receptor Well Locations

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APPENDIX H - ATTACHMENT A:
CONTAMINANTS OF POTENTIAL CONCERN

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APPENDIX H - ATTACHMENT B: SUPPLEMENTAL MODELING INFORMATION

APPENDIX H – ATTACHMENT A:
CONTAMINANTS OF POTENTIAL CONCERN

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CONTENTS

TABLES

ACRONYMS

BCV	Bear Creek Valley
COPC	contaminant of potential concern
DOE	U.S. Department of Energy
EMDF	Environmental Management Disposal Facility
EMWMF	Environmental Management Waste Management Facility
EPA	U.S. Environmental Protection Agency
K_d	solid-liquid partition coefficient or distribution coefficient
PreWAC	Preliminary Waste Acceptance Criteria
SF	Slope Factor
U.S.	United States

1. INTRODUCTION

This attachment provides a listing of contaminants of potential concern (COPCs) and pertinent data for those contaminants to supplement Appendix H, *On-site Disposal Facility Preliminary Waste Acceptance Criteria*, which discusses development of the Preliminary Waste Acceptance Criteria (PreWAC) for the On-site Disposal Alternative.

PATHRAE-RAD and PATHRAE-HAZ (Rogers and Associates Engineering, 1995a, 1995b) fate and transport models are used to calculate the peak time of arrival and peak concentrations for the potential radioactive constituents and toxicological constituents at the hypothetical receptor surface water location. Various contaminant-specific parameters are required to run the models. Section 2 provides those parameters for radionuclides. Section 3 provides parameters for hazardous constituents. References for all data are given.

2. RADIONUCLIDES

Table 2-1 summarizes the radioisotopes used in the modeling along with associated parameters (e.g., specific activity and solid-liquid partition coefficients [K_ds]). Those COPCs that were determined not to require modeling to the receptor are summarized in Table 2-2, along with the logic for their removal from consideration.

Solid-liquid partition coefficients, also known as distribution coefficients, are one key variable in determining a contaminant's fate-transport in the PATHRAE model. They are used frequently in this type of modeling, because of their conceptual simplicity. K_d is the ratio of the concentration of a nuclide present in the solid phase (sorbed or reacted on soil or sediment) divided by the equilibrium concentration in the contacting liquid phase (water). Use of a K_d implies a linear equilibrium isotherm between sorbed and non-sorbed species of an element, which is a simplification that holds true at lower concentrations and at constant temperature (as is the situation for most species modeled). Because values of K_d are very site-specific dependent (for example the presence of various competing contaminants, soil properties [e.g., sandy soil versus clay], and water properties [e.g., pH] all affect the K_d value determined for a species), it is best to determine K_ds in the environment expected. In practice K_d is measured and used for much more complex systems, and the lack of fit of the simple K_d model to the real system becomes part of the overall uncertainty in the values of K_d.

In the risk evaluation and determination of PreWAC, K_d is used as a quantitative indicator of the environmental mobility of the element. In general, all isotopes of an element are assumed to have the same K_d value, because sorption is a chemical property and not dependent on the isotopic mass. Because K_d is a simplification, the values are necessarily empirical and highly dependent on the system where they are measured.

The solid-liquid K_d values used in the PATHRAE modeling were based on site-specific and generic K_d factors for soils. Because the waste to be disposed in the landfill consists of debris surrounded by soil, as well as waste soil, soil K_ds were assumed to represent the advective movement of contaminants in the landfill/waste zone as well as the vadose zone. Where multiple K_ds were reported in the references, conservative values were selected for use in this modeling. Several references were consulted. Those references were given an order of preference (as noted in the Table 2-1 footnote):

1. ORNL 1990. *Laboratory Measurement of Radionuclide Sorption in Solid Waste Storage Area 6 Soil/Groundwater Systems*, ORNL-TM-10561, June 1990, Oak Ridge, TN.
2. ORNL 1984a. *Characterization of Soils at Proposed Solid Waste Storage Area (SWSA) 7*, ORNL/TM-9326, December 1984, Oak Ridge, TN.

3. ORNL 1997. *Performance Assessment for the Class L-II Disposal Facility*, ORNL/TM-13401, March 1997, Oak Ridge, TN.
4. ORNL 1984b. *A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides through Agriculture*, ORNL--5786, September 1984, Oak Ridge, TN.
5. DOE 1998. *Remedial Investigation/Feasibility Study for the Disposal of Oak Ridge Reservation Comprehensive Environmental Response, Compensation, and Liability Act of 1980 Waste.* DOE/OR/02-1637&D2, Jacobs EM Team, January 1998, Oak Ridge, TN.

The primary two references were those that gave site-specific K_ds. Both of these first two references gave site-specific K_ds that were determined experimentally for soils on the Oak Ridge Reservation in Melton Valley, similar to soils in Bear Creek Valley (BCV). The third reference consulted was the Performance Assessment for a proposed tumulus facility in Bear Creek. That reference reported K_ds for many isotopes obtained from various literature sources, and primarily drew data from the first two references given. Only a handful of element-specific K_ds were obtained from the fourth reference listed above. This document had an extensive list of K_ds, which compared closely with the values determined from the other previously consulted sources. The K_d for only a single element, carbon, was taken directly from the Environmental Management Waste Management Facility (EMWMF) Remedial Investigation/Feasibility Study; however, many of the previously consulted references served as the basis for the K_ds used in the EMWMF document.

Table 2-1. Summary of Radionuclides and Parameters Used in Modeling

Isotope	TRU Elements noted	Half-life (yr)[a]	Specific Activity (Ci/g)[b]	Previous Uses/Determination of Isotope				Soil Partition Coefficient (mL/g)	Partition Coefficient Reference[c]
				BCV Tumulus PA	In EMWMF RI/FS List	Characterized in EMWMF Waste Lot Analyses	Include in EMDF RI/FS Modeling		
Ac-227		21.773	7.20E+01					1.50E+03	ORNL 1984b.
Ag-108m		127	2.60E+01					4.50E+01	ORNL 1984b.
Al-26		7.16E+05	1.90E-02					3.00E+03	ORNL 1997.
Am-241	TRU	432.2	3.40E+00					4.00E+01	ORNL 1997.
Am-243	TRU	7380	2.00E-01					4.00E+01	ORNL 1997.
Ba-133		10.74	2.60E+02					6.00E+01	ORNL 1984b.
Bi-207		38	5.20E+01					5.00E+02	ORNL 1997.
C-14		5730	4.50E+00					1.09E+00	DOE 1998 (EMWMF RI/FS).
Cd-113m		13.6	2.2e-02					7.5e+01	DOE 1998 (EMWMF RI/FS).
Cf-249	TRU	350.6	4.10E+00					4.00E+01	ORNL 1997.
Cf-250		13.08	1.10E+02					4.00E+01	ORNL 1997.
Cf-251	TRU	898	1.60E+00					4.00E+01	ORNL 1997.
Cl-36		3.01E+05	3.30E-02					2.50E-01	ORNL 1984b.
Cm-243	TRU	28.5	5.20E+01					4.00E+01	ORNL 1997.
Cm-244		18.11	8.10E+01					4.00E+01	ORNL 1997.
Cm-245	TRU	8500	1.70E-01					4.00E+01	ORNL 1997.
Cm-246	TRU	4730	3.10E-01					4.00E+01	ORNL 1997.
Cm-247	TRU	1.56E+07	9.30E-05					4.00E+01	ORNL 1997.
Cm-248	TRU	3.39E+05	4.20E-03					4.00E+01	ORNL 1997.
Co-60		5.271	1.10E+03					3.00E+03	ORNL 1990.
Cs-135		2.30E+06	1.20E-03					3.00E+03	ORNL 1990.
Cs-137		30	8.70E+01					3.00E+03	ORNL 1990.
Eu-150		34.2	1.60E+06					3.00E+03	ORNL 1990.
Eu-152		13.33	1.80E+02					3.00E+03	ORNL 1990.
Eu-154		8.8	2.60E+02					3.00E+03	ORNL 1990.
H-3		12.35	9.70E+03					1.99E-01	ORNL 1997.
I-129		1.57E+07	1.80E-04					4.00E+00	ORNL 1984a.
K-40		1.28E+09	6.40E-06					3.00E+01	ORNL 1997.
Nb-93m		13.6	2.40E+02					1.00E+02	ORNL 1997.
Nb-94		2.03E+04	1.90E-01					1.00E+02	ORNL 1997.
Ni-59		7.50E+04	8.00E-02					2.00E+03	ORNL 1997.
Ni-63		96	5.70E+01					2.00E+03	ORNL 1997.
Np-237	TRU	2.14E+06	7.10E-04					4.00E+01	ORNL 1997.
Pa-231		3.28E+04	4.70E-02					4.00E+02	ORNL 1997.
Pb-210		22.3	7.60E+01					1.00E+02	ORNL 1997.
Pd-107		6.50E+06	5.10E-04					2.00E+03	ORNL 1997.

Table 2-1. Summary of Radionuclides and Parameters Used in Modeling (Continued)

Isotope	TRUElementas noted	Half-Life (yr)[a]	Specific Activity (Ci/g)[b]	Previous Uses/Determination of Isotope: BCV Tumulus PA	In EMWMF RI/FS List	Characterized in EMWMF Waste Lot Analyses	Include in EMDF RI/FS Modeling	Soil Partition Coefficient (mL/g)	Partition Coefficient Reference[c]
Pu-238	TRU	87.74	1.70E+01					4.00E+01	ORNL 1997.
Pu-239	TRU	24,065	6.20E-02					4.00E+01	ORNL 1997.
Pu-240	TRU	6537	2.30E-01					4.00E+01	ORNL 1997.
Pu-241		14.4	1.00E+02					4.00E+01	ORNL 1997.
Pu-242	TRU	3.76E+05	3.90E-03					4.00E+01	ORNL 1997.
Pu-244	TRU	8.26E+07	1.80E-05					4.00E+01	ORNL 1997.
Ra-226		1600	1.00E+00					3.00E+03	ORNL 1997.
Ra-228		5.75	2.70E+02					3.00E+03	ORNL 1997.
Re-187		4.12E10	4.62E-08					7.5E+00	ORNL 1984b.
Se-79		65,000	7.00E-02					3.00E+02	ORNL 1984b.
Si-32		450	1.10E+02					3.00E+01	ORNL 1984b.
Sm-151		90	2.60E+01					1.00E+03	ORNL 1997.
Sn-121m		55	5.40E+01					1.00E+02	ORNL 1997.
Sn-126		1.00E+05	2.80E-02					1.00E+02	ORNL 1997.
Sr-90		29.12	1.40E+02					3.00E+01	ORNL 1990.
Tc-99		2.13E+05	1.70E-02					1.50E+00	ORNL 1984b.
Th-229		7340	2.10E-01					3.00E+03	ORNL 1997.
Th-230		7.70E+04	2.10E-02					3.00E+03	ORNL 1997.
Th-232		1.41E+10	1.10E-07					3.00E+03	ORNL 1997.
U-232		72	2.20E+01					5.00E+01	ORNL 1990. Document recommends Kd 40 mL/g for U. States that at lower U concentrations, 50-60 mL/g is appropriate. The value of 40 was obtained at U concentrations of 235,000 ppm. EMWMF leachate average is 6 ppm uranium. Use the low end of the range for low U concentrations, 50 mL/g.
U-233		1.59E+05	9.70E-03					5.00E+01	
U-234		2.45E+05	6.20E-03					5.00E+01	
U-235		7.04E+08	2.20E-06					5.00E+01	
U-236		2.34E+07	6.50E-05					5.00E+01	
U-238		4.47E+09	3.40E-07					5.00E+01	
Zr-93		1.53E+06	2.50E-03					5.00E+01	ORNL 1997.

PA = Performance Assessment; RI/FS = Remedial Investigation/Feasibility Study; TRU = transuranic

[a] The half-lives above are taken from the International Commission on Radiological Protection Publication 107 (ICRP 2008).
[b] Specific activities (Ci/g) taken from 10 CFR 71, Appendix A.
[c] Partition coefficient (K_d) taken from references used in the following heirarchical order:

1. ORNL 1990. *Laboratory Measurement of Radionuclide Sorption in Solid Waste Storage Area 6 Soil/Groundwater Systems*, ORNL-TM-10561, June 1990, Oak Ridge, TN.
2. ORNL 1984a. *Characterization of Soils at Proposed Solid Waste Storage Area (SWSA) 7*, ORNL/TM-9326, December 1984, Oak Ridge, TN.
3. ORNL 1997. *Performance Assessment for the Class L-II Disposal Facility*, ORNL/TM-13401, March 1997, Oak Ridge, TN.
4. ORNL 1984b. *A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides through Agriculture*, ORNL--5786, September 1984, Oak Ridge, TN.
5. DOE 1998. *Remedial Investigation/Feasibility Study for the Disposal of Oak Ridge Reservation Comprehensive Environmental Response, Compensation, and Liability Act of 1980 Waste*. DOE/OR/02-1637&D2, Jacobs EM Team, January 1998, Oak Ridge, TN.

Table 2-2. Radionuclides Considered but not Modeled

Isotope	TRU Element as noted	Half-life (yr)[a]	Previous Uses/Determination of Isotope			Reason for Removal from COPC List
			In BCV Tumulus PA	In EMWMF RI/FS List	Characterized in EMWMF Waste Lot Analyses	
Ac-225		2.7E-02				Excluded, half-life < 5 years.
Ac-228		7.0E-04				Excluded, half-life < 5 years.
Ag-105		1.1E-01				Excluded, half-life < 5 years.
Ag-110m		6.8E-01				Excluded, half-life < 5 years.
Ag-111		2.0E-02				Excluded, half-life < 5 years.
Am-240		5.8E-03				Excluded, half-life < 5 years.
Am-242m	TRU	1.41E+02				Excluded, covered in modeling by Am-241, -243.
Am-242		1.8E-03				Excluded, half-life < 5 years.
As-72		3.0E-03				Excluded, half-life < 5 years.
As-73		2.2E-01				Excluded, half-life < 5 years.
As-74		4.9E-02				Excluded, half-life < 5 years.
Au-194		4.3E-03				Excluded, half-life < 5 years.
Au-195		5.1E-01				Excluded, half-life < 5 years.
Ba-137m		4.9E-06				Excluded, half-life < 5 years.
Ba-139		1.6E-04				Excluded, half-life < 5 years.
Ba-140		3.5E-02				Excluded, half-life < 5 years.
Be-10		1.5E+06				Excluded, no source, low mobility.
Be-7		1.5E-01				Excluded, half-life < 5 years.
Bi-210		1.4E-02				Excluded, half-life < 5 years.
Bi-211		4.1E-06				Excluded, half-life < 5 years.
Bi-212		1.2E-04				Excluded, half-life < 5 years.
Bi-214		3.8E-05				Excluded, half-life < 5 years.
Bk-247	TRU	1.4E+03				Exclude, low quantity, low mobility.
Bk-249		9.0E-01				Excluded, half-life < 5 years.
Br-76		1.8E-03				Excluded, half-life < 5 years.
Br-77		6.5E-03				Excluded, half-life < 5 years.
Br-82		4.0E-03				Excluded, half-life < 5 years.
Ca-41		1.0E+05				Excluded, no source.
Ca-45		4.5E-01				Excluded, half-life < 5 years.
Cd-109		1.3E+00				Excluded, half-life < 5 years.

Table 2-2. Radionuclides Considered but not Modeled (Continued)

Isotope	TRU Element as noted	Half-life (yr)[a]	Previous Uses/Determination of Isotope			Reason for Removal from COPC List
			In BCV Tumulus PA	In EMWMF RI/FS List	Characterized in EMWMF Waste Lot Analyses	
Cd-115		6.1E-03				Excluded, half-life < 5 years.
Ce-137		1.0E-03				Excluded, half-life < 5 years.
Ce-139		3.8E-01				Excluded, half-life < 5 years.
Ce-141		8.9E-02				Excluded, half-life < 5 years.
Ce-144		7.8E-01				Excluded, half-life < 5 years.
Cf-252		2.6E+00				Excluded, half-life < 5 years.
Cm-242		4.5E-01				Excluded, half-life < 5 years.
Co-56		2.1E-01				Excluded, half-life < 5 years.
Co-57		7.4E-01				Excluded, half-life < 5 years.
Co-58		1.9E-01				Excluded, half-life < 5 years.
Cr-51		7.6E-02				Excluded, half-life < 5 years.
Cs-134		2.1E+00				Excluded, half-life < 5 years.
Cs-136		3.6E-02				Excluded, half-life < 5 years.
Cu-67		7.1E-03				Excluded, half-life < 5 years.
Dy-154		3.0E+06				Excluded, no source, low mobility.
Dy-159		4.0E-01				Excluded, half-life < 5 years.
Eu-149		2.6E-01				Excluded, half-life < 5 years.
Eu-155		4.8E+00				Excluded, half-life < 5 years.
Eu-156		4.2E-02				Excluded, half-life < 5 years.
Eu-158		8.7E-05				Excluded, half-life < 5 years.
Fe-52		9.5E-04				Excluded, half-life < 5 years.
Fe-55		2.7E+00				Excluded, half-life < 5 years.
Fe-59		1.2E-01				Excluded, half-life < 5 years.
Ga-68		1.3E-04				Excluded, half-life < 5 years.
Gd-146		1.3E-01				Excluded, half-life < 5 years.
Gd-148		7.5E+01				Excluded, no source, low mobility.
Gd-150		1.8E+06				Excluded, no source, low mobility.
Gd-151		3.4E-01				Excluded, half-life < 5 years.
Gd-152		1.1E+14				Excluded, no source, low mobility.
Gd-153		6.6E-01				Excluded, half-life < 5 years.
Ge-68		7.4E-01				Excluded, half-life < 5 years.
Hf-172		1.9E+00				Excluded, half-life < 5 years.
Hf-175		1.9E-01				Excluded, half-life < 5 years.

Table 2-2. Radionuclides Considered but not Modeled (Continued)

Isotope	TRU Element as noted	Half-life (yr)[a]	Previous Uses/Determination of Isotope			Reason for Removal from COPC List
			In BCV Tumulus PA	In EMWMF RI/FS List	Characterized in EMWMF Waste Lot Analyses	
Hf-178m		3.1E+01				Excluded, no source, low mobility.
Hf-181		1.2E-01				Excluded, half-life < 5 years.
Hg-203		1.3E-01				Excluded, half-life < 5 years.
Ho-163		4.6E+03				Excluded, no source, low mobility.
Ho-166		3.1E-03				Excluded, half-life < 5 years.
Ho-166m		1.2E+03				Excluded, no source, low mobility.
I-125		1.6E-01				Excluded, half-life < 5 years.
I-131		2.2E-02				Excluded, half-life < 5 years.
In-114m		1.4E-01				Excluded, half-life < 5 years.
In-115m		5.1E-04				Excluded, half-life < 5 years.
Ir-192		2.0E-01				Excluded, half-life < 5 years.
Ir-194		2.2E-03				Excluded, half-life < 5 years.
Kr-81		2.3E+05				Excluded, gas.
Kr-85		1.1E+01				Excluded, gas.
La-137		6.0E+04				Excluded, low quantity, low mobility.
La-140		1.7E+00				Excluded, half-life < 5 years.
Lu-172		1.8E-02				Excluded, half-life < 5 years.
Lu-172m		7.0E-06				Excluded, half-life < 5 years.
Lu-173		1.4E+00				Excluded, half-life < 5 years.
Lu-174		3.3E+00				Excluded, half-life < 5 years.
Lu-176		3.8E+10				Excluded, low quantity, low mobility.
Lu-177		1.8E-02				Excluded, half-life < 5 years.
Mn-52		1.5E-02				Excluded, half-life < 5 years.
Mn-52m		4.0E-05				Excluded, half-life < 5 years.
Mn-54		8.6E-01				Excluded, half-life < 5 years.
Mn-56		2.9E-04				Excluded, half-life < 5 years.
Mo-93		3.5E+03				Excluded, low quantity, low mobility.
Mo-99		7.5E-03				Excluded, half-life < 5 years.
Na-22		2.6E+00				Excluded, half-life < 5 years.
Na-24		1.7E-03				Excluded, half-life < 5 years.
Nb-91		7.0E+02				Excluded, represented by Nb-93m, Nb-94 in modeling.
Nb-91m		1.7E-01				Excluded, half-life < 5 years.
Nb-92		3.5E+07				Excluded, represented by Nb-93m, Nb-94 in modeling.

Table 2-2. Radionuclides Considered but not Modeled (Continued)

Isotope	TRU Element as noted	Half-life (yr)[a]	Previous Uses/Determination of Isotope			Reason for Removal from COPC List
			In BCV Tumulus PA	In EMWMF RI/FS List	Characterized in EMWMF Waste Lot Analyses	
Nb-92m		2.8E-02				Excluded, half-life < 5 years.
Nb-95		9.6E-02				Excluded, half-life < 5 years.
Nd-144		2.4E+15				Excluded, low quantity, low mobility.
Nd-147		3.0E-02				Excluded, half-life < 5 years.
Ni-56		1.6E-02				Excluded, half-life < 5 years.
Ni-57		4.1E-03				Excluded, half-life < 5 years.
Ni-65		2.9E-04				Excluded, half-life < 5 years.
Np-234		1.21E-02				Excluded, half-life < 5 years.
Np-235		1.1E+00				Excluded, half-life < 5 years.
Np-239		6.5E-03				Excluded, half-life < 5 years.
Np-242		1.0E-05				Excluded, half-life < 5 years.
Os-194		6.0E+00				Excluded, short half-life and low quantity.
P-32		3.9E-02				Excluded, half-life < 5 years.
P-33		6.9E-02				Excluded, half-life < 5 years.
Pa-233		7.4E-02				Excluded, half-life < 5 years.
Pa-234		7.6E-04				Excluded, half-life < 5 years.
Pa-234m		2.2E-06				Excluded, half-life < 5 years.
Pb-203		5.9E-03				Excluded, half-life < 5 years.
Pb-211		6.9E-05				Excluded, half-life < 5 years.
Pb-212		1.2E-03				Excluded, half-life < 5 years.
Pb-214		5.1E-05				Excluded, half-life < 5 years.
Pm-143		7.3E-01				Excluded, half-life < 5 years.
Pm-145		1.8E+01				Excluded, short half-life and low quantity.
Pm-146		5.5E+00				Excluded, short half-life and low quantity.
Pm-147		2.6E+00				Excluded, half-life < 5 years.
Pm-148		1.47E-02				Excluded, half-life < 5 years.
Po-210		3.8E-01				Excluded, half-life < 5 years.
Po-212		9.48E-15				Excluded, half-life < 5 years.
Po-216		4.60E-09				Excluded, half-life < 5 years.
Pu-233		4.0E-05				Excluded, half-life < 5 years.
Pu-234		1.0E-03				Excluded, half-life < 5 years.
Pu-236		2.9E+00				Excluded, half-life < 5 years.
Ra-223		3.1E-02				Excluded, half-life < 5 years.
Ra-224		1.0E-02				Excluded, half-life < 5 years.
Rb-82		2.4E-06				Excluded, half-life < 5 years.
Rb-83		2.4E-01				Excluded, half-life < 5 years.
Rb-84		9.0E-02				Excluded, half-life < 5 years.

Table 2-2. Radionuclides Considered but not Modeled (Continued)

Isotope	TRU Element as noted	Half-life (yr)[a]	Previous Uses/Determination of Isotope: In BCV Tumulus PA	Previous Uses/Determination of Isotope: In EMWMF RI/FS List	Previous Uses/Determination of Isotope: Characterized in EMWMF Waste Lot Analyses	Reason for Removal from COPC List
Rb-86		5.1E-02				Excluded, half-life < 5 years.
Rb-87		4.80E+10				Excluded, no source, low mobility.
Re-183		1.9E-01				Excluded, half-life < 5 years.
Re-184		1.0E-01				Excluded, half-life < 5 years.
Re-184m		1.8E-01				Excluded, half-life < 5 years.
Re-188		1.9E-03				Excluded, half-life < 5 years.
Rh-101		3.3E+00				Excluded, half-life < 5 years.
Rh-102		5.7E-01				Excluded, half-life < 5 years.
Rh-102m		3.7E+00				Excluded, half-life < 5 years.
Rh-106		9.5E-07				Excluded, half-life < 5 years.
Rh-97		5.9E-05				Excluded, half-life < 5 years.
Rh-99		4.4E-02				Excluded, half-life < 5 years.
Rn-219		1.3E-07				Excluded, half-life < 5 years.
Ru-103		1.1E-01				Excluded, half-life < 5 years.
Ru-106		1.0E+00				Excluded, half-life < 5 years.
Rn-220		1.76E-06				Excluded, half-life < 5 years.
S-35		2.4E-01				Excluded, half-life < 5 years.
Sb-124		1.6E-01				Excluded, half-life < 5 years.
Sb-125		2.8E+00				Excluded, half-life < 5 years.
Sb-126		3.4E-02				Excluded, half-life < 5 years.
Sc-43		4.5E-04				Excluded, half-life < 5 years.
Sc-44		4.5E-04				Excluded, half-life < 5 years.
Sc-46		2.3E-01				Excluded, half-life < 5 years.
Sc-48		4.2E-04				Excluded, half-life < 5 years.
Se-73		8.1E-04				Excluded, half-life < 5 years.
Se-75		3.3E-01				Excluded, half-life < 5 years.
Sm-145		9.3E-01				Excluded, half-life < 5 years.
Sn-113		3.2E-01				Excluded, half-life < 5 years.
Sn-119m		8.0E-01				Excluded, half-life < 5 years.
Sn-121		3.1E-03				Excluded, half-life < 5 years.
Sn-123		3.5E-01				Excluded, half-life < 5 years.
Sr-82		6.9E-02				Excluded, half-life < 5 years.
Sr-85		1.8E-01				Excluded, half-life < 5 years.
Sr-89		1.4E-01				Excluded, half-life < 5 years.

Table 2-2. Radionuclides Considered but not Modeled (Continued)

Isotope	TRU Element as noted	Half-life (yr)[a]	Previous Uses/Determination of Isotope			Reason for Removal from COPC List
			In BCV Tumulus PA	In EMWMF RI/FS List	Characterized in EMWMF Waste Lot Analyses	
Ta-179		1.8E+00				Excluded, half-life < 5 years.
Ta-182		3.1E-01				Excluded, half-life < 5 years.
Ta-183		1.4E-02				Excluded, half-life < 5 years.
Tb-157		7.0E+01				Excluded, low quantity, low mobility.
Tb-158		1.8E+02				Excluded, low quantity, low mobility.
Tb-160		2.0E-01				Excluded, half-life < 5 years.
Tc-95		2.3E-03				Excluded, half-life < 5 years.
Tc-95m		1.7E-01				Excluded, half-life < 5 years.
Tc-97		4.2E+06				Excluded, low quantity and covered by Tc-99 in modeling.
Tc-99m		6.9E-04				Excluded, half-life < 5 years.
Te-125m		1.6E-01				Excluded, half-life < 5 years.
Te-129m		9.2E-02				Excluded, half-life < 5 years.
Th-227		5.1E-02				Excluded, half-life < 5 years.
Th-228		1.9E+00				Excluded, half-life < 5 years.
Th-231		2.9E-03				Excluded, half-life < 5 years.
Th-231		2.9E-03				Excluded, half-life < 5 years.
Th-234		6.6E-02				Excluded, half-life < 5 years.
Ti-44		6.0E+01				Excluded, low quantity, low mobility.
Tl-204		3.8E+00				Excluded, half-life < 5 years.
Tl-208		5.8E-06				Excluded, half-life < 5 years.
Tm-170		3.5E-01				Excluded, half-life < 5 years.
Tm-171		1.9E+00				Excluded, half-life < 5 years.
U-237		2.1E-03				Excluded, half-life < 5 years.
U-239		4.5E-05				Excluded, half-life < 5 years.
V-48		4.4E-02				Excluded, half-life < 5 years.
V-49		9.1E-01				Excluded, half-life < 5 years.
V-52		1.4E-06				Excluded, half-life < 5 years.
W-178		5.9E-02				Excluded, half-life < 5 years.
W-181		3.3E-01				Excluded, half-life < 5 years.
W-185		2.0E-01				Excluded, half-life < 5 years.
Xe-133		1.4E-02				Excluded, half-life < 5 years.

Table 2-2. Radionuclides Considered but not Modeled (Continued)

Isotope	TRU Elementas noted	Half-life (yr)[a]	Previous Uses/Determination of Isotope			Reason for Removal from COPC List
			In BCV Tumulus PA	In EMWMF RI/FS List	Characterized in EMWMF Waste Lot Analyses	
Y-88		2.9E-01				Excluded, half-life < 5 years.
Y-90		7.3E-03				Excluded, half-life < 5 years.
Y-91		1.6E-01				Excluded, half-life < 5 years.
Yb-169		8.8E-02				Excluded, half-life < 5 years.
Zn-65		6.7E-01				Excluded, half-life < 5 years.
Zn-69m		1.6E-03				Excluded, half-life < 5 years.
Zn-72		7.4E-04				Excluded, half-life < 5 years.
Zr-88		2.3E-01				Excluded, half-life < 5 years.
Zr-95		1.8E-01				Excluded, half-life < 5 years.

PA Performance Assessment;
RI/FS Remedial Investigation/Feasibility Study
TRU transuranic
[a] The half-lifes above are taken from the International Commission on Radiological Protection Publication 107 (ICRP 2008).

Reference Doses for toxicological COPCs and Slope Factors (SFs) for carcinogenic COPCs, as given in recent U.S. Environmental Protection Agency (EPA) risk guidance (EPA 2014a), are used to calculate the EMDF PreWAC. Where no values are provided in the EPA risk guidance, values previously used to calculate the EMWMF PreWAC are used. This chapter, Chapter 2, provides parameters for radionuclides. Chapter 3 provides parameters for toxicological COPCs.

Table 2-3 lists SF values for radioactive constituents. Table 2-4 lists the dose conversion factors for ingestion of the listed radionuclides (ORNL 2015).

Table 2-3. Slope Factors for Radioactive Constituents used in Modeling (taken from EPA 2014a)

Nuclide	Water Ingestion Slope Factor (1/pCi)	Nuclide	Water Ingestion Slope Factor (1/pCi)
Ac-227	2.01E-10	Ni-63	6.81E-13
Ag-108m	8.10E-12	Np-237	6.22E-11
Al-26	1.73E-11	Pa-231	1.72E-10
Am-241	1.04E-10	Pb-210	8.84e-10
Am-243	1.04E-10	Pd-107	2.59E-13
Ba-133	6.88E-12	Pu-238	1.31E-10
Bi-207	5.74E-12	Pu-239	1.35E-10
C-14	1.55E-12	Pu-240	1.35E-10
Cd-113m	2.9E-11	Pu-241	1.76E-12
Cf-249	1.27E-10	Pu-242	1.28E-10
Cf-250	8.92E-11	Pu-244	1.44E-10
Cf-251	1.31E-10	Ra-226	3.85E-10
Cl-36	3.30E-12	Ra-228	1.04E-09
Cm-243	9.51E-11	Re-187	1.67E-14
Cm-244	8.36E-11	Se-79	6.92E-12
Cm-245	1.05E-10	Si-32	3.56E-12
Cm-246	1.03E-10	Sm-151	5.59E-13
Cm-247	9.95E-11	Sn-121m	2.36E-12
Cm-248	4.55E-10	Sn-126	2.58E-11
Co-60	1.58E-11	Sr-90	5.59E-11
Cs-135	6.29E-12	Tc-99	2.75E-12
Cs-137	3.05E-11	Th-229	2.23E-10
Eu-150	4.03E-12	Th-230	9.14E-11
Eu-152	5.85E-12	Th-232	1.01E-10
Eu-154	9.84E-12	U-232	2.90E-10
H-3	5.07E-14	U-233	7.18E-11
I-129	1.51E-10	U-234	7.07E-11
K-40	2.47E-11	U-235	6.96E-11
Nb-93m	8.33E-13	U-236	6.66E-11
Nb-94	7.77E-12	U-238	6.40E-11
Ni-59	2.72E-13	Zr-93	1.08E-12

Table 2-4. Ingestion Dose Conversion Factors for Radioactive Constituents used in Modeling (taken from ORNL 2015)

Nuclide	Ingestion Dose Conversion Factor (mrem/pCi)	Nuclide	Ingestion Dose Conversion Factor (mrem/pCi)
Ac-227	4.07E-03	Ni-63	5.55E-07
Ag-108m	8.51E-06	Np-237	4.07E-04
Al-26	1.30E-05	Pa-231	2.63E-03
Am-241	7.40E-04	Pb-210	2.55E-03
Am-243	7.40E-04	Pd-107	1.37E-07
Ba-133	5.55E-06	Pu-238	8.51E-04
Bi-207	4.81E-06	Pu-239	9.25E-04
C-14	2.15E-06	Pu-240	9.25E-04
Cd-113m	1.61E-04	Pu-241	1.78E-05
Cf-249	1.30E-03	Pu-242	8.88E-04
Cf-250	5.92E-04	Pu-244	8.88E-04
Cf-251	1.33E-03	Ra-226	1.04E-03
Cl-36	3.44E-06	Ra-228	2.55E-03
Cm-243	5.55E-04	Re-187	9.52E-09
Cm-244	4.44E-04	Se-79	1.07E-05
Cm-245	7.77E-04	Si-32	2.07E-06
Cm-246	7.77E-04	Sm-151	3.63E-07
Cm-247	7.03E-04	Sn-121m	1.41E-06
Cm-248	2.85E-03	Sn-126	1.74E-05
Co-60	1.26E-05	Sr-90	1.04E-04
Cs-135	7.40E-06	Tc-99	2.37E-06
Cs-137	4.81E-05	Th-229	1.81E-03
Eu-150	4.81E-06	Th-230	7.77E-04
Eu-152	5.18E-06	Th-232	8.51E-04
Eu-154	7.40E-06	U-232	1.22E-03
H-3	1.55E-07	U-233	1.89E-04
I-129	4.07E-04	U-234	1.81E-04
K-40	2.29E-05	U-235	1.74E-04
Nb-93m	4.44E-07	U-236	1.74E-04
Nb-94	6.29E-06	U-238	1.67E-04
Ni-59	2.33E-07	Zr-93	4.07E-06

3. HAZARDOUS CONSTITUENTS

This section lists partition coefficients, slope factors, and reference doses for hazardous COPCs. Table 3-1 contains solid-liquid soil partition coefficients for the hazardous COPCs, taken from DOE 1998. Table 3-2 contains SFs and references doses for hazardous COPCs. Those COPCs with SFs are considered carcinogenic. Data were taken from EPA screening level tables (EPA 2014b) and DOE 1998.

Table 3-1. K_d Values for Hazardous Constituents used in PATHRAE

COPC	CAS	Soil Partition Coefficient (mL/g)
Antimony	(7440-36-0)	1.90E+01
Arsenic	(7440-38-2)	2.90E+01
Barium	(7440-39-3)	5.50E+01
Beryllium	(7440-41-7)	7.90E+02
Boron	(7440-42-8)	3.00E+00
Cadmium	(7440-43-9)	7.50E+01
Chromium VI	(18540-29-9)	1.00E+01
Chromium III	(7440-47-3)	1.00E+01
Copper	(7440-50-8)	3.50E+01
Lead	(7439-92-1)	1.00E+02
Manganese	(7439-96-5)	2.00E+02
Mercury	(7439-97-6)	5.80E+02
Molybdenum	(7439-98-7)	2.00E+01
Nickel	(7440-02-0)	6.50E+01
Selenium	(7782-49-2)	1.50E+01
Silver	(7440-22-4)	8.30E+00
Strontium	(7440-24-6)	1.35E+01
Tin	(7440-31-5)	2.50E+00
U-233	(1-1)	5.00E+01
U-234	(1-2)	5.00E+01
U-235	(1-3)	5.00E+01
U-236	(1-4)	5.00E+01
U-238	(1-5)	5.00E+01
Vanadium	(7440-62-2)	1.00E+02
Zinc	(7440-66-6)	6.20E+01
2,4-D	(94-75-7)	5.88E-02
2,4,5-T[Silvex]	(93-72-1)	1.61E-01
Acenaphthene	(83-32-9)	9.20E+01
Acenaphthylene	(208-96-8)	1.22E+01
Acetone	(67-64-1)	4.40E-02
Acetonitrile	(75-05-8)	1.54E-03
Acetophenone	(98-86-2)	9.24E-02
Acrolein	(107-02-8)	2.78E-03
Acrylonitrile	(107-13-1)	4.44E-03

Table 3-1. K_d Values for Hazardous Constituents used in PATHRAE (Continued)

COPC	CAS	Soil Partition Coefficient (mL/g)
Aldrin	(309-00-2)	9.74E+01
Aroclor-1221	(11104-28-2)	1.20E+02
Aroclor-1232	(11141-16-5)	1.50E+01
Benzene	(71-43-2)	1.70E+00
Benzoic Acid	(65-85-0)	1.20E-03
Benzyl Alcohol	(100-51-6)	3.13E-02
Benzidine	(92-87-5)	5.48E+00
alpha-BHC	(319-84-6)	3.52E+00
beta-BHC	(319-85-7)	4.28E+00
delta-BHC	(319-86-8)	4.28E+00
Bromodichloromethane	(75-27-4)	1.08E-02
Bromoform	(75-25-2)	2.52E-01
Bromomethane	(74-83-9)	2.83E-02
Butylbenzene	(104-51-8)	1.63E+00
Carbazole	(86-74-8)	6.78E+00
Carbon Disulfide	(75-15-0)	1.03E-01
Carbon Tetrachloride	(56-23-5)	2.20E+00
Chlordane	(57-74-9)	1.73E+02
Chlorobenzene	(108-90-7)	4.38E-01
Chloroform	(67-66-3)	6.20E-01
Chloromethane [Methyl Chloride]	(74-87-3)	2.86E-02
o-Chlorotoluene	(95-49-8)	8.86E-01
m-Cresol	(108-39-4)	9.56E-02
o-Cresol	(95-48-7)	1.82E-01
p-Cresol	(106-44-5)	9.22E-02
Cumene [Isopropylbenzene]	(98-82-8)	1.65E+00
Cyanide	(57-12-5)	9.90E+00
DDD	(72-54-8)	9.16E+01
DDE	(72-55-9)	1.73E+00
Di-n-butylphthalate	(84-74-2)	1.00E-06
Dibenz(a,h)anthracene	(53-70-3)	3.58E+03
Dibenzofuran	(123-64-9)	2.26E+02
Dibromochloromethane	(124-48-1)	1.41E-01
1,2-Dichlorobenzene	(95-50-1)	7.58E-01
1,3-Dichlorobenzene	(541-73-1)	1.61E+01
1,4-Dichlorobenzene	(106-46-7)	1.23E+00
1,2,-cis-Dichloroethylene	(156-59-2)	9.96E-01

Table 3-1. K_d Values for Hazardous Constituents used in PATHRAE (Continued)

COPC	CAS	Soil Partition Coefficient (mL/g)
1,2-trans-Dichloroethylene	(156-60-5)	7.60E-02
Dichlorodifluoromethane	(75-71-8)	1.37E-02
1,2-Dichloropropane	(78-87-5)	9.40E-02
Dieldrin	(60-57-1)	3.40E+01
Diethylphthalate	(84-66-2)	2.52E-01
1,2-Dimethylbenzene	(95-47-6)	4.80E-01
2,4-Dimethylphenol	(105-67-9)	2.52E+00
Dimethylphthalate	(131-11-3)	7.42E-02
2,4 Dinitrotoluene	(121-14-2)	1.02E-01
2,6 Dinitrotoluene	(606-20-2)	8.39E-02
Endosulfan plus metabolites****	(959-98-8)	4.08E-01
Endrin	(72-20-8)	2.16E+01
Endrin Aldehyde	(7421-93-4)	2.16E+00
Endrin Ketone	(53494-70-5)	2.16E+00
Ethylbenzene	(100-41-4)	4.08E-01
Ethylchloride	(75-00-3)	0.0E=00
Heptachlor	(76-44-8)	4.80E+01
Heptachlor Epoxide	(1024-57-3)	1.73E+01
Hexachlorobenzene	(118-74-1)	1.10E+02
Hexachloroethane	(67-72-1)	3.56E+00
n-Hexane	(110-54-3)	3.00E-01
1-Hexanol	(111-27-3)	0.00E+00
2-Hexanone	(591-78-6)	0.00E+00
Isophorone	(78-59-1)	1.70E+00
Lindane	(58-89-9)	6.80E+00
Methanol	(67-56-1)	0.00E+00
Dichloromethane	(75-09-2)	2.01E+03
Methylcyclohexane	(108-87-2)	0.00E+00
Methyl Isobutyl Ketone	(108-10-1)	4.70E-03
Methyl Methacrylate	(80-62-6)	2.00E-02
1-Methyl-4-(1-methylethyl)-benzene	(99-87-6)	1.65E+00
2-Methylnapthalene	(91-57-6)	5.94E+00
(1-Methylpropyl)benzene	(135-98-8)	1.65E+00
Naphthalene	(91-20-3)	1.90E+01
4-Nitrobenzenamine [4-Nitroaniline]	(100-01-6)	3.44E-01
Nitrobenzene	(98-95-3)	1.29E-01
2-Nitrophenol	(88-75-5)	7.10E-01

Table 3-1. K_d Values for Hazardous Constituents used in PATHRAE (Continued)

COPC	CAS	Soil Partition Coefficient (mL/g)
4-Nitrophenol	(100-02-7)	8.74E-01
N-nitrosodipropylamine	(621-64-7)	3.00E-01
N-Nitrosodiphenylamine	(86-30-6)	6.54E-01
Phenol	(108-95-2)	2.80E-01
Propylbenzene	(103-65-1)	1.65E+00
Propylene glycol	(57-55-6)	2.00E-03
Pyridine	(110-86-1)	1.38E-02
Styrene	(100-42-5)	1.82E+00
1,1,1,2-Tetrachloroethane	(630-20-6)	3.18E-01
1,1,2,2-Tetrachloroethane	(79-34-5)	1.56E-01
Tetrachloroethylene	(127-18-4)	7.20E+00
2,3,4,6-Tetrachlorophenol	(58-90-2)	2.49E+02
Toluene	(108-88-3)	6.00E+00
1,2,4-Trichlorobenzene	(120-82-1)	1.44E+00
Trichloroethylene	(79-01-6)	2.60E+00
Trichlorofluoromethane	(75-69-4)	2.68E-01
2,4,6-Trichlorophenol	(88-06-02)	6.36E-01
1,2,3-Trichloropropane	(96-18-4)	1.61E-01
Trimethylbenzene [mixture of isomers]	(25551-13-7)	1.44E+00
1,2,4-Trimethylbenzene	(95-63-6)	1.44E+00
1,3,5-Trimethylbenzene	(108-67-8)	3.34E+00
Vinyl Chloride	(75-01-4)	3.72E-01
Xylene [mixture of isomers]	(1330-20-7)	8.86E-01

Table 3-2. Slope Factors and Reference Doses for Hazardous COPCs

COPC	Slope Factor (1/(mg/kg-d))	Reference Dose (mg/kg-day)
Antimony		4.00E-04
Arsenic	1.5	3.00E-04
Barium		2.00E-01
Beryllium		2.00E-03
Boron		2.00E-01
Cadmium		5.00E-04
Chromium III		1.00E+00
Chromium VI	0.5	3.00E-03
Copper		4.00E-02
Lead		1.40E-03
Manganese		1.40E-01
Mercury		3.00E-04
Molybdenum		5.00E-03
Nickel		2.00E-02
Selenium		5.00E-03
Silver		5.00E-03
Strontium		6.00E-01
Tin		6.00E-01
U-233		3.00E-03
U-234		3.00E-03
U-235		3.00E-03
U-236		3.00E-03
U-238		3.00E-03
Vanadium		5.00E-03
Zinc		3.00E-01
2,4-D		1.00E-02
2,4,5-T[Silvex]		8.00E-03
Acenaphthene		6.00E-02
Acenaphthylene		6.00E-02
Acetone		9.00E-01
Acetonitrile		6.00E-03
Acetophenone		1.00E-01
Acrolein		5.00E-04
Acrylonitrile	5.40E-01	4.00E-02
Aldrin	1.70E+01	3.00E-05

Table 3-2. Slope Factors and Reference Doses for Hazardous COPCs (Continued)

COPC	Slope Factor (1/(mg/kg-d))	Reference Dose (mg/kg-day)
Aroclor-1221	2.00E+00	
Aroclor-1232	2.00E+00	
Benzene	5.50E-02	4.00E-03
Benzoic Acid		4.00E+00
Benzyl Alcohol		1.00E-01
Benzidine	2.30E+02	3.00E-03
alpha-BHC	6.30E+00	8.00E-03
beta-BHC	1.80E+00	
delta-BHC	1.80E+00	
Bromodichloromethane	6.20E-02	2.00E-02
Bromoform	7.90E-03	2.00E-02
Bromomethane		1.40E-03
Butylbenzene		5.00E-02
Carbazole	2.00E-02	
Carbon Disulfide		1.00E-01
Carbon tetrachloride	7.00E-02	4.00E-03
Chlordane	3.50E-01	5.00E-04
Chlorobenzene		2.00E-02
Chloroform	3.10E-02	1.00E-02
o-Chlorotoluene		2.00E-02
m-Cresol		5.00E-02
o-Cresol		5.00E-02
p-Cresol		1.00E-01
Cumene [Isopropylbenzene]		1.00E-01
Cyanide		6.00E-04
DDD	2.40E-01	
DDE	3.40E-01	
Di-n-butylphthalate		1.00E-01
Dibenz(a,h)anthracene	7.30E+00	
Dibenzofuran		1.00E-03
Dibromochloromethane	8.40E-02	2.00E-02
1,2-Dichlorobenzene		9.00E-02
1,3-Dichlorobenzene		8.90E-02
1,4-Dichlorobenzene	5.40E-03	7.00E-02
1,2,-cis-Dichloroethylene		2.00E-03
1,2-trans-Dichloroethylene		2.00E-02
Dichlorodifluoromethane		2.00E-01

Table 3-2. Slope Factors and Reference Doses for Hazardous COPCs (Continued)

COPC	Slope Factor (1/(mg/kg-d))	Reference Dose (mg/kg-day)
1,2-Dichloropropane	3.60E-02	9.00E-02
Dieldrin	1.60E+01	5.00E-05
Diethylphthalate		8.00E-01
1,2-Dimethylbenzene		2.00E-01
2,4-Dimethylphenol		2.00E-02
Dimethylphthalate		1.00E+01
2,4 Dinitrotoluene	3.10E-01	2.00E-03
2,6 Dinitrotoluene	1.50E+00	3.00E-04
Endosulfan plus metabolites		6.00E-03
Endrin		3.00E-04
Endrin Aldehyde		3.00E-04
Endrin Ketone		3.00E-04
Ethylbenzene	1.10E-02	1.00E-01
Ehtylchloride	0.00E+00	0.00E+00
Heptachlor	4.50E+00	5.00E-04
Heptachlor Epoxide	9.10E+00	1.30E-05
Hexachlorobenzene	1.60E+00	8.00E-04
Hexachloroethane	4.00E-02	7.00E-04
n-Hexane		6.00E-02
1-Hexanol		4.00E-02
2-Hexanone		5.00E-03
Isophorone	9.50E-04	2.00E-01
Lindane	1.10E+00	3.00E-04
Methanol		2.00E+00
Dichloromethane	2.00E-03	6.00E-03
Methylcyclohexane		6.00E-02
Methyl Isobutyl Ketone		8.00E-02
Methyl Methacrylate		1.40E+00
1-Methyl-4-(1-methylethyl)-benzene		3.70E-02
2-Methylnapthalene		4.00E-03
(1-Methylpropyl)benzene		3.70E-02
Naphthalene		2.00E-02
4-Nitrobenzenamine [4-Nitroaniline]	2.00E-02	4.00E-03
Nitrobenzene		2.00E-03
2-Nitrophenol		6.20E-02
4-Nitrophenol		6.20E-02
N-Nitrosodipropylamine	7.00E+00	
N-Nitrosodiphenylamine	4.90E-03	

Table 3-2. Slope Factors and Reference Doses for Hazardous COPCs (Continued)

COPC	Slope Factor (1/(mg/kg-d))	Reference Dose (mg/kg-day)
Phenol		3.00E-01
Propylbenzene		1.00E-01
Propylene glycol		2.00E+01
Pyridine		1.00E-03
Styrene		2.00E-01
1,1,1,2-Tetrachloroethane	2.60E-02	3.00E-02
1,1,2,2-Tetrachloroethane	2.00E-01	2.00E-02
Tetrachloroethylene	2.10E-03	6.00E-03
2,3,4,6-Tetrachlorophenol		3.00E-02
Toluene		8.00E-02
1,2,4-Trichlorobenzene	2.90E-02	1.00E-02
Trichloroethylene	4.60E-02	5.00E-04
Trichlorofluoromethane		3.00E-01
2,4,6-Trichlorophenol	1.10E-02	1.00E-03
1,2,3-Trichloropropane	3.00E+01	4.00E-03
Trimethylbenzene [mixture of isomers]	0.00E+00	0.00E+00
1,2,4-Trimethylbenzene	0.00E+00	0.00E+00
1,3,5-Trimethylbenzene		1.00E-02
Vinyl Chloride	7.20E-01	3.00E-03
Xylene [mixture of isomers]		2.00E-01

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APPENDIX H – ATTACHMENT B:
SUPPLEMENTAL MODELING INFORMATION

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CONTENTS

TABLES

ACRONYMS

COC	contaminant of concern
COPC	contaminant of potential concern
EMDF	Environmental Management Disposal Facility
HELP	Hydrologic Evaluation of Landfill Performance
PreWAC	Preliminary Waste Acceptance Criteria

1. INTRODUCTION

This attachment provides supplemental modeling information to Appendix H, *On-site Disposal Facility Preliminary Waste Acceptance Criteria* (PreWAC). Section 2 provides information about the Hydrologic Evaluation of Landfill Performance (HELP) model, including example base case model input and output files. Section 3 provides information about the PATHRAE model and PreWAC calculations, including PATHRAE example input and output files for the base case.

2. HELP MODEL

Detailed information about the HELP modeling analysis that was conducted to support PreWAC development is presented in this section. HELP model input parameters are summarized in Section 2.1, including the complete design and long-term (worst-case) scenarios. The long-term (worst-case) scenario was used for PreWAC development. HELP model output parameters are summarized in Section 2.2.

2.1 HELP MODEL INPUT PARAMETER SUMMARY

The HELP model requires general climatic data, design parameters, and soil characteristics to perform the analysis. These are as follows:

- **Climatic Data:** General climatic data input include the growing season, average quarterly relative humidity, normal mean monthly temperatures and precipitation, maximum leaf area index, evaporative zone depth, and latitude.
- **Design Parameters:** Disposal cell design parameters include the slope and maximum drainage distance for lateral drainage layers, layer thickness, layer description, area, leachate recirculation procedures, subsurface inflows, surface characteristics, and geomembrane characteristics.
- **Soil Characteristics:** Necessary soil data input include porosity, field capacity, wilting point, saturated hydraulic conductivity, initial moisture storage, and the United States Soil Conservation Service runoff curve number. The porosity, field capacity, wilting point, and saturated hydraulic conductivity are used to estimate the soil-water evaporation coefficient and Brooks-Corey soil moisture retention parameters. The HELP model contains default soil characteristics for 42 material types that are used when measurements or site-specific estimates are not available. Geotechnical parameters used in the model for each layer may be adjusted based on final design criteria as information becomes available.

2.1.1 Evapotranspiration and Weather Data

The same evapotranspiration and weather data were used for all base profile runs.

```
NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
         KNOXVILLE             TENNESSEE

    STATION LATITUDE                         =  35.49 DEGREES
    MAXIMUM LEAF AREA INDEX                  =   3.50
    START OF GROWING SEASON (JULIAN DATE)    =     85
    END OF GROWING SEASON (JULIAN DATE)      =    307
    EVAPORATIVE ZONE DEPTH                   =  21.0  INCHES
    AVERAGE ANNUAL WIND SPEED                =   7.10 MPH
    AVERAGE 1ST QUARTER RELATIVE HUMIDITY    =  68.00 %
    AVERAGE 2ND QUARTER RELATIVE HUMIDITY    =  69.00 %
    AVERAGE 3RD QUARTER RELATIVE HUMIDITY    =  76.00 %
    AVERAGE 4TH QUARTER RELATIVE HUMIDITY    =  72.00 %
```

```
NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
         COEFFICIENTS FOR    KNOXVILLE           TENNESSEE

         NORMAL MEAN MONTHLY PRECIPITATION (INCHES)
```

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.57	4.34	5.68	4.08	4.68	4.34
5.45	3.70	3.86	3.18	4.59	5.30

```
NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
         COEFFICIENTS FOR    KNOXVILLE           TENNESSEE

    NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)
```

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
35.00	38.80	47.90	56.80	64.90	72.40
75.80	75.20	69.10	57.40	47.30	38.60

```
NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
         COEFFICIENTS FOR    KNOXVILLE           TENNESSEE
           AND STATION LATITUDE  =  35.49 DEGREES
```

2.1.2 Base Case > 1,000 year Profile and Parameters

This is an example run, for the time period greater than 1,000 years.

```
TIME:   8:47     DATE:   2/26/2016   (File name: EMDFBAS4.OUT)
 **************************************************************************

      TITLE:  EMDF Base 4 (Greater Than 1000 Years)

 **************************************************************************


      NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
               COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

                              LAYER  1
                              --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER   4
            THICKNESS                    =     24.00   INCHES
            POROSITY                     =      0.4370 VOL/VOL
            FIELD CAPACITY               =      0.1050 VOL/VOL
            WILTING POINT                =      0.0470 VOL/VOL
            INITIAL SOIL WATER CONTENT   =      0.1454 VOL/VOL
            EFFECTIVE SAT. HYD. COND.    =  0.170000002000E-02 CM/SEC
          NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  4.63
                   FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                              LAYER  2
                              --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER   3
            THICKNESS                    =     12.00   INCHES
            POROSITY                     =      0.4570 VOL/VOL
            FIELD CAPACITY               =      0.0830 VOL/VOL
            WILTING POINT                =      0.0330 VOL/VOL
            INITIAL SOIL WATER CONTENT   =      0.1756 VOL/VOL
            EFFECTIVE SAT. HYD. COND.    =  0.310000009000E-02 CM/SEC


                              LAYER  3
                              --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER   1
            THICKNESS                    =     24.00   INCHES
            POROSITY                     =      0.4170 VOL/VOL
            FIELD CAPACITY               =      0.0450 VOL/VOL
            WILTING POINT                =      0.0180 VOL/VOL
            INITIAL SOIL WATER CONTENT   =      0.1271 VOL/VOL
            EFFECTIVE SAT. HYD. COND.    =  0.999999978000E-02 CM/SEC
```

```
                    LAYER  4
                    --------

         TYPE 2 - LATERAL DRAINAGE LAYER
           MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.3970 VOL/VOL
FIELD CAPACITY               =      0.0320 VOL/VOL
WILTING POINT                =      0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.3932 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.300000003000E-02 CM/SEC
SLOPE                        =      5.00   PERCENT
DRAINAGE LENGTH              =    100.0    FEET


                    LAYER  5
                    --------

           TYPE 3 - BARRIER SOIL LINER
           MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.4270 VOL/VOL
FIELD CAPACITY               =      0.4180 VOL/VOL
WILTING POINT                =      0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.699999987000E-07 CM/SEC


                    LAYER  6
                    --------

       TYPE 1 - VERTICAL PERCOLATION LAYER
           MATERIAL TEXTURE NUMBER  16
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.4270 VOL/VOL
FIELD CAPACITY               =      0.4180 VOL/VOL
WILTING POINT                =      0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.100000001000E-06 CM/SEC


                    LAYER  7
                    --------

       TYPE 1 - VERTICAL PERCOLATION LAYER
           MATERIAL TEXTURE NUMBER  21
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.3970 VOL/VOL
FIELD CAPACITY               =      0.0320 VOL/VOL
WILTING POINT                =      0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0579 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.300000012000     CM/SEC
```

```
                          LAYER  8
                          --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER  22
THICKNESS                   =    600.00   INCHES
POROSITY                    =      0.4190 VOL/VOL
FIELD CAPACITY              =      0.3070 VOL/VOL
WILTING POINT               =      0.1800 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.3070 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.189999992000E-04 CM/SEC


                          LAYER  9
                          --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   8
THICKNESS                   =     12.00   INCHES
POROSITY                    =      0.4630 VOL/VOL
FIELD CAPACITY              =      0.2320 VOL/VOL
WILTING POINT               =      0.1160 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.2373 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.369999994000E-03 CM/SEC


                          LAYER 10
                          --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER  21
THICKNESS                   =     12.00   INCHES
POROSITY                    =      0.3970 VOL/VOL
FIELD CAPACITY              =      0.0320 VOL/VOL
WILTING POINT               =      0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0525 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.300000012000     CM/SEC


                          LAYER 11
                          --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER  20
THICKNESS                   =      0.30   INCHES
POROSITY                    =      0.8500 VOL/VOL
FIELD CAPACITY              =      0.0100 VOL/VOL
WILTING POINT               =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0100 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =   10.0000000000     CM/SEC


                          LAYER 12
                          --------
```

```
              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER  16
THICKNESS                    =    36.00   INCHES
POROSITY                     =     0.4270 VOL/VOL
FIELD CAPACITY               =     0.4180 VOL/VOL
WILTING POINT                =     0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT   =     0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.100000001000E-06 CM/SEC


                        LAYER 13
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  26
THICKNESS                    =   120.00   INCHES
POROSITY                     =     0.4450 VOL/VOL
FIELD CAPACITY               =     0.3930 VOL/VOL
WILTING POINT                =     0.2770 VOL/VOL
INITIAL SOIL WATER CONTENT   =     0.3930 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.190000003000E-05 CM/SEC


                        LAYER 14
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  25
THICKNESS                    =    84.00   INCHES
POROSITY                     =     0.4370 VOL/VOL
FIELD CAPACITY               =     0.3730 VOL/VOL
WILTING POINT                =     0.2660 VOL/VOL
INITIAL SOIL WATER CONTENT   =     0.3732 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.359999990000E-05 CM/SEC
```

2.1.3 General Design and Evaporative Zone Data

```
 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE # 4 WITH A
          GOOD STAND OF GRASS, A SURFACE SLOPE OF  5.%
          AND A SLOPE LENGTH OF  450. FEET.

SCS RUNOFF CURVE NUMBER              =    49.30
FRACTION OF AREA ALLOWING RUNOFF     =   100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE   =    35.000  ACRES
EVAPORATIVE ZONE DEPTH               =    21.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE    =     2.910  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE   =     9.177  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE   =     0.987  INCHES
INITIAL SNOW WATER                   =     0.000  INCHES
INITIAL WATER IN LAYER MATERIALS     =   305.886  INCHES
TOTAL INITIAL WATER                  =   305.886  INCHES
TOTAL SUBSURFACE INFLOW              =     0.00   INCHES/YEAR
```

2.2 HELP MODEL OUTPUT SUMMARY

HELP model simulations provide the water budget for the proposed waste Environmental Management Disposal Facility (EMDF) and estimate infiltration rates to groundwater. The modeling results for the complete design scenario and long-term (worst-case) scenario are presented in Section 2.2.1 and Section 2.2.2, respectively.

2.2.1 Initial Long-term Scenario

```
*******************************************************************************
          AVERAGE MONTHLY VALUES IN INCHES FOR YEARS    1 THROUGH  100
 ------------------------------------------------------------------------------

                         JAN/JUL  FEB/AUG  MAR/SEP  APR/OCT  MAY/NOV  JUN/DEC
                         -------  -------  -------  -------  -------  -------
  PRECIPITATION
  -------------
    TOTALS                 4.24     4.48     5.39     4.02     5.06     4.21
                           5.65     3.86     4.34     3.15     4.54     5.45

    STD. DEVIATIONS        1.89     2.06     2.54     1.95     2.15     1.95
                           2.59     1.61     2.34     1.93     2.35     2.99

  RUNOFF
  ------
    TOTALS                 0.193    0.477    0.001    0.001    0.000    0.000
                           0.000    0.000    0.000    0.000    0.000    0.014

    STD. DEVIATIONS        0.583    1.107    0.007    0.008    0.002    0.000
                           0.000    0.000    0.000    0.000    0.000    0.087

  EVAPOTRANSPIRATION
  ------------------
    TOTALS                 0.995    1.280    2.538    2.960    4.780    4.142
                           4.425    3.920    2.612    1.348    1.021    0.878

    STD. DEVIATIONS        0.257    0.364    0.365    0.649    0.855    1.413
                           1.476    1.218    0.843    0.281    0.160    0.184

  LATERAL DRAINAGE COLLECTED FROM LAYER  4
  ----------------------------------------
    TOTALS                 3.0258   2.6805   3.1380   2.5577   1.9027   1.3752
                           1.0366   0.7914   0.6199   0.7143   1.0997   2.5402

    STD. DEVIATIONS        1.6046   1.3087   1.3759   1.2047   0.8662   0.6436
                           0.5608   0.4421   0.3686   0.6182   1.0996   2.0144

  PERCOLATION/LEAKAGE THROUGH LAYER  5
  ------------------------------------
    TOTALS                 0.1340   0.1217   0.1374   0.1260   0.1168   0.1033
                           0.0978   0.0923   0.0859   0.0905   0.0951   0.1220

    STD. DEVIATIONS        0.0218   0.0174   0.0165   0.0164   0.0150   0.0141
                           0.0120   0.0103   0.0086   0.0144   0.0192   0.0277

  PERCOLATION/LEAKAGE THROUGH LAYER 12
  ------------------------------------
    TOTALS                 0.1116   0.1018   0.1117   0.1080   0.1118   0.1082
                           0.1118   0.1118   0.1083   0.1120   0.1085   0.1122

    STD. DEVIATIONS        0.0054   0.0039   0.0028   0.0031   0.0023   0.0022
                           0.0022   0.0022   0.0022   0.0022   0.0020   0.0021

  PERCOLATION/LEAKAGE THROUGH LAYER 14
  ------------------------------------
    TOTALS                 0.1112   0.1014   0.1115   0.1080   0.1115   0.1078
                           0.1112   0.1112   0.1076   0.1113   0.1078   0.1115

    STD. DEVIATIONS        0.0053   0.0053   0.0045   0.0045   0.0048   0.0046
                           0.0052   0.0052   0.0048   0.0047   0.0042   0.0040
```

3. PATHRAE MODEL

3.1 PATHRAE RESULTS BASED ON UNIT CONCENTRATIONS

This section includes the results of PATHRAE runs for the unit concentrations of 1 Ci/m^3 for radiological contaminants of potential concern (COPC) in Table 1 (results from PATHRAE RAD) and 1 kg/m^3 for hazardous COPCs in Table 2 (results from PATHRAE HAZ).

Table 1. PATHRAE-RAD Results and Peak Effective Risk for Radionuclide COPCs (Determined on the Basis of 1 Ci/m^3 COPC Source)

Nuclide COPC	Peak Conc. in Bear Creek, PC_{creek} (pCi/L)	Total Equivalent Uptake, EU (L/year)	Peak Effective Risk, PR_{eff} (ELCR)	Peak Time (Year)
Ac-227	No Peak			
Ag-108m	No Peak			
Al-26				>1.0E+6
Am-241	2.93E-08	7.303E+02	9.031E-13	16,297
Am-243	9.01E+03	7.303E+02	2.777E-01	20,822
Ba-133	No Peak			
Bi-207	No Peak			
C-14	1.93E+06	9.564E+02	9.068E-01	1,037
Cd-113m	No Peak	7.300E+02		
Cf-249	7.37E-11	7.300E+02	2.774E-15	16,046
Cf-250	No Peak			
Cf-251	3.30E-02	7.300E+02	1.281E-06	17,322
Cl-36	1.83E+06	1.150E+03	1.793E+00	944
Cm-243	No Peak			
Cm-244	No Peak			
Cm-245	1.17E+04	7.301E+02	3.641E-01	21,062
Cm-246	3.08E+03	7.301E+02	9.401E-02	20,055
Cm-247	7.44E+04	7.301E+02	2.194E+00	33,203
Cm-248	7.03E+04	7.301E+02	9.479E+00	27,116
Co-60	No Peak			
Cs-135				>1.0E+6
Cs-137	No Peak			
Eu-150	No Peak			
Eu-152	No Peak			
Eu-154	No Peak			
H-3	1.09E-11	1.166E+03	1.643E-19	694
I-129	7.02E+05	8.293E+02	3.173E+01	4,069
K-40	9.91E+04	8.712E+02	7.358E-01	30,047
Nb-93m	No Peak			
Nb-94	4.40E+03	7.300E+02	1.013E-02	51,998
Ni-59	1.82E-01	8.858E+02	1.490E-08	892,141
Ni-63	No Peak			
Np-237	7.38E+04	7.348E+02	1.361E+00	29,882
Pa-231	9.14E+01	7.538E+02	4.670E-03	191,613
Pb-210	No Peak			

For those COPCs for which the Peak Arrival Time is given as > 1E+06, no PreWAC was derived. For "No Peak" in the peak concentration column, the COPC does not reach the surface water in a measurable concentration and therefore presents no risk to the receptor.

Table 1. PATHRAE-RAD Results and Peak Effective Risk for Radionuclide COPCs (continued) (Determined on the Basis of 1 Ci/m^3 COPC Source)

Nuclide COPC	Peak Conc. in Bear Creek PC_{creek} (pCi/L)	Total Equivalent Uptake, EU (L/year)	Peak Effective Risk PR_{eff} (ELCR)	Peak Time (Year)
Pd-107				>1.0E+6
Pu-238	No Peak			
Pu-239	3.69E+04	7.305E+02	1.476E+00	22,827
Pu-240	7.02E+03	7.305E+02	2.809E-01	20,620
Pu-241	No Peak			
Pu-242	7.07E+04	7.305E+02	2.682E+00	27,254
Pu-244	7.45E+04	7.305E+02	3.179E+00	35,416
Ra-226	No Peak			
Ra-228	No Peak			
Re-187	3.86E+05	7.300E+02	1.910E-03	8,451
Se-79	1.65E+03	7.300E+02	3.384E-03	156,297
Si-32	5.79E-05	7.300E+02	6.108E-11	12,623
Sm-151	No Peak			
Sn-121m	No Peak			
Sn-126	1.94E+04	7.300E+02	1.483E-01	58,726
Sr-90	No Peak			
Tc-99	1.68E+06	7.371E+02	1.370E+00	1,537
Th-229	No Peak			
Th-230				>1.0E+6
Th-232				>1.0E+6
U-232	No Peak			
U-233	5.15E+04	7.356E+02	1.096E+00	31,886
U-234	5.41E+04	7.356E+02	1.134E+00	32,748
U-235	5.97E+04	7.356E+02	1.232E+00	49,639
U-236	5.96E+04	7.356E+02	1.177E+00	41,366
U-238	5.97E+04	7.356E+02	1.133E+00	52,397
Zr-93	5.87E+04	7.300E+02	1.879E-02	36,195

For those COPCs for which the Peak Arrival Time is given as > 1E+06, no PreWAC was derived. For "No Peak" in the peak concentration column, the COPC does not reach the surface water in a measurable concentration and therefore presents no risk to the receptor.

Table 2. PATHRAE-HAZ Results and Peak Effective Risk/Dose for Hazardous COPCs (Determined on the Basis of 1 kg/m^3 COPC Source)

COPC	Peak Conc. in Bear Creek PC'_{creek} (mg/L)	Peak Time (Year)	Total Equivalent Uptake EU´ (L/year)	Peak Effective Risk PR'_{eff} (ELCR)	Peak Effective Dose PD'_{eff} (mg/kg-day)
Antimony	1.56E-01	21,413	3.66E+02		2.82E-01
Arsenic	1.03E-01	32,297	3.72E+02	2.56E-02	1.86E-01
Barium	5.43E-02	57,567	3.72E+02		9.80E-02
Beryllium	3.80E-03	774,542	3.69E+02		6.86E-03
Boron	9.17E-01	3,598	3.85E+02		1.66E+00
Cadmium	3.99E-02	78,247	3.78E+02		7.21E-02
Chromium VI	2.92E-01	11,036	3.91E+02	2.43E-02	5.28E-01
Chromium III	2.92E-01	11,036	3.98E+02		5.29E-01
Copper	8.51E-02	38,828	4.10E+02		1.54E-01
Lead	2.99E-02	104,098	3.70E+02		5.40E-02
Manganese	1.50E-02	196,579	3.68E+02		2.71E-02
Mercury	5.17E-03	568,827	3.99E+02		9.36E-03
Molybdenum	1.48E-01	22,501	3.87E+02		2.68E-01
Nickel	4.60E-02	67,907	3.94E+02		8.32E-02
Selenium	1.97E-01	17,059	7.52E+02		3.69E-01
Silver	3.50E-01	9,278	5.89E+02		6.46E-01
Strontium	2.18E-01	5,995	4.19E+02		3.95E-01
Tin	1.08E+00	3,108	4.05E+02		1.96E+00
U-233	5.15E-02	31,886	3.71E+02		9.30E-02
U-234	5.41E-02	32,748	3.71E+02		9.77E-02
U-235	5.97E-02	49,639	3.71E+02		1.08E-01
U-236	5.96E-02	41,366	3.71E+02		1.08E-01
U-238	5.97E-02	52,397	3.71E+02		1.08E-01
Vanadium	2.99E-02	104,098	3.73E+02		5.40E-02
Zinc	4.82E-02	64,805	6.45E+02		8.94E-02
2,4-D	1.05E+00	786	3.66E+02		3.44E+00
2,4,5-T[Silvex]	3.08E-01	971	3.67E+02		9.38E+00
Acenaphthene	No Peak				
Acenaphthylene	No Peak				
Acetone	3.03E+00	753	3.66E+02		1.07E+02
Acetonitrile	3.50E+00	682	3.66E+02		6.19E-01
Acetophenone	2.63E+00	847	3.66E+02		1.37E+01
Acrolein	3.48E+00	685	3.66E+02		5.19E-02
Acrylonitrile	3.46E+00	688	3.66E+02	2.97E-01	4.17E+00
Aldrin	No Peak				
Aroclor-1221	No Peak				
Aroclor-1232	No Peak				
Benzene		>1000			
Benzoic Acid	3.50E+00	682	3.66E+02		4.13E+02

Model results are given for all hazardous elements. However,because all elements peak after the 1000 year compliance period, noPreWAC were calculated except for uranium. For hazardous chemical compounds with peak time given as >1000 no model resuls are listed because these COPCs are assumed to completely degrade before 1000 years. For "No Peak" in the peak concentration column, the COPC does not reach the surface water in a measurable concentration and therefore presents no risk to the receptor.

Table 2. PATHRAE-HAZ Results and Peak Effective Risk/Dose for Hazardous Contaminants Determined on the Basis of 1 kg/m^3 COPC Source (Continued)

COPC	Peak Conc. In Bear Creek PC'_{creek} (mg/L)	Peak Time (Year)	Total Equivalent Uptake EU´ (L/year)	Peak Effective Risk PR'_{eff} (ELCR)	Peak Effective Dose PD'_{eff} (mg/kg-day)
Benzyl Alcohol	3.15E+00	736	3.66E+02		5.45E+00
Benzidine		>1000			
alpha-BHC		>1000			
beta-BHC		>1000			
delta-BHC		>1000			
Bromodichloromethane	3.38E+00	699	3.66E+02	3.33E-02	5.85E+00
Bromoform		>1000			
Bromomethane	3.19E+00	731	3.66E+02		5.52E+00
Butylbenzene		>1000			
Carbazole		>1000			
Carbon disulfide	1.81E+00	866	3.66E+02		3.13E+00
Carbon tetrachloride		>1000			
Chlordane	No Peak				
Chlorobenzene		>1000			
Chloroform		>1000			
Chloromethane [Methyl Chloride]	3.18E+00	732	3.66E+02	6.57E-03	
o-Chlorotoluene		>1000			
m-Cresol	2.61E+00	853	3.66E+02		4.52E+00
o-Cresol		>1000			
p-Cresol	2.63E+00	847	3.66E+02		4.55E+00
Cumene [Isopropylbenzene]		>1000			
Cyanide		>1000			
DDD	No Peak				
DDE		>1000			
Di-n-butylphthalate	3.52E+00	680	4.28E+02		6.13E+00
Dibenz(a,h)anthracene	No Peak				
Dibenzofuran	No Peak				
Dibromochloromethane	2.32E+00	935	3.66E+02	3.10E-02	4.02E+00
1,2-Dichlorobenzene		>1000			
1,3-Dichlorobenzene	No Peak				
1,4-Dichlorobenzene		>1000			
1,2,-cis-Dichloroethylene		>1000			
1,2-trans-Dichloroethylene	2.75E+00	817	3.66E+02		4.76E+00
Dichlorodifluoromethane	4.31E-01	705	3.66E+02		7.46E-01
1,2-Dichloropropane	2.62E+00	850	3.66E+02	1.50E-02	4.54E+00
Dieldrin	No Peak				
Diethylphthalate		>1000			
1,2-Dimethylbenzene		>1000			
2,4-Dimethylphenol		>1000			
Dimethylphthalate	2.77E+00	814	3.66E+02		4.79E+00
2,4 Dinitrotoluene	4.15E-01	865	3.66E+02	2.05E-02	7.18E-01
2,6 Dinitrotoluene	5.41E-01	832	3.66E+02	1.29E-01	9.36E-01

Model results are given for all hazardous elements. However,because all elements peak after the 1000 year compliance period, noPreWAC were calculated except for uranium. For hazardous chemical compounds with peak time given as >1000 no model resuls are listed because these COPCs are assumed to completely degrade before 1000 years. For "No Peak" in the peak concentration column, the COPC does not reach the surface water in a measurable concentration and therefore presents no risk to the receptor.

Table 2. PATHRAE-HAZ Results and Peak Effective Risk/Dose for Hazardous Contaminants Determined on the Basis of 1 kg/m^3 COPC Source (Continued)

COPC	Peak Conc. In Bear Creek PC´$_{creek}$ (mg/L)	Peak Time (Year)	Total Equivalent Uptake EU´ (L/year)	Peak Effective Risk PR´$_{eff}$ (ELCR)	Peak Effective Dose PD´$_{eff}$ (mg/kg-day)
Endosulfan & metabolites		>1000			
Endrin	No Peak				
Endrin Aldehyde	No Peak				
Endrin Ketone	No Peak				
Ethylbenzene		>1000			
Ethylchloride	3.00E+00	766	3.66E+02		
Heptachlor	No Peak				
Heptachlor Epoxide	No Peak				
Hexachlorobenzene	No Peak				
Hexachloroethane		>1000			
n-Hexane		>1000			
1-Hexanol	3.21E+00	727	3.66E+02		5.56E+00
2-Hexanone	3.21E+00	727	3.66E+02		5.56E+00
Isophorone		>1000			
Lindane		>1000			
Methanol	3.49E+00	683	3.66E+02		6.04E+00
Dichloromethane	No Peak				
Methylcyclohexane	2.15E-02	680	3.66E+02		3.72E-02
Methyl Isobutyl Ketone	3.46E+00	688	3.66E+02		5.99E+00
Methyl Methacrylate	3.28E+00	716	3.66E+02		5.68E+00
1-Methyl-4-(1-methylethyl)-benzene		>1000			
2-Methylnapthalene		>1000			
(1-Methylpropyl)-benzene		>1000			
Naphthalene	No Peak				
4-Nitrobenzenamine [4-Nitroaniline]		>1000			
Nitrobenzene	2.39E+00	913	3.66E+02		4.14E+00
2-Nitrophenol		>1000			
4-Nitrophenol		>1000			
N-nitrosodipropylamine		>1000			
N-Nitrosodiphenylamine		>1000			
Phenol		>1000			
Propylbenzene		>1000			
Propylene glycol	3.49E+00	683	3.66E+02		6.04E+00
Pyridine	3.35E+00	705	3.66E+02		5.80E+00
Styrene		>1000			
1,1,1,2-Tetrachloroethane		>1000			
1,1,2,2-Tetrachloroethane	2.23E+00	962	3.66E+02	7.09E-02	3.86E+00
Tetrachloroethylene		>1000			
2,3,4,6-Tetrachlorophenol		>1000			

Model results are given for all hazardous elements. However,because all elements peak after the 1000 year compliance period, noPreWAC were calculated except for uranium. For hazardous chemical compounds with peak time given as >1000 no model resuls are listed because these COPCs are assumed to completely degrade before 1000 years. For "No Peak" in the peak concentration column, the COPC does not reach the surface water in a measurable concentration and therefore presents no risk to the receptor.

Table 2. PATHRAE-HAZ Results and Peak Effective Risk/Dose for Hazardous Contaminants Determined on the Basis of 1 kg/m^3 COPC Source (Continued)

COPC	Peak Conc. In Bear Creek PC'_{creek} (mg/L)	Peak Time (Year)	Total Equivalent Uptake EU´ (L/year)	Peak Effective Risk PR'_{eff} (ELCR)	Peak Effective Dose PD'_{eff} (mg/kg-day)
Toluene		> 1,000			
1,2,4-Trichlorobenzene		> 1,000			
Trichloroethylene		> 1,000			
Trichlorofluoromethane		> 1,000			
2,4,6-Trichlorophenol		> 1,000			
1,2,3-Trichloropropane	2.21E+00	971	3.72E+02	1.05E+01	3.83E+00
Trimethylbenzene [isomers]		> 1,000			
1,2,4-Trimethylbenzene		> 1,000			
1,3,5-Trimethylbenzene		> 1,000			
Vinyl Chloride		> 1,000			
Xylene [isomer mix]		> 1,000			

Model results are given for all hazardous elements. However,because all elements peak after the 1000 year compliance period, noPreWAC were calculated except for uranium. For hazardous chemical compounds with peak time given as >1000 no model resuls are listed because these COPCs are assumed to completely degrade before 1000 years. For "No Peak" in the peak concentration column, the COPC does not reach the surface water in a measurable concentration and therefore presents no risk to the receptor.

3.2 PATHRAE MODEL INPUT AND OUTPUT FILES

The PATHRAE-RAD model was used for radionuclides and the PATHRAE-HAZ model was used for hazardous constituents. Example PATHRAE-RAD and PATHRAE-HAZ output (text) files are listed in Section 3.2.1 and Section 3.2.2 below, respectively. The output files contain a mirror image of the input files used to conduct PATHRAE model simulation.

3.2.1 PATHRAE-RAD

FILE = PATHRAD-NB-HR-5C-CL-200yr-peak.OUT (high recharge rate, post-1000 years)

```
PATHRAE-RAD(PC)  Version 2.2d  February 1995


 PATHRAE-RAD(PC)  Version 2.2d  February 1995
   Date: 12-16-2015
   Time: 11: 7:45

 pWAC RAD – January, 2015 EMDF in UBCV

 *****  Mirror Image of Input Files  *****

 -- Input File:  ABCDEF.DAT
 pWAC RAD – January, 2015 EMDF in UBCV
 10, 0., 500.,1000.,5000.,10000.,50000.,100000.,200000.,500000.,1000000.
 60,0,2
 1,2, 2,3,
 0.0, 243.19, 427., 7.36E+05, 1., 476., 0.
 1800., 47.6, 0., 0., 0.867, 0., 0.315, 0.
 20, 2, 0, 1, 1, 0
 3.35, 16.16, 1.68E+06, 0., 0., 1600., 0.40, 0.705, 0.90, 1.
 1.0E-7, 8000., 0.705, 200., 1.0E+00, 0.01
 240., 5.56E-04, 0.22, 0.02, 3.0E-4, 20., 0.01
 4, 6.3, 0.23, 0., 1.1E-06, 0.01, 0., 0., 0., 0., 0.
 0, 0, 0, 0, 0, 0, 0
 1, 0, 0, 1
```

```
0.034, 21.3, 0.04, 6.3, 0.000, 24.0, 0.00001, 1.0, 0., 0.438

-- Input File:  BRCDCF.DAT
101,Ac-227   4.07E-03,  8.14E-01,  1.65E-08,
102,Ag-108m  8.51E-06,  2.74E-05,  1.81E-04,
103,Al-26    1.30E-05,  7.40E-05,  2.88E-04,
104,Am-241   7.40E-04,  1.55E-01,  2.72E-06,
105,Am-243   7.40E-04,  1.52E-01,  5.59E-06,
106,Ba-133   5.55E-06,  1.15E-05,  4.35E-05,
107,Bi-207   4.81E-06,  2.07E-05,  1.69E-04,
108,C-14     2.15E-06,  2.29E-08,  1.48E-09,
109,Cf-249   1.30E-03,  2.59E-01,  3.68E-05,
110,Cf-250   5.92E-04,  1.26E-01,  6.21E-08,
111,Cf-251   1.33E-03,  2.63E-01,  1.32E-05,
112,Cl-36    3.44E-06,  2.70E-05,  1.31E-06,
113,Cm-243   5.55E-04,  1.15E-01,  1.38E-05,
114,Cm-244   4.44E-04,  9.99E-02,  7.52E-08,
115,Cm-245   7.77E-04,  1.55E-01,  9.39E-06,
116,Cm-246   7.77E-04,  1.55E-01,  6.72E-08,
117,Cm-247   7.03E-04,  1.44E-01,  3.49E-05,
118,Cm-248   2.85E-03,  5.55E-01,  1.42E-04,
119,Co-60    1.26E-05,  3.70E-05,  2.68E-04,
120,Cs-135   7.40E-06,  2.55E-06,  3.14E-09,
121,Cs-137   4.81E-05,  1.70E-05,  3.49E-07,
122,Eu-150   4.81E-06,  1.96E-04,  1.66E-04,
123,Eu-152   5.18E-06,  1.55E-04,  1.26E-04,
124,Eu-154   7.40E-06,  1.96E-04,  1.37E-04,
125,H-3      1.55E-07,  1.52E-07,  0.00E+00,
126,I-129    4.07E-04,  2.74E-04,  2.28E-06,
127,K-40     2.29E-05,  7.77E-06,  2.38E-05,
128,Nb-93m   4.44E-07,  1.89E-06,  7.96E-08,
129,Nb-94    6.29E-06,  4.07E-05,  1.74E-04,
130,Ni-59    2.33E-07,  4.81E-07,  0.00E+00,
131,Ni-63    5.55E-07,  1.78E-06,  0.00E+00,
132,Np-237   4.07E-04,  8.51E-02,  2.94E-06,
133,Pa-231   2.63E-03,  5.18E-01,  4.41E-06,
134,Pb-210   2.55E-03,  4.07E-03,  2.49E-07,
135,Pd-107   1.37E-07,  3.15E-07,  0.00E+00,
136,Pu-238   8.51E-04,  1.70E-01,  7.31E-08,
137,Pu-239   9.25E-04,  1.85E-01,  3.31E-08,
138,Pu-240   9.25E-04,  1.85E-01,  7.01E-08,
139,Pu-241   1.78E-05,  3.33E-03,  2.01E-10,
140,Pu-242   8.88E-04,  1.78E-01,  5.81E-08,
141,Pu-244   8.88E-04,  1.74E-01,  2.36E-06,
142,Ra-226   1.04E-03,  1.30E-02,  7.13E-07,
143,Ra-228   2.55E-03,  9.62E-03,  0.00E+00,
144,Se-79    1.07E-05,  4.07E-06,  1.91E-09,
145,Si-32    2.07E-06,  6.29E-05,  2.92E-09,
146,Sm-151   3.63E-07,  1.48E-05,  4.13E-10,
147,Sn-121m  1.41E-06,  1.67E-05,  4.20E-07,
148,Sn-126   1.74E-05,  1.04E-04,  5.62E-06,
149,Sr-90    1.04E-04,  1.33E-04,  1.91E-07,
150,Tc-99    2.37E-06,  1.48E-05,  7.55E-09,
151,Th-229   1.81E-03,  2.63E-01,  9.21E-06,
152,Th-230   7.77E-04,  5.18E-02,  7.43E-08,
153,Th-232   8.51E-04,  9.25E-02,  5.31E-08,
154,U-232    1.22E-03,  2.89E-02,  9.42E-08,
155,U-233    1.89E-04,  1.33E-02,  6.99E-08,
156,U-234    1.81E-04,  1.30E-02,  6.84E-08,
157,U-235    1.74E-04,  1.15E-02,  1.63E-05,
158,U-236    1.74E-04,  1.18E-02,  5.87E-08,
159,U-238    1.67E-04,  1.07E-02,  4.94E-08,
160,Zr-93    4.07E-06,  3.70E-05,  0.00E+00,

-- Input File:  INVNTRY.DAT
 101,  2.18E+01,  1.68E+06,       0.0,       0.0,       0.0,       0.0,       1.0,             Ac-227
102,  1.27E+02,  1.68E+06,       0.0,       0.0,       0.0,       0.0,       1.0,             Ag-108m
103,  7.16E+05,  1.68E+06,      43.5,       0.1,       0.0,       0.0,       1.0,             Al-26
104,  4.32E+02,  1.68E+06,      22.2,       0.2,       0.0,       0.0,       1.0,             Am-241
105,  7.38E+03,  1.68E+06,       0.0,       0.0,       0.0,       0.0,       1.0,             Am-243
106,  1.07E+01,  1.68E+06,       0.0,       0.0,       0.0,       0.0,       1.0,             Ba-133
107,  3.80E+01,  1.68E+06,       0.0,       0.0,       0.0,       0.0,       1.0,             Bi-207
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108,  5.73E+03,  1.68E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            C-14
109,  3.51E+02,  1.68E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Cf-249
110,  1.31E+01,  1.68E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Cf-250
111,  8.98E+02,  1.68E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Cf-251
112,  3.01E+05,  1.68E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Cl-36
113,  2.85E+01,  1.68E+06,      22.0,       0.2,       0.0,       0.0,       1.0,            Cm-243
114,  1.81E+01,  1.68E+06,      43.5,       0.1,       0.0,       0.0,       1.0,            Cm-244
115,  8.50E+03,  1.68E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Cm-245
116,  4.73E+03,  1.68E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Cm-246
117,  1.56E+07,  1.68E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Cm-247
118,  3.39E+05,  1.68E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Cm-248
119,  5.27E+00,  1.68E+06,       9.2,       1.3,       0.0,       0.0,       1.0,            Co-60
120,  2.30E+06,  1.68E+06,      12.1,       0.7,       0.0,       0.0,       1.0,            Cs-135
121,  3.00E+01,  1.68E+06,      12.8,       0.6,       0.0,       0.0,       1.0,            Cs-137
122,  3.42E+01,  1.68E+06,      14.0,       0.5,       0.0,       0.0,       1.0,            Eu-150
123,  1.33E+01,  1.68E+06,      12.5,       0.7,       0.0,       0.0,       1.0,            Eu-152
124,  8.80E+00,  1.68E+06,      32.1,       0.1,       0.0,       0.0,       1.0,            Eu-154
125,  1.24E+01,  1.68E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            H-3
126,  1.57E+07,  1.68E+06,      62.0,       0.0,       0.0,       0.0,       1.0,            I-129
127,  1.28E+09,  1.68E+06,      10.3,       1.0,       0.0,       0.0,       1.0,            K-40
128,  1.36E+01,  1.68E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Nb-93m
129,  2.03E+04,  1.68E+06,      11.6,       0.8,       0.0,       0.0,       1.0,            Nb-94
130,  7.50E+04,  1.68E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Ni-59
131,  9.60E+01,  1.68E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Ni-63
132,  2.14E+06,  1.68E+06,      34.9,       0.1,       0.0,       0.0,       1.0,            Np-237
133,  3.28E+04,  1.68E+06,      22.8,       0.1,       0.0,       0.0,       1.0,            Pa-231
134,  2.23E+01,  1.68E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Pb-210
135,  6.50E+06,  1.68E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Pd-107
136,  8.77E+01,  1.68E+06,      45.3,       0.1,       0.0,       0.0,       1.0,            Pu-238
137,  2.41E+04,  1.68E+06,      25.8,       0.1,       0.0,       0.0,       1.0,            Pu-239
138,  6.54E+03,  1.68E+06,      46.3,       0.1,       0.0,       0.0,       1.0,            Pu-240
139,  1.44E+01,  1.68E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Pu-241
140,  3.76E+05,  1.68E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Pu-242
141,  8.26E+07,  1.68E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Pu-244
142,  1.60E+03,  1.68E+06,      21.5,       0.2,       0.0,       0.0,       1.0,            Ra-226
143,  5.75E+00,  1.68E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Ra-228
144,  6.50E+04,  1.68E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Se-79
145,  4.50E+02,  1.68E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Si-32
146,  9.00E+01,  1.68E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Sm-151
147,  5.50E+01,  1.68E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Sn-121m
148,  1.00E+05,  1.68E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Sn-126
149,  2.91E+01,  1.68E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Sr-90
150,  2.13E+05,  1.68E+06,      29.2,       0.1,       0.0,       0.0,       1.0,            Tc-99
151,  7.34E+03,  1.68E+06,      28.8,       0.1,       0.0,       0.0,       1.0,            Th-229
152,  7.70E+04,  1.68E+06,      30.3,       0.1,       0.0,       0.0,       1.0,            Th-230
153,  1.41E+10,  1.68E+06,      35.5,       0.1,       0.0,       0.0,       1.0,            Th-232
154,  7.20E+01,  1.68E+06,      25.7,       0.0,       0.0,       0.0,       1.0,            U-232
155,  1.59E+05,  1.68E+06,      25.7,       0.1,       0.0,       0.0,       1.0,            U-233
156,  2.45E+05,  1.68E+06,      35.5,       0.1,       0.0,       0.0,       1.0,            U-234
157,  7.04E+08,  1.68E+06,      21.6,       0.2,       0.0,       0.0,       1.0,            U-235
158,  2.34E+07,  1.68E+06,      36.6,       0.1,       0.0,       0.0,       1.0,            U-236
159,  4.47E+09,  1.68E+06,      12.0,       0.7,       0.0,       0.0,       1.0,            U-238
160,  1.53E+06,  1.68E+06,       0.0,       0.0,       0.0,       0.0,       1.0,            Zr-93
```

```
-- Input File:  RQSITE.DAT
 101, -1.50E+03,  1.50E+02,  1.50E+03,       Ac-227
102, -4.50E+01,  4.50E+00,  4.50E+01,       Ag-108m
103, -3.00E+03,  3.00E+02,  3.00E+03,       Al-26
104, -4.00E+01,  4.00E+00,  4.00E+01,       Am-241
105, -4.00E+01,  4.00E+00,  4.00E+01,       Am-243
106, -6.00E+01,  6.00E+00,  6.00E+01,       Ba-133
107, -5.00E+02,  5.00E+01,  5.00E+02,       Bi-207
108, -1.09E+00,  1.09E-01,  1.09E+00,       C-14
109, -4.00E+01,  4.00E+00,  4.00E+01,       Cf-249
110, -4.00E+01,  4.00E+00,  4.00E+01,       Cf-250
111, -4.00E+01,  4.00E+00,  4.00E+01,       Cf-251
112, -2.50E-01,  2.50E-02,  2.50E-01,       Cl-36
113, -4.00E+01,  4.00E+00,  4.00E+01,       Cm-243
114, -4.00E+01,  4.00E+00,  4.00E+01,       Cm-244
115, -4.00E+01,  4.00E+00,  4.00E+01,       Cm-245
116, -4.00E+01,  4.00E+00,  4.00E+01,       Cm-246
117, -4.00E+01,  4.00E+00,  4.00E+01,       Cm-247
118, -4.00E+01,  4.00E+00,  4.00E+01,       Cm-248
119, -3.00E+03,  3.00E+02,  3.00E+03,       Co-60
120, -3.00E+03,  3.00E+02,  3.00E+03,       Cs-135
121, -3.00E+03,  3.00E+02,  3.00E+03,       Cs-137
122, -3.00E+03,  3.00E+02,  3.00E+03,       Eu-150
123, -3.00E+03,  3.00E+02,  3.00E+03,       Eu-152
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124, -3.00E+03,  3.00E+02,  3.00E+03,       Eu-154
125, -1.99E-01,  1.99E-02,  1.99E-01,       H-3
126, -4.00E+00,  4.00E-01,  4.00E+00,       I-129
127, -3.00E+01,  3.00E+00,  3.00E+01,       K-40
128, -1.00E+02,  1.00E+01,  1.00E+02,       Nb-93m
129, -1.00E+02,  1.00E+01,  1.00E+02,       Nb-94
130, -2.00E+03,  2.00E+02,  2.00E+03,       Ni-59
131, -2.00E+03,  2.00E+02,  2.00E+03,       Ni-63
132, -4.00E+01,  4.00E+00,  4.00E+01,       Np-237
133, -4.00E+02,  4.00E+01,  4.00E+02,       Pa-231
134, -1.00E+02,  1.00E+01,  1.00E+02,       Pb-210
135, -2.00E+03,  2.00E+02,  2.00E+03,       Pd-107
136, -4.00E+01,  4.00E+00,  4.00E+01,       Pu-238
137, -4.00E+01,  4.00E+00,  4.00E+01,       Pu-239
138, -4.00E+01,  4.00E+00,  4.00E+01,       Pu-240
139, -4.00E+01,  4.00E+00,  4.00E+01,       Pu-241
140, -4.00E+01,  4.00E+00,  4.00E+01,       Pu-242
141, -4.00E+01,  4.00E+00,  4.00E+01,       Pu-244
142, -3.00E+03,  3.00E+02,  3.00E+03,       Ra-226
143, -3.00E+03,  3.00E+02,  3.00E+03,       Ra-228
144, -3.00E+02,  3.00E+01,  3.00E+02,       Se-79
145, -3.00E+01,  3.00E+00,  3.00E+01,       Si-32
146, -1.00E+03,  1.00E+02,  1.00E+03,       Sm-151
147, -1.00E+02,  1.00E+01,  1.00E+02,       Sn-121m
148, -1.00E+02,  1.00E+01,  1.00E+02,       Sn-126
149, -3.00E+01,  3.00E+00,  3.00E+01,       Sr-90
150, -1.50E+00,  1.50E-01,  1.50E+00,       Tc-99
151, -3.00E+03,  3.00E+02,  3.00E+03,       Th-229
152, -3.00E+03,  3.00E+02,  3.00E+03,       Th-230
153, -3.00E+03,  3.00E+02,  3.00E+03,       Th-232
154, -5.00E+01,  5.00E+00,  5.00E+01,       U-232
155, -5.00E+01,  5.00E+00,  5.00E+01,       U-233
156, -5.00E+01,  5.00E+00,  5.00E+01,       U-234
157, -5.00E+01,  5.00E+00,  5.00E+01,       U-235
158, -5.00E+01,  5.00E+00,  5.00E+01,       U-236
159, -5.00E+01,  5.00E+00,  5.00E+01,       U-238
160, -5.00E+01,  5.00E+00,  5.00E+01,       Zr-93

-- Input File:  UPTAKE.DAT
0.5,   0.2,    1.89
0.67,  0.65,   2.1E-3,   438.,   438.
0.0,   2160.,  24.,     1440.,     1.,  0.83
50.,   6.,     48.,      480.,    48.
.05,  0.0008,  60.,        8.,    50.
14.,    176., 110.,        0.,    95.,   730., 0.0
Ac-227      0.25,2.50E-03,  2.50E-04,  2.00E-05,       0.0,  2.00E-05,  0.00E+00
Ag-108m     0.25,1.50E-01,  1.50E-02,  2.50E-02,       0.0,  3.00E-03,  0.00E+00
Al-26       0.25,4.00E-03,  4.00E-04,  0.00E+00,       0.0,  0.00E+00,  0.00E+00
Am-241      0.25,1.00E-03,  1.00E-04,  2.00E-06,       0.0,  5.00E-05,  0.00E+00
Am-243      0.25,1.00E-03,  1.00E-04,  2.00E-06,       0.0,  5.00E-05,  0.00E+00
Ba-133      0.25,5.00E-03,  5.00E-04,  0.00E+00,       0.0,  0.00E+00,  0.00E+00
Bi-207      0.25,1.00E-01,  1.00E-02,  5.00E-04,       0.0,  2.00E-03,  0.00E+00
C-14        0.25,5.50E+00,  5.50E-01,  1.20E-02,       0.0,  3.10E-02,  0.00E+00
Cf-249      0.25,1.00E-03,  1.00E-04,  0.00E+00,       0.0,  0.00E+00,  0.00E+00
Cf-250      0.25,1.00E-03,  1.00E-04,  0.00E+00,       0.0,  0.00E+00,  0.00E+00
Cf-251      0.25,1.00E-03,  1.00E-04,  0.00E+00,       0.0,  0.00E+00,  0.00E+00
Cl-36       0.25,2.00E+01,  2.00E+00,  2.00E-02,       0.0,  6.00E-02,  0.00E+00
Cm-243      0.25,1.00E-03,  1.00E-04,  2.00E-06,       0.0,  2.00E-05,  0.00E+00
Cm-244      0.25,1.00E-03,  1.00E-04,  2.00E-06,       0.0,  2.00E-05,  0.00E+00
Cm-245      0.25,1.00E-03,  1.00E-04,  2.00E-06,       0.0,  2.00E-05,  0.00E+00
Cm-246      0.25,1.00E-03,  1.00E-04,  2.00E-06,       0.0,  2.00E-05,  0.00E+00
Cm-247      0.25,1.00E-03,  1.00E-04,  2.00E-06,       0.0,  2.00E-05,  0.00E+00
Cm-248      0.25,1.00E-03,  1.00E-04,  2.00E-06,       0.0,  2.00E-05,  0.00E+00
Co-60       0.25,8.00E-02,  8.00E-03,  2.00E-03,       0.0,  2.00E-02,  0.00E+00
Cs-135      0.25,4.00E-02,  4.00E-03,  8.00E-03,       0.0,  3.00E-02,  0.00E+00
Cs-137      0.25,4.00E-02,  4.00E-03,  8.00E-03,       0.0,  3.00E-02,  0.00E+00
Eu-150      0.25,2.50E-03,  2.50E-04,  2.00E-05,       0.0,  2.00E-03,  0.00E+00
Eu-152      0.25,2.50E-03,  2.50E-04,  2.00E-05,       0.0,  2.00E-03,  0.00E+00
Eu-154      0.25,2.50E-03,  2.50E-04,  2.00E-05,       0.0,  2.00E-03,  0.00E+00
H-3         0.25,4.80E+00,  4.80E-01,  1.00E-02,       0.0,  1.20E-02,  0.00E+00
I-129       0.25,2.00E-02,  2.00E-03,  1.00E-02,       0.0,  7.00E-03,  0.00E+00
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K-40	0.25,3.00E-01,	3.00E-02,	7.00E-03,	0.0,	2.00E-02,	0.00E+00
Nb-93m	0.25,1.00E-02,	1.00E-03,	2.00E-06,	0.0,	3.00E-07,	0.00E+00
Nb-94	0.25,1.00E-02,	1.00E-03,	2.00E-06,	0.0,	3.00E-07,	0.00E+00
Ni-59	0.25,5.00E-02,	5.00E-03,	2.00E-02,	0.0,	5.00E-03,	0.00E+00
Ni-63	0.25,5.00E-02,	5.00E-03,	2.00E-02,	0.0,	5.00E-03,	0.00E+00
Np-237	0.25,2.00E-02,	2.00E-03,	5.00E-06,	0.0,	1.00E-03,	0.00E+00
Pa-231	0.25,1.00E-02,	1.00E-03,	5.00E-06,	0.0,	5.00E-03,	0.00E+00
Pb-210	0.25,1.00E-02,	1.00E-03,	3.00E-04,	0.0,	8.00E-04,	0.00E+00
Pd-107	0.25,1.00E-01,	1.00E-02,	0.00E+00,	0.0,	0.00E+00,	0.00E+00
Pu-238	0.25,1.00E-03,	1.00E-04,	1.00E-06,	0.0,	1.00E-04,	0.00E+00
Pu-239	0.25,1.00E-03,	1.00E-04,	1.00E-06,	0.0,	1.00E-04,	0.00E+00
Pu-240	0.25,1.00E-03,	1.00E-04,	1.00E-06,	0.0,	1.00E-04,	0.00E+00
Pu-241	0.25,1.00E-03,	1.00E-04,	1.00E-06,	0.0,	1.00E-04,	0.00E+00
Pu-242	0.25,1.00E-03,	1.00E-04,	1.00E-06,	0.0,	1.00E-04,	0.00E+00
Pu-244	0.25,1.00E-03,	1.00E-04,	1.00E-06,	0.0,	1.00E-04,	0.00E+00
Ra-226	0.25,4.00E-02,	4.00E-03,	1.00E-03,	0.0,	1.00E-03,	0.00E+00
Ra-228	0.25,4.00E-02,	4.00E-03,	1.00E-03,	0.0,	1.00E-03,	0.00E+00
Se-79	0.25,1.00E-01,	1.00E-02,	0.00E+00,	0.0,	0.00E+00,	0.00E+00
Si-32	0.25,0.00E+00,	0.00E+00,	0.00E+00,	0.0,	0.00E+00,	0.00E+00
Sm-151	0.25,2.50E-03,	2.50E-04,	2.00E-05,	0.0,	2.00E-03,	0.00E+00
Sn-121m	0.25,2.50E-03,	2.50E-04,	0.00E+00,	0.0,	0.00E+00,	0.00E+00
Sn-126	0.25,2.50E-03,	2.50E-04,	0.00E+00,	0.0,	0.00E+00,	0.00E+00
Sr-90	0.25,3.00E-01,	3.00E-02,	2.00E-03,	0.0,	8.00E-03,	0.00E+00
Tc-99	0.25,5.00E+00,	5.00E-01,	1.00E-03,	0.0,	1.00E-04,	0.00E+00
Th-229	0.25,1.00E-03,	1.00E-04,	5.00E-06,	0.0,	1.00E-04,	0.00E+00
Th-230	0.25,1.00E-03,	1.00E-04,	5.00E-06,	0.0,	1.00E-04,	0.00E+00
Th-232	0.25,1.00E-03,	1.00E-04,	5.00E-06,	0.0,	1.00E-04,	0.00E+00
U-232	0.25,2.50E-03,	2.50E-04,	6.00E-04,	0.0,	3.40E-04,	0.00E+00
U-233	0.25,2.50E-03,	2.50E-04,	6.00E-04,	0.0,	3.40E-04,	0.00E+00
U-234	0.25,2.50E-03,	2.50E-04,	6.00E-04,	0.0,	3.40E-04,	0.00E+00
U-235	0.25,2.50E-03,	2.50E-04,	6.00E-04,	0.0,	3.40E-04,	0.00E+00
U-236	0.25,2.50E-03,	2.50E-04,	6.00E-04,	0.0,	3.40E-04,	0.00E+00
U-238	0.25,2.50E-03,	2.50E-04,	6.00E-04,	0.0,	3.40E-04,	0.00E+00
Zr-93	0.25,1.00E-03,	1.00E-04,	0.00E+00,	0.0,	0.00E+00,	0.00E+00

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TOTAL EQUIVALENT UPTAKE FACTORS FOR PATHRAE

NUCLIDE	UT(J,1) RIVER L/YR	UT(J,2) WELL L/YR	UT(J,3) EROSION L/YR	UT(J,4) BATHTUB L/YR	UT(J,5) SPILLAGE L/YR	UT(J,6) FOOD KG/YR
Ac-227	7.302E+02	7.300E+02	7.302E+02	7.302E+02	7.302E+02	1.064E-02
Ag-108m	9.092E+02	7.300E+02	9.092E+02	9.092E+02	9.092E+02	6.956E+00
Al-26	7.300E+02	7.300E+02	7.301E+02	7.301E+02	7.301E+02	1.686E-02
Am-241	7.303E+02	7.300E+02	7.303E+02	7.303E+02	7.303E+02	4.283E-03
Am-243	7.303E+02	7.300E+02	7.303E+02	7.303E+02	7.303E+02	4.284E-03
Ba-133	7.300E+02	7.300E+02	7.300E+02	7.300E+02	7.300E+02	2.090E-02
Bi-207	7.428E+02	7.300E+02	7.428E+02	7.428E+02	7.428E+02	7.603E-01
C-14	9.564E+02	7.300E+02	9.564E+02	9.564E+02	9.564E+02	0.000E+00
Cf-249	7.300E+02	7.300E+02	7.300E+02	7.300E+02	7.300E+02	4.214E-03
Cf-250	7.300E+02	7.300E+02	7.300E+02	7.300E+02	7.300E+02	4.187E-03
Cf-251	7.300E+02	7.300E+02	7.300E+02	7.300E+02	7.300E+02	4.215E-03
Cl-36	1.150E+03	7.300E+02	1.148E+03	1.148E+03	1.150E+03	2.280E+03
Cm-243	7.301E+02	7.300E+02	7.301E+02	7.301E+02	7.301E+02	4.231E-03
Cm-244	7.301E+02	7.300E+02	7.301E+02	7.301E+02	7.301E+02	4.224E-03
Cm-245	7.301E+02	7.300E+02	7.301E+02	7.301E+02	7.301E+02	4.245E-03
Cm-246	7.301E+02	7.300E+02	7.301E+02	7.301E+02	7.301E+02	4.245E-03
Cm-247	7.301E+02	7.300E+02	7.301E+02	7.301E+02	7.301E+02	4.245E-03
Cm-248	7.301E+02	7.300E+02	7.301E+02	7.301E+02	7.301E+02	4.245E-03
Co-60	8.375E+02	7.300E+02	8.375E+02	8.375E+02	8.375E+02	2.653E+00
Cs-135	9.253E+02	7.300E+02	9.464E+02	9.455E+02	9.378E+02	2.242E+00
Cs-137	9.251E+02	7.300E+02	9.251E+02	9.251E+02	9.251E+02	2.236E+00
Eu-150	7.396E+02	7.300E+02	7.396E+02	7.396E+02	7.396E+02	1.717E-02
Eu-152	7.396E+02	7.300E+02	7.396E+02	7.396E+02	7.396E+02	1.710E-02
Eu-154	7.396E+02	7.300E+02	7.396E+02	7.396E+02	7.396E+02	1.705E-02
H-3	1.166E+03	7.300E+02	1.166E+03	1.166E+03	1.166E+03	0.000E+00
I-129	8.293E+02	7.300E+02	8.293E+02	8.293E+02	8.293E+02	5.749E-01
K-40	8.712E+02	7.300E+02	8.725E+02	8.725E+02	8.725E+02	1.240E+01

Nb-93m	7.300E+02	7.300E+02	7.300E+02	7.300E+02	7.300E+02	4.191E-02
Nb-94	7.300E+02	7.300E+02	7.300E+02	7.300E+02	7.300E+02	4.219E-02
Ni-59	8.858E+02	7.300E+02	8.880E+02	8.872E+02	8.944E+02	2.070E+00
Ni-63	8.857E+02	7.300E+02	8.857E+02	8.857E+02	8.857E+02	2.068E+00
Np-237	7.348E+02	7.300E+02	7.348E+02	7.348E+02	7.348E+02	1.109E-01
Pa-231	7.538E+02	7.300E+02	7.538E+02	7.538E+02	7.539E+02	1.082E-01
Pb-210	7.358E+02	7.300E+02	7.358E+02	7.358E+02	7.358E+02	5.708E-02
Pd-107	7.300E+02	7.300E+02	7.328E+02	7.328E+02	7.319E+02	4.215E-01
Pu-238	7.305E+02	7.300E+02	7.305E+02	7.305E+02	7.305E+02	4.344E-03
Pu-239	7.305E+02	7.300E+02	7.305E+02	7.305E+02	7.305E+02	4.349E-03
Pu-240	7.305E+02	7.300E+02	7.305E+02	7.305E+02	7.305E+02	4.349E-03
Pu-241	7.305E+02	7.300E+02	7.305E+02	7.305E+02	7.305E+02	4.322E-03
Pu-242	7.305E+02	7.300E+02	7.305E+02	7.305E+02	7.305E+02	4.349E-03
Pu-244	7.305E+02	7.300E+02	7.305E+02	7.305E+02	7.305E+02	4.349E-03
Ra-226	7.414E+02	7.300E+02	7.414E+02	7.414E+02	7.414E+02	2.826E-01
Ra-228	7.413E+02	7.300E+02	7.413E+02	7.413E+02	7.413E+02	2.787E-01
Se-79	7.300E+02	7.300E+02	7.301E+02	7.300E+02	7.304E+02	4.215E-01
Si-32	7.300E+02	7.300E+02	7.300E+02	7.300E+02	7.300E+02	0.000E+00
Sm-151	7.396E+02	7.300E+02	7.396E+02	7.396E+02	7.396E+02	1.720E-02
Sn-121m	7.300E+02	7.300E+02	7.300E+02	7.300E+02	7.300E+02	1.052E-02
Sn-126	7.300E+02	7.300E+02	7.300E+02	7.300E+02	7.300E+02	1.054E-02
Sr-90	7.812E+02	7.300E+02	7.811E+02	7.811E+02	7.811E+02	5.336E+00
Tc-99	7.372E+02	7.300E+02	7.371E+02	7.371E+02	7.372E+02	2.938E+01
Th-229	7.305E+02	7.300E+02	7.305E+02	7.305E+02	7.305E+02	4.355E-03
Th-230	7.305E+02	7.300E+02	7.305E+02	7.305E+02	7.305E+02	4.355E-03
Th-232	7.305E+02	7.300E+02	7.306E+02	7.306E+02	7.305E+02	4.355E-03
U-232	7.356E+02	7.300E+02	7.356E+02	7.356E+02	7.356E+02	1.394E-02
U-233	7.356E+02	7.300E+02	7.356E+02	7.356E+02	7.356E+02	1.395E-02
U-234	7.356E+02	7.300E+02	7.356E+02	7.356E+02	7.356E+02	1.395E-02
U-235	7.356E+02	7.300E+02	7.356E+02	7.356E+02	7.356E+02	1.395E-02
U-236	7.356E+02	7.300E+02	7.356E+02	7.356E+02	7.356E+02	1.395E-02
U-238	7.356E+02	7.300E+02	7.356E+02	7.356E+02	7.356E+02	1.395E-02
Zr-93	7.300E+02	7.300E+02	7.300E+02	7.300E+02	7.300E+02	4.215E-03

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**********  PATHRAE INPUT SUMMARY  **********

THERE ARE 80 ISOTOPES IN THE DOSE FACTOR LIBRARY
NUMBER OF TIMES FOR CALCULATION IS 10
YEARS TO BE CALCULATED ARE ...

      .00   500.00  1000.00  5000.00 10000.00
 50000.00100000.00200000.00500000.00*********

THERE ARE  60 ISOTOPES IN THE INVENTORY FILE
THE VALUE OF IFLAG IS 0
NUMBER OF PATHWAYS IS  2

           PATHWAY            TYPE OF USAGE
                            FOR UPTAKE FACTORS
   1  GROUNDWATER TO RIVER         2
   2  GROUNDWATER TO WELL          3

TIME OF OPERATION OF WASTE FACILITY IN YEARS                      0.
LENGTH OF REPOSITORY (M)                                        243.
WIDTH OF REPOSITORY (M)                                         427.
RIVER FLOW RATE (M**3/YR)                                         7.36E+05
STREAM FLOW RATE (M**3/YR)                                        1.00E+00
DISTANCE TO RIVER (M)                                           476.

OPERATIONAL SPILLAGE FRACTION                                     0.00E+00
DENSITY OF AQUIFER (KG/M**3)                                   1800.
LONGITUDINAL DISPERSIVITY (M)                                     4.76E+01
LATERAL DISPERSION COEFFICIENT -- Y AXIS (M**2/YR)                0.00E+00
NUMBER OF MESH POINTS FOR DISPERSION CALCULATION                 20
FLAG FOR GAMMA PATHWAY OPTIONS                                    2
FLAG FOR GAMMA BUILDUP CALCULATION                                0
FLAG FOR ATMOSPHERIC PATHWAY                                      0

COVER THICKNESS OVER WASTE (M)                                    3.35
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THICKNESS OF WASTE IN PITS (M)	16.16
TOTAL WASTE VOLUME (M**3)	1.680E+06
DISTANCE TO WELL -- X COORDINATE (M)	0.
DISTANCE TO WELL -- Y COORDINATE (M)	0.
DENSITY OF WASTE (KG/M**3)	1600.
FRACTION OF FOOD CONSUMED THAT IS GROWN ON SITE	.400
FRACTION OF YEAR SPENT IN DIRECT RADIATION FIELD	.705
DEPTH OF PLANT ROOT ZONE (M)	.900
AREAL DENSITY OF PLANTS (KG/M**2)	1.000
AVERAGE DUST LOADING IN AIR (KG/M**3)	1.00E-07
ANNUAL ADULT BREATHING RATE (M**3/YR)	8000.
FRACTION OF YEAR EXPOSED TO DUST	.705
CANISTER LIFETIME (YEARS)	200.
INVENTORY SCALING FACTOR	1.00E+00
HEIGHT OF ROOMS IN RECLAIMER HOUSE (CM)	240.
AIR CHANGE RATE IN RECLAIMER HOUSE (CHANGES/SEC)	5.56E-04
RADON EMANATING POWER OF THE WASTE	2.20E-01
DIFFUSION COEFF. OF RADON IN WASTE (CM**2/SEC)	2.00E-02
DIFFUSION COEFF. OF RN IN CONCRETE (CM**2/SEC)	3.00E-04
THICKNESS OF CONCRETE SLAB FLOOR (CM)	20.0
DIFFUSION COEFF. OF RADON IN COVER (CM**2/SEC)	1.00E-02
ATMOSPHERIC STABILITY CLASS	4
AVERAGE WIND SPEED (M/S)	6.30
FRACTION OF TIME WIND BLOWS TOWARD RECEPTOR	.2300
RECEPTOR DISTANCE FOR ATMOSPHERIC PATHWAY (M)	.0
DUST RESUSPENSION RATE FOR OFFSITE TRANSPORT (M**3/S)	1.10E-06
DEPOSITION VELOCITY (M/S)	.0100
STACK HEIGHT (M)	.0
STACK INSIDE DIAMETER (M)	.00
STACK GAS VELOCITY (M/S)	.0
HEAT EMISSION RATE FROM BURNING (CAL/S)	0.00E+00
DECAY CHAIN FLAGS	0 0 0 0 0 0 0
FLAG FOR INPUT SUMMARY PRINTOUT	1
FLAG FOR DIRECTION OF TRENCH FILLING	0
FLAG FOR GROUNDWATER PATHWAY OPTIONS	1
AMOUNT OF WATER PERCOLATING THROUGH WASTE ANNUALLY (M)	3.40E-02
DEGREE OF SOIL SATURATION	.867
RESIDUAL SOIL SATURATION	.000
PERMEABILITY OF VERTICAL ZONE (M/YR)	.32
SOIL NUMBER	.000
POROSITY OF AQUIFER	.04
POROSITY OF UNSATURATED ZONE	.44
DISTANCE FROM AQUIFER TO WASTE (M)	6.3
AVERAGE VERTICAL GROUNDWATER VELOCITY (M/YR)	8.95E-02
HORIZONTAL VELOCITY OF AQUIFER (M/YR)	21.3
LENGTH OF PERFORATED WELL CASING (M)	24.000
SURFACE EROSION RATE (M/YR)	1.000E-05
LEACH RATE SCALING FACTOR	1.000E+00
ANNUAL RUNOFF OF PRECIPITATION (M)	0.00E+00

NUCLIDE	INGESTION DOSE FACTORS (MREM/PCI)	INHALATION DOSE FACTORS (MREM/PCI)	DIRECT GAMMA DOSE FACTORS (MREM-M2/PCI-YR)	HALF LIFE (YR)
Ac-227	4.070E-03	8.140E-01	1.650E-08	2.180E+01
Ag-108m	8.510E-06	2.740E-05	1.810E-04	1.270E+02
Al-26	1.300E-05	7.400E-05	2.880E-04	7.160E+05
Am-241	7.400E-04	1.550E-01	2.720E-06	4.320E+02
Am-243	7.400E-04	1.520E-01	5.590E-06	7.380E+03
Ba-133	5.550E-06	1.150E-05	4.350E-05	1.070E+01
Bi-207	4.810E-06	2.070E-05	1.690E-04	3.800E+01
C-14	2.150E-06	2.290E-08	1.480E-09	5.730E+03

Cf-249	1.300E-03	2.590E-01	3.680E-05	3.510E+02
Cf-250	5.920E-04	1.260E-01	6.210E-08	1.310E+01
Cf-251	1.330E-03	2.630E-01	1.320E-05	8.980E+02
Cl-36	3.440E-06	2.700E-05	1.310E-06	3.010E+05
Cm-243	5.550E-04	1.150E-01	1.380E-05	2.850E+01
Cm-244	4.440E-04	9.990E-02	7.520E-08	1.810E+01
Cm-245	7.770E-04	1.550E-01	9.390E-06	8.500E+03
Cm-246	7.770E-04	1.550E-01	6.720E-08	4.730E+03
Cm-247	7.030E-04	1.440E-01	3.490E-05	1.560E+07
Cm-248	2.850E-03	5.550E-01	1.420E-04	3.390E+05
Co-60	1.260E-05	3.700E-05	2.680E-04	5.270E+00
Cs-135	7.400E-06	2.550E-06	3.140E-09	2.300E+06
Cs-137	4.810E-05	1.700E-05	3.490E-07	3.000E+01
Eu-150	4.810E-06	1.960E-04	1.660E-04	3.420E+01
Eu-152	5.180E-06	1.550E-04	1.260E-04	1.330E+01
Eu-154	7.400E-06	1.960E-04	1.370E-04	8.800E+00
H-3	1.550E-07	1.520E-07	0.000E+00	1.240E+01
I-129	4.070E-04	2.740E-04	2.280E-06	1.570E+07
K-40	2.290E-05	7.770E-06	2.380E-05	1.280E+09
Nb-93m	4.440E-07	1.890E-06	7.960E-08	1.360E+01
Nb-94	6.290E-06	4.070E-05	1.740E-04	2.030E+04
Ni-59	2.330E-07	4.810E-07	0.000E+00	7.500E+04
Ni-63	5.550E-07	1.780E-06	0.000E+00	9.600E+01
Np-237	4.070E-04	8.510E-02	2.940E-06	2.140E+06
Pa-231	2.630E-03	5.180E-01	4.410E-06	3.280E+04
Pb-210	2.550E-03	4.070E-03	2.490E-07	2.230E+01
Pd-107	1.370E-07	3.150E-07	0.000E+00	6.500E+06
Pu-238	8.510E-04	1.700E-01	7.310E-08	8.770E+01
Pu-239	9.250E-04	1.850E-01	3.310E-08	2.410E+04
Pu-240	9.250E-04	1.850E-01	7.010E-08	6.540E+03
Pu-241	1.780E-05	3.330E-03	2.010E-10	1.440E+01
Pu-242	8.880E-04	1.780E-01	5.810E-08	3.760E+05
Pu-244	8.880E-04	1.740E-01	2.360E-06	8.260E+07
Ra-226	1.040E-03	1.300E-02	7.130E-07	1.600E+03
Ra-228	2.550E-03	9.620E-03	0.000E+00	5.750E+00
Se-79	1.070E-05	4.070E-06	1.910E-09	6.500E+04
Si-32	2.070E-06	6.290E-05	2.920E-09	4.500E+02
Sm-151	3.630E-07	1.480E-05	4.130E-10	9.000E+01
Sn-121m	1.410E-06	1.670E-05	4.200E-07	5.500E+01
Sn-126	1.740E-05	1.040E-04	5.620E-06	1.000E+05
Sr-90	1.040E-04	1.330E-04	1.910E-07	2.910E+01
Tc-99	2.370E-06	1.480E-05	7.550E-09	2.130E+05
Th-229	1.810E-03	2.630E-01	9.210E-06	7.340E+03
Th-230	7.770E-04	5.180E-02	7.430E-08	7.700E+04
Th-232	8.510E-04	9.250E-02	5.310E-08	1.410E+10
U-232	1.220E-03	2.890E-02	9.420E-08	7.200E+01
U-233	1.890E-04	1.330E-02	6.990E-08	1.590E+05
U-234	1.810E-04	1.300E-02	6.840E-08	2.450E+05
U-235	1.740E-04	1.150E-02	1.630E-05	7.040E+08
U-236	1.740E-04	1.180E-02	5.870E-08	2.340E+07
U-238	1.670E-04	1.070E-02	4.940E-08	4.470E+09
Zr-93	4.070E-06	3.700E-05	0.000E+00	1.530E+06

NUCLIDE	VOLATILITY FRACTION	GAMMA ENERGY (MEV)	GAMMA ATTENUATION (1/M)
Ac-227	0.000E+00	0.000E+00	0.000E+00
Ag-108m	0.000E+00	0.000E+00	0.000E+00
Al-26	0.000E+00	1.000E-01	4.350E+01
Am-241	0.000E+00	2.000E-01	2.220E+01
Am-243	0.000E+00	0.000E+00	0.000E+00
Ba-133	0.000E+00	0.000E+00	0.000E+00
Bi-207	0.000E+00	0.000E+00	0.000E+00
C-14	0.000E+00	0.000E+00	0.000E+00
Cf-249	0.000E+00	0.000E+00	0.000E+00
Cf-250	0.000E+00	0.000E+00	0.000E+00
Cf-251	0.000E+00	0.000E+00	0.000E+00
Cl-36	0.000E+00	0.000E+00	0.000E+00
Cm-243	0.000E+00	2.000E-01	2.200E+01

Cm-244	0.000E+00	1.000E-01	4.350E+01
Cm-245	0.000E+00	0.000E+00	0.000E+00
Cm-246	0.000E+00	0.000E+00	0.000E+00
Cm-247	0.000E+00	0.000E+00	0.000E+00
Cm-248	0.000E+00	0.000E+00	0.000E+00
Co-60	0.000E+00	1.300E+00	9.200E+00
Cs-135	0.000E+00	7.000E-01	1.210E+01
Cs-137	0.000E+00	6.000E-01	1.280E+01
Eu-150	0.000E+00	5.000E-01	1.400E+01
Eu-152	0.000E+00	7.000E-01	1.250E+01
Eu-154	0.000E+00	1.000E-01	3.210E+01
H-3	0.000E+00	0.000E+00	0.000E+00
I-129	0.000E+00	0.000E+00	6.200E+01
K-40	0.000E+00	1.000E+00	1.030E+01
Nb-93m	0.000E+00	0.000E+00	0.000E+00
Nb-94	0.000E+00	8.000E-01	1.160E+01
Ni-59	0.000E+00	0.000E+00	0.000E+00
Ni-63	0.000E+00	0.000E+00	0.000E+00
Np-237	0.000E+00	1.000E-01	3.490E+01
Pa-231	0.000E+00	1.000E-01	2.280E+01
Pb-210	0.000E+00	0.000E+00	0.000E+00
Pd-107	0.000E+00	0.000E+00	0.000E+00
Pu-238	0.000E+00	1.000E-01	4.530E+01
Pu-239	0.000E+00	1.000E-01	2.580E+01
Pu-240	0.000E+00	1.000E-01	4.630E+01
Pu-241	0.000E+00	0.000E+00	0.000E+00
Pu-242	0.000E+00	0.000E+00	0.000E+00
Pu-244	0.000E+00	0.000E+00	0.000E+00
Ra-226	0.000E+00	2.000E-01	2.150E+01
Ra-228	0.000E+00	0.000E+00	0.000E+00
Se-79	0.000E+00	0.000E+00	0.000E+00
Si-32	0.000E+00	0.000E+00	0.000E+00
Sm-151	0.000E+00	0.000E+00	0.000E+00
Sn-121m	0.000E+00	0.000E+00	0.000E+00
Sn-126	0.000E+00	0.000E+00	0.000E+00
Sr-90	0.000E+00	0.000E+00	0.000E+00
Tc-99	0.000E+00	1.000E-01	2.920E+01
Th-229	0.000E+00	1.000E-01	2.880E+01
Th-230	0.000E+00	1.000E-01	3.030E+01
Th-232	0.000E+00	1.000E-01	3.550E+01
U-232	0.000E+00	0.000E+00	2.570E+01
U-233	0.000E+00	1.000E-01	2.570E+01
U-234	0.000E+00	1.000E-01	3.550E+01
U-235	0.000E+00	2.000E-01	2.160E+01
U-236	0.000E+00	1.000E-01	3.660E+01
U-238	0.000E+00	7.000E-01	1.200E+01
Zr-93	0.000E+00	0.000E+00	0.000E+00

NUCLIDE	INPUT LEACH RATE (1/YR)	FINAL LEACH RATE (1/YR)	SOLUBILITY (MOLE/L)	INPUT INVENTORY (CI)
Ac-227	-1.500E+03	8.765E-07	0.000E+00	1.680E+06
Ag-108m	-4.500E+01	2.904E-05	0.000E+00	1.680E+06
Al-26	-3.000E+03	4.383E-07	0.000E+00	1.680E+06
Am-241	-4.000E+01	3.265E-05	0.000E+00	1.680E+06
Am-243	-4.000E+01	3.265E-05	0.000E+00	1.680E+06
Ba-133	-6.000E+01	2.182E-05	0.000E+00	1.680E+06
Bi-207	-5.000E+02	2.629E-06	0.000E+00	1.680E+06
C-14	-1.090E+00	9.642E-04	0.000E+00	1.680E+06
Cf-249	-4.000E+01	3.265E-05	0.000E+00	1.680E+06
Cf-250	-4.000E+01	3.265E-05	0.000E+00	1.680E+06
Cf-251	-4.000E+01	3.265E-05	0.000E+00	1.680E+06
Cl-36	-2.500E-01	2.511E-03	0.000E+00	1.680E+06
Cm-243	-4.000E+01	3.265E-05	0.000E+00	1.680E+06
Cm-244	-4.000E+01	3.265E-05	0.000E+00	1.680E+06
Cm-245	-4.000E+01	3.265E-05	0.000E+00	1.680E+06
Cm-246	-4.000E+01	3.265E-05	0.000E+00	1.680E+06
Cm-247	-4.000E+01	3.265E-05	0.000E+00	1.680E+06
Cm-248	-4.000E+01	3.265E-05	0.000E+00	1.680E+06
Co-60	-3.000E+03	4.383E-07	0.000E+00	1.680E+06

Cs-135	-3.000E+03	4.383E-07	0.000E+00	1.680E+06
Cs-137	-3.000E+03	4.383E-07	0.000E+00	1.680E+06
Eu-150	-3.000E+03	4.383E-07	0.000E+00	1.680E+06
Eu-152	-3.000E+03	4.383E-07	0.000E+00	1.680E+06
Eu-154	-3.000E+03	4.383E-07	0.000E+00	1.680E+06
H-3	-1.990E-01	2.782E-03	0.000E+00	1.680E+06
I-129	-4.000E+00	3.077E-04	0.000E+00	1.680E+06
K-40	-3.000E+01	4.344E-05	0.000E+00	1.680E+06
Nb-93m	-1.000E+02	1.311E-05	0.000E+00	1.680E+06
Nb-94	-1.000E+02	1.311E-05	0.000E+00	1.680E+06
Ni-59	-2.000E+03	6.574E-07	0.000E+00	1.680E+06
Ni-63	-2.000E+03	6.574E-07	0.000E+00	1.680E+06
Np-237	-4.000E+01	3.265E-05	0.000E+00	1.680E+06
Pa-231	-4.000E+02	3.285E-06	0.000E+00	1.680E+06
Pb-210	-1.000E+02	1.311E-05	0.000E+00	1.680E+06
Pd-107	-2.000E+03	6.574E-07	0.000E+00	1.680E+06
Pu-238	-4.000E+01	3.265E-05	0.000E+00	1.680E+06
Pu-239	-4.000E+01	3.265E-05	0.000E+00	1.680E+06
Pu-240	-4.000E+01	3.265E-05	0.000E+00	1.680E+06
Pu-241	-4.000E+01	3.265E-05	0.000E+00	1.680E+06
Pu-242	-4.000E+01	3.265E-05	0.000E+00	1.680E+06
Pu-244	-4.000E+01	3.265E-05	0.000E+00	1.680E+06
Ra-226	-3.000E+03	4.383E-07	0.000E+00	1.680E+06
Ra-228	-3.000E+03	4.383E-07	0.000E+00	1.680E+06
Se-79	-3.000E+02	4.379E-06	0.000E+00	1.680E+06
Si-32	-3.000E+01	4.344E-05	0.000E+00	1.680E+06
Sm-151	-1.000E+03	1.315E-06	0.000E+00	1.680E+06
Sn-121m	-1.000E+02	1.311E-05	0.000E+00	1.680E+06
Sn-126	-1.000E+02	1.311E-05	0.000E+00	1.680E+06
Sr-90	-3.000E+01	4.344E-05	0.000E+00	1.680E+06
Tc-99	-1.500E+00	7.414E-04	0.000E+00	1.680E+06
Th-229	-3.000E+03	4.383E-07	0.000E+00	1.680E+06
Th-230	-3.000E+03	4.383E-07	0.000E+00	1.680E+06
Th-232	-3.000E+03	4.383E-07	0.000E+00	1.680E+06
U-232	-5.000E+01	2.616E-05	0.000E+00	1.680E+06
U-233	-5.000E+01	2.616E-05	0.000E+00	1.680E+06
U-234	-5.000E+01	2.616E-05	0.000E+00	1.680E+06
U-235	-5.000E+01	2.616E-05	0.000E+00	1.680E+06
U-236	-5.000E+01	2.616E-05	0.000E+00	1.680E+06
U-238	-5.000E+01	2.616E-05	0.000E+00	1.680E+06
Zr-93	-5.000E+01	2.616E-05	0.000E+00	1.680E+06

NUCLIDE	AQUIFER SORPTION	AQUIFER RETARDATION	VERTICAL SORPTION	VERTICAL RETARDATION
Ac-227	1.500E+02	6.751E+03	1.500E+03	7.111E+03
Ag-108m	4.500E+00	2.035E+02	4.500E+01	2.143E+02
Al-26	3.000E+02	1.350E+04	3.000E+03	1.422E+04
Am-241	4.000E+00	1.810E+02	4.000E+01	1.906E+02
Am-243	4.000E+00	1.810E+02	4.000E+01	1.906E+02
Ba-133	6.000E+00	2.710E+02	6.000E+01	2.854E+02
Bi-207	5.000E+01	2.251E+03	5.000E+02	2.371E+03
C-14	1.090E-01	5.905E+00	1.090E+00	6.167E+00
Cf-249	4.000E+00	1.810E+02	4.000E+01	1.906E+02
Cf-250	4.000E+00	1.810E+02	4.000E+01	1.906E+02
Cf-251	4.000E+00	1.810E+02	4.000E+01	1.906E+02
Cl-36	2.500E-02	2.125E+00	2.500E-01	2.185E+00
Cm-243	4.000E+00	1.810E+02	4.000E+01	1.906E+02
Cm-244	4.000E+00	1.810E+02	4.000E+01	1.906E+02
Cm-245	4.000E+00	1.810E+02	4.000E+01	1.906E+02
Cm-246	4.000E+00	1.810E+02	4.000E+01	1.906E+02
Cm-247	4.000E+00	1.810E+02	4.000E+01	1.906E+02
Cm-248	4.000E+00	1.810E+02	4.000E+01	1.906E+02
Co-60	3.000E+02	1.350E+04	3.000E+03	1.422E+04
Cs-135	3.000E+02	1.350E+04	3.000E+03	1.422E+04
Cs-137	3.000E+02	1.350E+04	3.000E+03	1.422E+04
Eu-150	3.000E+02	1.350E+04	3.000E+03	1.422E+04
Eu-152	3.000E+02	1.350E+04	3.000E+03	1.422E+04
Eu-154	3.000E+02	1.350E+04	3.000E+03	1.422E+04
H-3	1.990E-02	1.896E+00	1.990E-01	1.943E+00

I-129	4.000E-01	1.900E+01	4.000E+00	1.996E+01
K-40	3.000E+00	1.360E+02	3.000E+01	1.432E+02
Nb-93m	1.000E+01	4.510E+02	1.000E+02	4.750E+02
Nb-94	1.000E+01	4.510E+02	1.000E+02	4.750E+02
Ni-59	2.000E+02	9.001E+03	2.000E+03	9.481E+03
Ni-63	2.000E+02	9.001E+03	2.000E+03	9.481E+03
Np-237	4.000E+00	1.810E+02	4.000E+01	1.906E+02
Pa-231	4.000E+01	1.801E+03	4.000E+02	1.897E+03
Pb-210	1.000E+01	4.510E+02	1.000E+02	4.750E+02
Pd-107	2.000E+02	9.001E+03	2.000E+03	9.481E+03
Pu-238	4.000E+00	1.810E+02	4.000E+01	1.906E+02
Pu-239	4.000E+00	1.810E+02	4.000E+01	1.906E+02
Pu-240	4.000E+00	1.810E+02	4.000E+01	1.906E+02
Pu-241	4.000E+00	1.810E+02	4.000E+01	1.906E+02
Pu-242	4.000E+00	1.810E+02	4.000E+01	1.906E+02
Pu-244	4.000E+00	1.810E+02	4.000E+01	1.906E+02
Ra-226	3.000E+02	1.350E+04	3.000E+03	1.422E+04
Ra-228	3.000E+02	1.350E+04	3.000E+03	1.422E+04
Se-79	3.000E+01	1.351E+03	3.000E+02	1.423E+03
Si-32	3.000E+00	1.360E+02	3.000E+01	1.432E+02
Sm-151	1.000E+02	4.501E+03	1.000E+03	4.741E+03
Sn-121m	1.000E+01	4.510E+02	1.000E+02	4.750E+02
Sn-126	1.000E+01	4.510E+02	1.000E+02	4.750E+02
Sr-90	3.000E+00	1.360E+02	3.000E+01	1.432E+02
Tc-99	1.500E-01	7.750E+00	1.500E+00	8.110E+00
Th-229	3.000E+02	1.350E+04	3.000E+03	1.422E+04
Th-230	3.000E+02	1.350E+04	3.000E+03	1.422E+04
Th-232	3.000E+02	1.350E+04	3.000E+03	1.422E+04
U-232	5.000E+00	2.260E+02	5.000E+01	2.380E+02
U-233	5.000E+00	2.260E+02	5.000E+01	2.380E+02
U-234	5.000E+00	2.260E+02	5.000E+01	2.380E+02
U-235	5.000E+00	2.260E+02	5.000E+01	2.380E+02
U-236	5.000E+00	2.260E+02	5.000E+01	2.380E+02
U-238	5.000E+00	2.260E+02	5.000E+01	2.380E+02
Zr-93	5.000E+00	2.260E+02	5.000E+01	2.380E+02

BIOACCUMULATION FACTORS

NUCLIDE	SOIL-PLANT Bv	SOIL-PLANT Br	FORAGE-MILK Fm (D/L)	FORAGE-MEAT Ff (D/KG)
Ac-227	2.500E-03	2.500E-04	2.000E-05	2.000E-05
Ag-108m	1.500E-01	1.500E-02	2.500E-02	3.000E-03
Al-26	4.000E-03	4.000E-04	0.000E+00	0.000E+00
Am-241	1.000E-03	1.000E-04	2.000E-06	5.000E-05
Am-243	1.000E-03	1.000E-04	2.000E-06	5.000E-05
Ba-133	5.000E-03	5.000E-04	0.000E+00	0.000E+00
Bi-207	1.000E-01	1.000E-02	5.000E-04	2.000E-03
C-14	5.500E+00	5.500E-01	1.200E-02	3.100E-02
Cf-249	1.000E-03	1.000E-04	0.000E+00	0.000E+00
Cf-250	1.000E-03	1.000E-04	0.000E+00	0.000E+00
Cf-251	1.000E-03	1.000E-04	0.000E+00	0.000E+00
Cl-36	2.000E+01	2.000E+00	2.000E-02	6.000E-02
Cm-243	1.000E-03	1.000E-04	2.000E-06	2.000E-05
Cm-244	1.000E-03	1.000E-04	2.000E-06	2.000E-05
Cm-245	1.000E-03	1.000E-04	2.000E-06	2.000E-05
Cm-246	1.000E-03	1.000E-04	2.000E-06	2.000E-05
Cm-247	1.000E-03	1.000E-04	2.000E-06	2.000E-05
Cm-248	1.000E-03	1.000E-04	2.000E-06	2.000E-05
Co-60	8.000E-02	8.000E-03	2.000E-03	2.000E-02
Cs-135	4.000E-02	4.000E-03	8.000E-03	3.000E-02
Cs-137	4.000E-02	4.000E-03	8.000E-03	3.000E-02
Eu-150	2.500E-03	2.500E-04	2.000E-05	2.000E-03
Eu-152	2.500E-03	2.500E-04	2.000E-05	2.000E-03
Eu-154	2.500E-03	2.500E-04	2.000E-05	2.000E-03
H-3	4.800E+00	4.800E-01	1.000E-02	1.200E-02
I-129	2.000E-02	2.000E-03	1.000E-02	7.000E-03
K-40	3.000E-01	3.000E-02	7.000E-03	2.000E-02
Nb-93m	1.000E-02	1.000E-03	2.000E-06	3.000E-07
Nb-94	1.000E-02	1.000E-03	2.000E-06	3.000E-07
Ni-59	5.000E-02	5.000E-03	2.000E-02	5.000E-03

Ni-63	5.000E-02	5.000E-03	2.000E-02	5.000E-03
Np-237	2.000E-02	2.000E-03	5.000E-06	1.000E-03
Pa-231	1.000E-02	1.000E-03	5.000E-06	5.000E-03
Pb-210	1.000E-02	1.000E-03	3.000E-04	8.000E-04
Pd-107	1.000E-01	1.000E-02	0.000E+00	0.000E+00
Pu-238	1.000E-03	1.000E-04	1.000E-06	1.000E-04
Pu-239	1.000E-03	1.000E-04	1.000E-06	1.000E-04
Pu-240	1.000E-03	1.000E-04	1.000E-06	1.000E-04
Pu-241	1.000E-03	1.000E-04	1.000E-06	1.000E-04
Pu-242	1.000E-03	1.000E-04	1.000E-06	1.000E-04
Pu-244	1.000E-03	1.000E-04	1.000E-06	1.000E-04
Ra-226	4.000E-02	4.000E-03	1.000E-03	1.000E-03
Ra-228	4.000E-02	4.000E-03	1.000E-03	1.000E-03
Se-79	1.000E-01	1.000E-02	0.000E+00	0.000E+00
Si-32	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Sm-151	2.500E-03	2.500E-04	2.000E-05	2.000E-03
Sn-121m	2.500E-03	2.500E-04	0.000E+00	0.000E+00
Sn-126	2.500E-03	2.500E-04	0.000E+00	0.000E+00
Sr-90	3.000E-01	3.000E-02	2.000E-03	8.000E-03
Tc-99	5.000E+00	5.000E-01	1.000E-03	1.000E-04
Th-229	1.000E-03	1.000E-04	5.000E-06	1.000E-04
Th-230	1.000E-03	1.000E-04	5.000E-06	1.000E-04
Th-232	1.000E-03	1.000E-04	5.000E-06	1.000E-04
U-232	2.500E-03	2.500E-04	6.000E-04	3.400E-04
U-233	2.500E-03	2.500E-04	6.000E-04	3.400E-04
U-234	2.500E-03	2.500E-04	6.000E-04	3.400E-04
U-235	2.500E-03	2.500E-04	6.000E-04	3.400E-04
U-236	2.500E-03	2.500E-04	6.000E-04	3.400E-04
U-238	2.500E-03	2.500E-04	6.000E-04	3.400E-04
Zr-93	1.000E-03	1.000E-04	0.000E+00	0.000E+00

***** PEAK CONCENTRATIONS AND TIMES FOR PATHWAY 1 *****
***** RIVER AT 476.0 M *****

NUCLIDE	PEAK CONCENTRATION (CI/M**3)	PEAK TIME (YR)	AVERAGE DOSE AT PEAK TIME (MREM/YR)	AVERAGE RISK AT PEAK TIME (HE/YR)
Al-26	1.94E-07	1571792.3	1.84E+00	5.15E-07
Am-241	2.93E-17	16297.3	1.58E-08	4.44E-15
Am-243	9.01E-06	20821.5	4.87E+03	1.36E-03
C-14	1.93E-03	1037.4	3.97E+03	1.11E-03
Cf-249	7.37E-20	16046.3	7.00E-11	1.96E-17
Cf-251	3.30E-11	17322.2	3.20E-02	8.96E-09
Cl-36	5.72E-03	602.8	2.26E+04	6.34E-03
Cm-245	1.17E-05	21061.6	6.62E+03	1.85E-03
Cm-246	3.08E-06	20054.6	1.75E+03	4.89E-04
Cm-247	7.44E-05	33202.7	3.82E+04	1.07E-02
Cm-248	7.03E-05	27115.5	1.46E+05	4.10E-02
Cs-135	5.75E-07	1719785.8	3.94E+00	1.10E-06
H-3	1.42E-12	380.0	2.57E-07	7.20E-14
I-129	7.02E-04	4069.0	2.37E+05	6.64E-02
K-40	9.91E-05	30047.2	1.98E+03	5.54E-04
Nb-94	4.40E-06	51998.3	2.02E+01	5.65E-06
Ni-59	1.82E-10	892141.3	3.75E-05	1.05E-11
Np-237	7.38E-05	29882.4	2.21E+04	6.18E-03
Pa-231	9.14E-08	191612.7	1.81E+02	5.07E-05
Pd-107	1.30E-06	1265740.9	1.30E-01	3.64E-08
Pu-239	3.69E-05	22826.8	2.49E+04	6.98E-03
Pu-240	7.02E-06	20620.4	4.74E+03	1.33E-03
Pu-242	7.07E-05	27253.9	4.58E+04	1.28E-02
Pu-244	7.45E-05	35416.2	4.83E+04	1.35E-02
Se-79	1.65E-06	156296.8	1.29E+01	3.62E-06
Si-32	5.79E-14	12623.1	8.75E-08	2.45E-14
Sn-126	1.94E-05	58726.3	2.46E+02	6.89E-05
Tc-99	1.68E-03	1537.4	2.94E+03	8.24E-04
Th-230	2.90E-12	1293792.0	1.65E-03	4.61E-10

Th-232	1.00E-06	2776152.7	6.22E+02	1.74E-04
U-233	5.15E-05	31886.3	7.16E+03	2.01E-03
U-234	5.41E-05	32748.1	7.21E+03	2.02E-03
U-235	5.97E-05	49639.2	7.64E+03	2.14E-03
U-236	5.96E-05	41366.0	7.63E+03	2.14E-03
U-238	5.97E-05	52396.9	7.33E+03	2.05E-03
Zr-93	5.87E-05	36195.2	1.74E+02	4.88E-05

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***** PEAK CONCENTRATIONS AND TIMES FOR PATHWAY  2 *****
***** WELL  AT     .0 M *****
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NUCLIDE	PEAK CONCENTRATION (CI/M**3)	PEAK TIME (YR)	AVERAGE DOSE AT PEAK TIME (MREM/YR)	AVERAGE RISK AT PEAK TIME (HE/YR)
Ag-108m	2.50E-40	15390.9	1.55E-33	4.34E-40
Al-26	2.43E-05	1204869.8	2.31E+02	6.47E-05
Am-241	3.62E-13	14044.6	1.96E-04	5.48E-11
Am-243	1.26E-03	16091.6	6.79E+05	1.90E-01
C-14	1.67E-01	826.8	2.62E+05	7.34E-02
Cf-249	2.03E-15	13956.6	1.93E-06	5.40E-13
Cf-251	4.99E-08	14449.0	4.85E+01	1.36E-05
Cl-36	4.83E-01	498.3	1.21E+06	3.39E-01
Cm-245	1.54E-03	16225.1	8.71E+05	2.44E-01
Cm-246	5.46E-04	15695.6	3.09E+05	8.66E-02
Cm-247	6.27E-03	25618.5	3.22E+06	9.02E-01
Cm-248	6.01E-03	20281.3	1.25E+07	3.50E+00
Cs-135	5.56E-05	1295136.9	3.01E+02	8.41E-05
H-3	1.23E-09	347.4	1.40E-04	3.91E-11
I-129	5.92E-02	3219.8	1.76E+07	4.92E+00
K-40	8.36E-03	23208.9	1.40E+05	3.91E-02
Nb-94	5.88E-04	40014.6	2.70E+03	7.57E-04
Ni-59	1.05E-07	726148.4	1.78E-02	5.00E-09
Np-237	6.23E-03	22629.7	1.85E+06	5.19E-01
Pa-231	2.12E-05	151365.0	4.07E+04	1.14E-02
Pd-107	1.14E-04	947278.2	1.14E+01	3.18E-06
Pu-239	3.70E-03	17292.5	2.50E+06	6.99E-01
Pu-240	1.04E-03	15975.2	7.00E+05	1.96E-01
Pu-242	6.04E-03	20494.8	3.91E+06	1.10E+00
Pu-244	6.28E-03	27326.4	4.07E+06	1.14E+00
Se-79	2.16E-04	119992.3	1.68E+03	4.71E-04
Si-32	2.47E-10	10726.4	3.73E-04	1.04E-10
Sn-126	1.82E-03	44167.7	2.31E+04	6.48E-03
Tc-99	1.42E-01	1207.6	2.46E+05	6.88E-02
Th-230	3.27E-09	1069681.0	1.85E+00	5.19E-07
Th-232	8.43E-05	2135013.6	5.24E+04	1.47E-02
U-233	4.50E-03	23922.2	6.22E+05	1.74E-01
U-234	4.67E-03	24586.7	6.18E+05	1.73E-01
U-235	5.03E-03	38275.5	6.39E+05	1.79E-01
U-236	5.03E-03	31896.3	6.39E+05	1.79E-01
U-238	5.03E-03	42528.4	6.14E+05	1.72E-01
Zr-93	4.97E-03	27643.4	1.48E+04	4.13E-03

3.2.2 PATHRAE-HAZ

The PATHRAE-HAZ model is limited to 99 contaminants of concern (COCs) per run. Two runs were conducted to address all the COCs. The input and output files for the run for the first group of COCs (inorganics) and the remaining COCs (organics) are provided in Section 3.2.2.1 and Section 3.2.2.2, respectively.

3.2.2.1 First Contaminants of Concern (Inorganics)

FILE = PATHHAZ-inorg-NB-HR-5C-CL-200yr-peak.OUT (high recharge, post 1,000 yr)

PATHRAE-HAZ(PC) Version 2.3d January 1997
Date: 1- 6-2016
Time: 11:13:51

pWAC HAZ- Inorganic – Nov 2015 EMDF in UBCV

TOTAL EQUIVALENT UPTAKE FACTORS FOR PATHRAE

CONTAMINANT	UT(J,1) RIVER L/YR	UT(J,2) WELL L/YR	UT(J,3) EROSION L/YR	UT(J,4) BATHTUB L/YR	UT(J,5) SPILLAGE L/YR	UT(J,6) FOOD KG/YR
Antimony	7.332E+02	7.300E+02	7.332E+02	7.332E+02	7.332E+02	2.153E-01
Barium	7.372E+02	7.300E+02	7.373E+02	7.373E+02	7.373E+02	5.213E-01
Boron	7.477E+02	7.300E+02	7.477E+02	7.477E+02	7.477E+02	3.026E+01
Chromium-III	7.787E+02	7.300E+02	7.787E+02	7.787E+02	7.787E+02	6.445E-01
Lead	7.369E+02	7.300E+02	7.371E+02	7.371E+02	7.371E+02	4.682E-01
Manganese	7.355E+02	7.300E+02	7.379E+02	7.379E+02	7.378E+02	3.346E+00
Molybdenum	7.498E+02	7.300E+02	7.500E+02	7.500E+02	7.500E+02	3.254E+00
Selenium	1.312E+03	7.300E+02	1.316E+03	1.316E+03	1.316E+03	7.577E+01
Strontium	7.941E+02	7.300E+02	7.941E+02	7.941E+02	7.941E+02	2.096E+01
Tin	7.909E+02	7.300E+02	7.909E+02	7.909E+02	7.909E+02	1.895E+01
Vanadium	7.457E+02	7.300E+02	7.457E+02	7.457E+02	7.457E+02	4.151E-02
U-233	7.371E+02	7.300E+02	7.371E+02	7.371E+02	7.371E+02	1.201E-01
U-234	7.371E+02	7.300E+02	7.371E+02	7.371E+02	7.371E+02	1.201E-01
U-235	7.371E+02	7.300E+02	7.371E+02	7.371E+02	7.371E+02	1.201E-01
U-236	7.371E+02	7.300E+02	7.371E+02	7.371E+02	7.371E+02	1.201E-01
U-238	7.371E+02	7.300E+02	7.371E+02	7.371E+02	7.371E+02	1.201E-01
Mercury	7.870E+02	7.300E+02	8.238E+02	8.238E+02	8.198E+02	1.814E+01
Arsenic	7.434E+02	7.300E+02	7.434E+02	7.434E+02	7.434E+02	2.779E-01
Beryllium	7.379E+02	7.300E+02	7.380E+02	7.380E+02	7.380E+02	5.537E-02
Cadmium	7.426E+02	7.300E+02	7.435E+02	7.435E+02	7.435E+02	3.559E+00
Chromium-VI	7.713E+02	7.300E+02	7.713E+02	7.713E+02	7.713E+02	1.033E-01
Copper	7.942E+02	7.300E+02	7.952E+02	7.952E+02	7.952E+02	7.885E+00
Nickel	7.703E+02	7.300E+02	7.705E+02	7.705E+02	7.705E+02	8.200E-01
Silver	8.880E+02	7.300E+02	8.885E+02	8.885E+02	8.885E+02	1.550E+01
Zinc	1.242E+03	7.300E+02	1.272E+03	1.272E+03	1.271E+03	1.349E+02

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**********  Image of Input Files  **********

-- Input File:  ABCDEF.DAT
pWAC HAZ- Inorganic – Nov 2015 EMDF in UBCV
10, 0., 500.,1000.,5000.,10000.,50000.,100000.,200000.,500000.,1000000.
25,0,2
1,2, 2,3,
0.0, 243.19, 427., 7.36E+05, 1., 476., 0.
1800., 47.6, 0., 0., 0.867, 0., 0.315, 0.
20, 2, 0, 1, 1, 0
3.35, 16.16, 1.68E+06, 0., 0., 1600., 0.40, 0.705, 0.90, 1.
1.0E-7, 8000., 0.705, 200., 1.0E+00, 0.01
240., 5.56E-04, 0.22, 0.02, 3.0E-4, 20., 0.01
4, 6.3, 0.23, 0., 1.1E-06, 0.01, 0., 0., 0., 0., 0.
0, 0, 0, 0, 0, 0, 0
1, 0, 0, 1
0.034, 21.3, 0.04, 6.3, 0.000, 24.0, 0.00001, 1.0, 0., 0.438

-- Input File:  BRCDCF.DAT
102,Antimony         0.00E+00,4.00E-04,0.00E+00,0.00E+00
104,Barium           0.00E+00,2.00E-01,0.00E+00,0.00E+00
106,Boron            0.00E+00,2.00E-01,0.00E+00,0.00E+00
109,Chromium-III     0.00E+00,0.00E+00,0.00E+00,0.00E+00
118,Lead             0.00E+00,0.00E+00,0.00E+00,0.00E+00
121,Manganese        0.00E+00,1.40E-01,0.00E+00,0.00E+00
123,Molybdenum       0.00E+00,5.00E-03,0.00E+00,0.00E+00
128,Selenium         0.00E+00,5.00E-03,0.00E+00,0.00E+00
131,Strontium        0.00E+00,6.00E-01,0.00E+00,0.00E+00
134,Tin              0.00E+00,6.00E-01,0.00E+00,0.00E+00
136,Vanadium         0.00E+00,5.00E-03,0.00E+00,0.00E+00
140,U-233            0.00E+00,3.00E-03,0.00E+00,0.00E+00
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141,U-234           0.00E+00,3.00E-03,0.00E+00,0.00E+00
142,U-235           0.00E+00,3.00E-03,0.00E+00,0.00E+00
143,U-236           0.00E+00,3.00E-03,0.00E+00,0.00E+00
144,U-238           0.00E+00,3.00E-03,0.00E+00,0.00E+00
122,Mercury         0.00E+00,3.00E-04,0.00E+00,0.00E+00
704,Arsenic         0.00E+00,3.00E-04,0.00E+00,0.00E+00
705,Beryllium       0.00E+00,2.00E-03,0.00E+00,0.00E+00
706,Cadmium         0.00E+00,5.00E-04,0.00E+00,0.00E+00
707,Chromium-VI     0.00E+00,3.00E-03,0.00E+00,0.00E+00
708,Copper          0.00E+00,4.00E-02,0.00E+00,0.00E+00
709,Nickel          0.00E+00,2.00E-02,0.00E+00,0.00E+00
710,Silver          0.00E+00,5.00E-03,0.00E+00,0.00E+00
711,Zinc            0.00E+00,3.00E-01,0.00E+00,0.00E+00

-- Input File:  INVNTRY.DAT
102,  1.00E+10, 1.680E+06,         0,          0, 0.000E+00,         0,         Antimony
104,  1.00E+10, 1.680E+06,         0,          0, 0.000E+00,         0,         Barium
106,  1.00E+10, 1.680E+06,         0,          0, 0.000E+00,         0,         Boron
109,  1.00E+10, 1.680E+06,         0,          0, 0.000E+00,         0,         Chromium-III
118,  1.00E+10, 1.680E+06,         0,          0, 0.000E+00,         0,         Lead
121,  1.00E+10, 1.680E+06,         0,          0, 0.000E+00,         0,         Manganese
123,  1.00E+10, 1.680E+06,         0,          0, 7.660E+04,         0,         Molybdenum
128,  1.00E+10, 1.680E+06,         0,          0, 0.000E+00,         0,         Selenium
131,  1.00E+10, 1.680E+06,         0,          0, 0.000E+00,         0,         Strontium
134,  1.00E+10, 1.680E+06,         0,          0, 0.000E+00,         0,         Tin
136,  1.00E+10, 1.680E+06,         0,          0, 0.000E+00,         0,         Vanadium
140,  1.59E+05, 1.680E+06,         0,          0, 0.000E+00,         0,         U-233
141,  2.44E+05, 1.680E+06,         0,          0, 0.000E+00,         0,         U-234
142,  7.04E+08, 1.680E+06,         0,          0, 0.000E+00,         0,         U-235
143,  2.34E+07, 1.680E+06,         0,          0, 0.000E+00,         0,         U-236
144,  4.47E+09, 1.680E+06,         0,          0, 0.000E+00,         0,         U-238
122,  1.00E+10, 1.680E+06,         0,          0, 5.700E+01,         0,         Mercury
704,  1.00E+10, 1.680E+06,         0,          0, 0.000E+00,         0,         Arsenic
705,  1.00E+10, 1.680E+06,         0,          0, 0.000E+00,         0,         Beryllium
706,  1.00E+10, 1.680E+06,         0,          0, 0.000E+00,         0,         Cadmium
707,  1.00E+10, 1.680E+06,         0,          0, 0.000E+00,         0,         Chromium-VI
708,  1.00E+10, 1.680E+06,         0,          0, 0.000E+00,         0,         Copper
709,  1.00E+10, 1.680E+06,         0,          0, 0.000E+00,         0,         Nickel
710,  1.00E+10, 1.680E+06,         0,          0, 0.000E+00,         0,         Silver
711,  1.00E+10, 1.680E+06,         0,          0, 0.000E+00,         0,         Zinc

-- Input File:  RQSITE.DAT
102,-1.900E+01, 1.900E+00, 1.900E+01,      Antimony
104,-5.500E+01, 5.500E+00, 5.500E+01,      Barium
106,-3.000E+00, 3.000E-01, 3.000E+00,      Boron
109,-1.000E+01, 1.000E+00, 1.000E+01,      Chromium-III
118,-1.000E+02, 1.000E+01, 1.000E+02,      Lead
121,-2.000E+02, 2.000E+01, 2.000E+02,      Manganese
123,-2.000E+01, 2.000E+00, 2.000E+01,      Molybdenum
128,-1.500E+01, 1.500E+00, 1.500E+01,      Selenium
131,-1.350E+01, 0.000E+00, 1.350E+01,      Strontium
134,-2.500E+00, 2.500E-01, 2.500E+00,      Tin
136,-1.000E+02, 1.000E+01, 1.000E+02,      Vanadium
140,-5.000E+01, 5.000E+00, 5.000E+01,      U-233
141,-5.000E+01, 5.000E+00, 5.000E+01,      U-234
142,-5.000E+01, 5.000E+00, 5.000E+01,      U-235
143,-5.000E+01, 5.000E+00, 5.000E+01,      U-236
144,-5.000E+01, 5.000E+00, 5.000E+01,      U-238
122,-5.800E+02, 5.800E+01, 5.800E+02,      Mercury
704,-2.900E+01, 2.900E+00, 2.900E+01,      Arsenic
705,-7.900E+02, 7.900E+01, 7.900E+02,      Beryllium
706,-7.500E+01, 7.500E+00, 7.500E+01,      Cadmium
707,-1.000E+01, 1.000E+00, 1.000E+01,      Chromium-VI
708,-3.500E+01, 3.500E+00, 3.500E+01,      Copper
709,-6.500E+01, 6.500E+00, 6.500E+01,      Nickel
710,-8.300E+00, 8.300E-01, 8.300E+00,      Silver
711,-6.200E+01, 6.200E+00, 6.200E+01,      Zinc

-- Input File:  UPTAKE.DAT
0.5,   0.2,    1.89
0.67,  0.65,   2.1E-3,   438.,   438.
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 0.0,   2160., 24.,     1440.,     1., 0.83
 50.,   6.,    48.,      480.,    48.
 .05, 0.0008, 60.,         8.,    50.
 14.,   176., 110.,        0.,    95.,  730., 0.0
 Antimony             0.25, 5.00E-02, 5.00E-03, 2.50E-05,         0, 4.00E-05, 1.00E+02,        102
 Barium               0.25, 1.00E-01, 1.00E-02, 4.80E-04,         0, 2.00E-04, 4.00E+00,        104
 Boron                0.25, 4.00E+00, 4.00E-01, 1.50E-03,         0, 8.00E-04, 0.00E+00,        106
 Chromium-III         0.25, 4.00E-02, 4.00E-03, 1.00E-05,         0, 9.00E-03, 2.00E+02,        109
 Lead                 0.25, 9.00E-02, 9.00E-03, 3.00E-04,         0, 4.00E-04, 3.00E+02,        118
 Manganese            0.25, 6.80E-01, 6.80E-02, 3.00E-05,         0, 5.00E-04, 4.00E+02,        121
 Molybdenum           0.25, 4.00E-01, 4.00E-02, 1.70E-03,         0, 1.00E-03, 0.00E+00,        123
 Selenium             0.25, 5.00E-01, 5.00E-02, 1.00E-02,         0, 1.00E-01, 0.00E+00,        128
 Strontium            0.25, 1.10E+00, 1.10E-01, 2.80E-03,         0, 8.00E-03, 0.00E+00,        131
 Tin                  0.25, 1.00E+00, 1.00E-01, 1.00E-03,         0, 1.00E-02, 3.00E+03,        134
 Vanadium             0.25, 5.50E-03, 5.50E-04, 2.00E-05,         0, 2.50E-03, 1.00E+01,        136
 U-233                0.25, 2.30E-02, 2.30E-03, 4.00E-04,         0, 3.00E-04, 1.00E+01,        140
 U-234                0.25, 2.30E-02, 2.30E-03, 4.00E-04,         0, 3.00E-04, 1.00E+01,        141
 U-235                0.25, 2.30E-02, 2.30E-03, 4.00E-04,         0, 3.00E-04, 1.00E+01,        142
 U-236                0.25, 2.30E-02, 2.30E-03, 4.00E-04,         0, 3.00E-04, 1.00E+01,        143
 U-238                0.25, 2.30E-02, 2.30E-03, 4.00E-04,         0, 3.00E-04, 1.00E+01,        144
 Mercury              0.25, 1.00E+00, 1.00E-01, 4.70E-04,         0, 1.00E-02, 1.00E+03,        122
 Arsenic              0.25, 4.00E-02, 4.00E-03, 6.00E-05,         0, 2.00E-03, 0.00E+00,        704
 Beryllium            0.25, 1.00E-02, 1.00E-03, 9.00E-07,         0, 1.00E-03, 0.00E+00,        705
 Cadmium              0.25, 5.50E-01, 5.50E-02, 1.00E-03,         0, 5.50E-04, 0.00E+00,        706
 Chromium-VI          0.25, 7.50E-03, 7.50E-04, 1.50E-03,         0, 5.50E-03, 0.00E+00,        707
 Copper               0.25, 4.00E-01, 4.00E-02, 1.50E-03,         0, 1.00E-02, 0.00E+00,        708
 Nickel               0.25, 6.00E-02, 6.00E-03, 1.00E-03,         0, 6.00E-03, 0.00E+00,        709
 Silver               0.25, 4.00E-01, 4.00E-02, 2.00E-02,         0, 3.00E-03, 0.00E+00,        710
 Zinc                 0.25, 9.90E-01, 9.90E-02, 0.00E+00,         0, 1.00E-01, 0.00E+00,        711
1


 **********  PATHRAE INPUT SUMMARY  **********

 THERE ARE 99 CONTAMINANTS IN THE RISK FACTOR LIBRARY
 NUMBER OF TIMES FOR CALCULATION IS 10
 YEARS TO BE CALCULATED ARE ...

       .00   500.00  1000.00  5000.00 10000.00
  50000.00100000.00200000.00500000.00*********

 THERE ARE  25 CONTAMINANTS IN THE INVENTORY FILE
 THE VALUE OF IFLAG IS 0
 NUMBER OF PATHWAYS IS  2

            PATHWAY           TYPE OF USAGE
                            FOR UPTAKE FACTORS
    1  GROUNDWATER TO RIVER         2
    2  GROUNDWATER TO WELL          3

 TIME OF OPERATION OF WASTE FACILITY IN YEARS                      0.
 LENGTH OF REPOSITORY (M)                                        243.
 WIDTH OF REPOSITORY (M)                                         427.
 RIVER FLOW RATE (M**3/YR)                                         7.36E+05
 STREAM FLOW RATE (M**3/YR)                                        1.00E+00
 DISTANCE TO RIVER (M)                                           476.

 OPERATIONAL SPILLAGE FRACTION                                     0.00E+00
 DENSITY OF AQUIFER (KG/M**3)                                   1800.
 LONGITUDINAL DISPERSIVITY (M)                                     4.76E+01
 LATERAL DISPERSION COEFFICIENT -- Y AXIS (M**2/YR)                0.00E+00
 NUMBER OF MESH POINTS FOR DISPERSION CALCULATION                20
 FLAG FOR ATMOSPHERIC PATHWAY                                      0

 COVER THICKNESS OVER WASTE (M)                                    3.35
 THICKNESS OF WASTE IN PITS (M)                                   16.16
 TOTAL WASTE VOLUME (M**3)                                         1.680E+06
 DISTANCE TO WELL -- X COORDINATE (M)                              0.
 DISTANCE TO WELL -- Y COORDINATE (M)                              0.
 DENSITY OF WASTE (KG/M**3)                                     1600.
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FRACTION OF FOOD CONSUMED THAT IS GROWN ON SITE	.400
FRACTION OF YEAR CONTAMINANTS CONTACT SKIN	.705
AREA OF SKIN IN CONTACT WITH CONTAMINANTS (M**2)	.0100
DEPTH OF PLANT ROOT ZONE (M)	.900
AREAL DENSITY OF PLANTS (KG/M**2)	1.000
AVERAGE DUST LOADING IN AIR (KG/M**3)	1.00E-07
ANNUAL ADULT BREATHING RATE (M**3/YR)	8000.
FRACTION OF YEAR EXPOSED TO DUST	.705
CANISTER LIFETIME (YEARS)	200.
INVENTORY SCALING FACTOR	1.00E+00
HEIGHT OF ROOMS IN RECLAIMER HOUSE (CM)	240.
AIR CHANGE RATE IN RECLAIMER HOUSE (CHANGES/SEC)	5.56E-04
ATMOSPHERIC STABILITY CLASS	4
AVERAGE WIND SPEED (M/S)	6.30
FRACTION OF TIME WIND BLOWS TOWARD RECEPTOR	.2300
RECEPTOR DISTANCE FOR ATMOSPHERIC PATHWAY (M)	.0
DUST RESUSPENSION RATE FOR OFFSITE TRANSPORT (M**3/S)	1.10E-06
DEPOSITION VELOCITY (M/S)	.0100
STACK HEIGHT (M)	.0
STACK INSIDE DIAMETER (M)	.00
STACK GAS VELOCITY (M/S)	.0
HEAT EMISSION RATE FROM BURNING (CAL/S)	0.00E+00
FLAGS FOR DEGRADATION SERIES	0 0 0 0 0 0 0
FLAG FOR INPUT SUMMARY PRINTOUT	1
FLAG FOR DIRECTION OF TRENCH FILLING	0
FLAG FOR GROUNDWATER PATHWAY OPTIONS	1
AMOUNT OF WATER PERCOLATING THROUGH WASTE ANNUALLY (M)	3.40E-02
DEGREE OF SOIL SATURATION	.867
RESIDUAL SOIL SATURATION	.000
PERMEABILITY OF VERTICAL ZONE (M/YR)	.32
SOIL NUMBER	.000
POROSITY OF AQUIFER	.04
POROSITY OF UNSATURATED ZONE	.44
DISTANCE FROM AQUIFER TO WASTE (M)	6.3
AVERAGE VERTICAL GROUNDWATER VELOCITY (M/YR)	8.95E-02
HORIZONTAL VELOCITY OF AQUIFER (M/YR)	2.13E+01
LENGTH OF PERFORATED WELL CASING (M)	24.000
SURFACE EROSION RATE (M/YR)	1.000E-05
LEACH RATE SCALING FACTOR	1.000E+00
ANNUAL RUNOFF OF PRECIPITATION (M)	0.00E+00

	INGESTION		INHALATION		
CONTAMINANT	UNIT RISK FACTORS (KG-DAY/MG)	ALLOWABLE DAILY INTAKES (MG/KG-DAY)	UNIT RISK FACTORS (KG-DAY/MG)	ALLOWABLE DAILY INTAKES (MG/KG-DAY)	HALF LIFE (YR)
Antimony	0.000E+00	4.000E-04	0.000E+00	0.000E+00	1.000E+10
Barium	0.000E+00	2.000E-01	0.000E+00	0.000E+00	1.000E+10
Boron	0.000E+00	2.000E-01	0.000E+00	0.000E+00	1.000E+10
Chromium-III	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.000E+10
Lead	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.000E+10
Manganese	0.000E+00	1.400E-01	0.000E+00	0.000E+00	1.000E+10
Molybdenum	0.000E+00	5.000E-03	0.000E+00	0.000E+00	1.000E+10
Selenium	0.000E+00	5.000E-03	0.000E+00	0.000E+00	1.000E+10
Strontium	0.000E+00	6.000E-01	0.000E+00	0.000E+00	1.000E+10
Tin	0.000E+00	6.000E-01	0.000E+00	0.000E+00	1.000E+10
Vanadium	0.000E+00	5.000E-03	0.000E+00	0.000E+00	1.000E+10
U-233	0.000E+00	3.000E-03	0.000E+00	0.000E+00	1.590E+05
U-234	0.000E+00	3.000E-03	0.000E+00	0.000E+00	2.440E+05
U-235	0.000E+00	3.000E-03	0.000E+00	0.000E+00	7.040E+08
U-236	0.000E+00	3.000E-03	0.000E+00	0.000E+00	2.340E+07
U-238	0.000E+00	3.000E-03	0.000E+00	0.000E+00	4.470E+09

Mercury	0.000E+00	3.000E-04	0.000E+00	0.000E+00	1.000E+10
Arsenic	0.000E+00	3.000E-04	0.000E+00	0.000E+00	1.000E+10
Beryllium	0.000E+00	2.000E-03	0.000E+00	0.000E+00	1.000E+10
Cadmium	0.000E+00	5.000E-04	0.000E+00	0.000E+00	1.000E+10
Chromium-VI	0.000E+00	3.000E-03	0.000E+00	0.000E+00	1.000E+10
Copper	0.000E+00	4.000E-02	0.000E+00	0.000E+00	1.000E+10
Nickel	0.000E+00	2.000E-02	0.000E+00	0.000E+00	1.000E+10
Silver	0.000E+00	5.000E-03	0.000E+00	0.000E+00	1.000E+10
Zinc	0.000E+00	3.000E-01	0.000E+00	0.000E+00	1.000E+10

CONTAMINANT	VOLATILITY FRACTION	VAPORIZATION RATE (1/S)	SKIN ABSORPTION (M/HR)
Antimony	0.000E+00	0.000E+00	0.000E+00
Barium	0.000E+00	0.000E+00	0.000E+00
Boron	0.000E+00	0.000E+00	0.000E+00
Chromium-III	0.000E+00	0.000E+00	0.000E+00
Lead	0.000E+00	0.000E+00	0.000E+00
Manganese	0.000E+00	0.000E+00	0.000E+00
Molybdenum	0.000E+00	0.000E+00	0.000E+00
Selenium	0.000E+00	0.000E+00	0.000E+00
Strontium	0.000E+00	0.000E+00	0.000E+00
Tin	0.000E+00	0.000E+00	0.000E+00
Vanadium	0.000E+00	0.000E+00	0.000E+00
U-233	0.000E+00	0.000E+00	0.000E+00
U-234	0.000E+00	0.000E+00	0.000E+00
U-235	0.000E+00	0.000E+00	0.000E+00
U-236	0.000E+00	0.000E+00	0.000E+00
U-238	0.000E+00	0.000E+00	0.000E+00
Mercury	0.000E+00	0.000E+00	0.000E+00
Arsenic	0.000E+00	0.000E+00	0.000E+00
Beryllium	0.000E+00	0.000E+00	0.000E+00
Cadmium	0.000E+00	0.000E+00	0.000E+00
Chromium-VI	0.000E+00	0.000E+00	0.000E+00
Copper	0.000E+00	0.000E+00	0.000E+00
Nickel	0.000E+00	0.000E+00	0.000E+00
Silver	0.000E+00	0.000E+00	0.000E+00
Zinc	0.000E+00	0.000E+00	0.000E+00

CONTAMINANT	INPUT LEACH (1/YR)	FINAL LEACH (1/YR)	SOLUBILITY (MG/L)	INPUT INVENTORY (KG)
Antimony	-1.900E+01	6.823E-05	0.000E+00	1.680E+06
Barium	-5.500E+01	2.379E-05	0.000E+00	1.680E+06
Boron	-3.000E+00	4.017E-04	0.000E+00	1.680E+06
Chromium-III	-1.000E+01	1.280E-04	0.000E+00	1.680E+06
Lead	-1.000E+02	1.311E-05	0.000E+00	1.680E+06
Manganese	-2.000E+02	6.566E-06	0.000E+00	1.680E+06
Molybdenum	-2.000E+01	6.486E-05	7.660E+04	1.680E+06
Selenium	-1.500E+01	8.609E-05	0.000E+00	1.680E+06
Strontium	-1.350E+01	9.547E-05	0.000E+00	1.680E+06
Tin	-2.500E+00	4.741E-04	0.000E+00	1.680E+06
Vanadium	-1.000E+02	1.311E-05	0.000E+00	1.680E+06
U-233	-5.000E+01	2.616E-05	0.000E+00	1.680E+06
U-234	-5.000E+01	2.616E-05	0.000E+00	1.680E+06
U-235	-5.000E+01	2.616E-05	0.000E+00	1.680E+06
U-236	-5.000E+01	2.616E-05	0.000E+00	1.680E+06
U-238	-5.000E+01	2.616E-05	0.000E+00	1.680E+06
Mercury	-5.800E+02	2.266E-06	5.700E+01	1.680E+06
Arsenic	-2.900E+01	4.492E-05	0.000E+00	1.680E+06
Beryllium	-7.900E+02	1.664E-06	0.000E+00	1.680E+06
Cadmium	-7.500E+01	1.747E-05	0.000E+00	1.680E+06
Chromium-VI	-1.000E+01	1.280E-04	0.000E+00	1.680E+06
Copper	-3.500E+01	3.728E-05	0.000E+00	1.680E+06
Nickel	-6.500E+01	2.015E-05	0.000E+00	1.680E+06
Silver	-8.300E+00	1.534E-04	0.000E+00	1.680E+06
Zinc	-6.200E+01	2.112E-05	0.000E+00	1.680E+06

CONTAMINANT	AQUIFER SORPTION	AQUIFER RETARDATION	VERTICAL SORPTION	VERTICAL RETARDATION
Antimony	1.900E+00	8.650E+01	1.900E+01	9.106E+01
Barium	5.500E+00	2.485E+02	5.500E+01	2.617E+02
Boron	3.000E-01	1.450E+01	3.000E+00	1.522E+01
Chromium-III	1.000E+00	4.600E+01	1.000E+01	4.840E+01
Lead	1.000E+01	4.510E+02	1.000E+02	4.750E+02
Manganese	2.000E+01	9.010E+02	2.000E+02	9.490E+02
Molybdenum	2.000E+00	9.100E+01	2.000E+01	9.580E+01
Selenium	1.500E+00	6.850E+01	1.500E+01	7.210E+01
Strontium	0.000E+00	1.000E+00	1.350E+01	6.499E+01
Tin	2.500E-01	1.225E+01	2.500E+00	1.285E+01
Vanadium	1.000E+01	4.510E+02	1.000E+02	4.750E+02
U-233	5.000E+00	2.260E+02	5.000E+01	2.380E+02
U-234	5.000E+00	2.260E+02	5.000E+01	2.380E+02
U-235	5.000E+00	2.260E+02	5.000E+01	2.380E+02
U-236	5.000E+00	2.260E+02	5.000E+01	2.380E+02
U-238	5.000E+00	2.260E+02	5.000E+01	2.380E+02
Mercury	5.800E+01	2.611E+03	5.800E+02	2.750E+03
Arsenic	2.900E+00	1.315E+02	2.900E+01	1.385E+02
Beryllium	7.900E+01	3.556E+03	7.900E+02	3.746E+03
Cadmium	7.500E+00	3.385E+02	7.500E+01	3.565E+02
Chromium-VI	1.000E+00	4.600E+01	1.000E+01	4.840E+01
Copper	3.500E+00	1.585E+02	3.500E+01	1.669E+02
Nickel	6.500E+00	2.935E+02	6.500E+01	3.091E+02
Silver	8.300E-01	3.835E+01	8.300E+00	4.034E+01
Zinc	6.200E+00	2.800E+02	6.200E+01	2.949E+02

	BIOACCUMULATION FACTORS			
CONTAMINANT	SOIL-PLANT Bv	SOIL-PLANT Br	FORAGE-MILK Fm (D/L)	FORAGE-MEAT Ff (D/KG)
Antimony	5.000E-02	5.000E-03	2.500E-05	4.000E-05
Barium	1.000E-01	1.000E-02	4.800E-04	2.000E-04
Boron	4.000E+00	4.000E-01	1.500E-03	8.000E-04
Chromium-III	4.000E-02	4.000E-03	1.000E-05	9.000E-03
Lead	9.000E-02	9.000E-03	3.000E-04	4.000E-04
Manganese	6.800E-01	6.800E-02	3.000E-05	5.000E-04
Molybdenum	4.000E-01	4.000E-02	1.700E-03	1.000E-03
Selenium	5.000E-01	5.000E-02	1.000E-02	1.000E-01
Strontium	1.100E+00	1.100E-01	2.800E-03	8.000E-03
Tin	1.000E+00	1.000E-01	1.000E-03	1.000E-02
Vanadium	5.500E-03	5.500E-04	2.000E-05	2.500E-03
U-233	2.300E-02	2.300E-03	4.000E-04	3.000E-04
U-234	2.300E-02	2.300E-03	4.000E-04	3.000E-04
U-235	2.300E-02	2.300E-03	4.000E-04	3.000E-04
U-236	2.300E-02	2.300E-03	4.000E-04	3.000E-04
U-238	2.300E-02	2.300E-03	4.000E-04	3.000E-04
Mercury	1.000E+00	1.000E-01	4.700E-04	1.000E-02
Arsenic	4.000E-02	4.000E-03	6.000E-05	2.000E-03
Beryllium	1.000E-02	1.000E-03	9.000E-07	1.000E-03
Cadmium	5.500E-01	5.500E-02	1.000E-03	5.500E-04
Chromium-VI	7.500E-03	7.500E-04	1.500E-03	5.500E-03
Copper	4.000E-01	4.000E-02	1.500E-03	1.000E-02
Nickel	6.000E-02	6.000E-03	1.000E-03	6.000E-03
Silver	4.000E-01	4.000E-02	2.000E-02	3.000E-03
Zinc	9.900E-01	9.900E-02	0.000E+00	1.000E-01

***** PEAK CONCENTRATIONS AND TIMES FOR PATHWAY 1 *****
***** RIVER AT 476.0 M *****

CONTAMINANT	PEAK CONCENTRATION (MG/L)	PEAK TIME (YR)	AVERAGE DOSE AT PEAK TIME (MG/KG-DAY)	AVERAGE RISK AT PEAK TIME (HE/LIFE)	FRACTION OF ADI

Antimony	1.56E-01	21412.9	4.47E-03		1.12E+01
Barium	5.43E-02	57567.0	1.57E-03		7.83E-03
Boron	9.17E-01	3598.0	2.68E-02		1.34E-01
Chromium-III	2.92E-01	11036.1	8.90E-03		
Lead	2.99E-02	104098.0	8.63E-04		
Manganese	1.50E-02	196579.0	4.31E-04		3.08E-03
Molybdenum	1.48E-01	22501.4	4.34E-03		8.69E-01
Selenium	1.97E-01	17059.1	1.01E-02		2.02E+00
Strontium	2.18E-01	5994.6	6.77E-03		1.13E-02
Tin	1.08E+00	3108.2	3.35E-02		5.58E-02
Vanadium	2.99E-02	104098.0	8.74E-04		1.75E-01
U-233	5.15E-02	31886.3	1.49E-03		4.95E-01
U-234	5.41E-02	32748.1	1.56E-03		5.20E-01
U-235	5.97E-02	49639.2	1.72E-03		5.74E-01
U-236	5.96E-02	41366.0	1.72E-03		5.73E-01
U-238	5.97E-02	52396.9	1.72E-03		5.74E-01
Mercury	5.17E-03	568826.6	1.59E-04		5.31E-01
Arsenic	1.03E-01	32297.3	2.98E-03		9.94E+00
Beryllium	3.80E-03	774542.3	1.10E-04		5.48E-02
Cadmium	3.99E-02	78247.4	1.16E-03		2.32E+00
Chromium-VI	2.92E-01	11036.1	8.82E-03		2.94E+00
Copper	8.51E-02	38828.0	2.65E-03		6.61E-02
Nickel	4.60E-02	67907.2	1.39E-03		6.93E-02
Silver	3.50E-01	9278.2	1.22E-02		2.43E+00
Zinc	4.82E-02	64805.2	2.34E-03		7.81E-03

***** PEAK CONCENTRATIONS AND TIMES FOR PATHWAY 2 *****
***** WELL AT .0 M *****

CONTAMINANT	PEAK CONCENTRATION (MG/L)	PEAK TIME (YR)	AVERAGE DOSE AT PEAK TIME (MG/KG-DAY)	AVERAGE RISK AT PEAK TIME (HE/LIFE)	FRACTION OF ADI
Antimony	1.31E+01	16580.3	3.75E-01		9.38E+02
Barium	4.58E+00	46713.5	1.31E-01		6.54E-01
Boron	7.73E+01	3187.7	2.21E+00		1.10E+01
Chromium-III	2.46E+01	9047.0	7.04E-01		
Lead	2.52E+00	84380.1	7.21E-02		
Manganese	1.26E+00	168083.6	3.61E-02		2.58E-01
Molybdenum	1.25E+01	17417.3	3.57E-01		7.13E+01
Selenium	1.66E+01	13232.1	4.73E-01		9.47E+01
Strontium	1.84E+01	5966.6	5.25E-01		8.75E-01
Tin	9.12E+01	2769.2	2.61E+00		4.34E+00
Vanadium	2.52E+00	84380.1	7.21E-02		1.44E+01
U-233	4.50E+00	23922.2	1.29E-01		4.29E+01
U-234	4.67E+00	24453.8	1.34E-01		4.45E+01
U-235	5.03E+00	38275.5	1.44E-01		4.79E+01
U-236	5.03E+00	31896.3	1.44E-01		4.79E+01
U-238	5.03E+00	42528.4	1.44E-01		4.79E+01
Mercury	4.36E-01	437541.1	1.25E-02		4.15E+01
Arsenic	8.64E+00	24950.6	2.47E-01		8.23E+02
Beryllium	3.20E-01	595740.6	9.15E-03		4.57E+00
Cadmium	3.36E+00	63454.2	9.60E-02		1.92E+02
Chromium-VI	2.46E+01	9047.0	7.04E-01		2.35E+02
Copper	7.17E+00	29972.8	2.05E-01		5.12E+00
Nickel	3.88E+00	55083.9	1.11E-01		5.54E+00
Silver	2.95E+01	7624.0	8.43E-01		1.69E+02
Zinc	4.06E+00	52572.8	1.16E-01		3.87E-01

3.2.2.2 Remaining Contaminants of Concern (Organics)

FILE=PATHHAZ-Org-1-Child.OUT (run to get surface water EU for child)

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PATHRAE-HAZ(PC)  Version 2.3d  January 1997
   Date:  1- 6-2016
   Time: 12: 2:46

 pWAC HAZ - Organics-1 – Nov 2015 EMDF in UBCV
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TOTAL EQUIVALENT UPTAKE FACTORS FOR PATHRAE

CONTAMINANT	UT(J,1) RIVER L/YR	UT(J,2) WELL L/YR	UT(J,3) EROSION L/YR	UT(J,4) BATHTUB L/YR	UT(J,5) SPILLAGE L/YR	UT(J,6) FOOD KG/YR
24-D	3.660E+02	3.650E+02	3.660E+02	3.660E+02	3.660E+02	2.266E+00
245-TP(silvex)	3.672E+02	3.650E+02	3.672E+02	3.672E+02	3.672E+02	4.250E-01
Acenaphthene	3.691E+02	3.650E+02	3.691E+02	3.692E+02	3.692E+02	2.962E-01
Acenaphthylene	3.668E+02	3.650E+02	3.668E+02	3.668E+02	3.668E+02	5.182E-01
Acetone	3.660E+02	3.650E+02	3.660E+02	3.660E+02	3.660E+02	2.251E+01
Acentonitrile	3.660E+02	3.650E+02	3.660E+02	3.660E+02	3.660E+02	1.039E+02
acetophenone	3.660E+02	3.650E+02	3.660E+02	3.660E+02	3.660E+02	6.760E+00
Acrolien	3.660E+02	3.650E+02	3.660E+02	3.660E+02	3.660E+02	7.445E+01
Acylonitrle	3.660E+02	3.650E+02	3.660E+02	3.660E+02	3.660E+02	4.675E+01
Aldrin	3.661E+02	3.650E+02	3.661E+02	3.665E+02	3.666E+02	1.220E+00
Aroclor1221	3.679E+02	3.650E+02	3.679E+02	3.680E+02	3.681E+02	3.501E-01
Aroclor1232	3.662E+02	3.650E+02	3.662E+02	3.663E+02	3.663E+02	9.491E-01
Benzene	3.660E+02	3.650E+02	3.660E+02	3.660E+02	3.660E+02	1.010E+00
Benzoic-acid	3.660E+02	3.650E+02	3.660E+02	3.660E+02	3.660E+02	5.203E+00
Benzyl-alcohol	3.660E+02	3.650E+02	3.660E+02	3.660E+02	3.660E+02	1.507E+01
benzidine	3.660E+02	3.650E+02	3.660E+02	3.662E+02	3.662E+02	1.161E+01
Alpha-BHC	3.672E+02	3.650E+02	3.672E+02	3.672E+02	3.672E+02	4.250E-01
Beta-BHC	3.675E+02	3.650E+02	3.675E+02	3.675E+02	3.675E+02	3.776E-01
Delta-BHC	3.661E+02	3.650E+02	3.661E+02	3.661E+02	3.661E+02	1.579E+00
Bromodichloro	3.660E+02	3.650E+02	3.660E+02	3.660E+02	3.660E+02	3.993E+00
Bromoform	3.660E+02	3.650E+02	3.660E+02	3.660E+02	3.660E+02	2.611E+00
Bromometh	3.660E+02	3.650E+02	3.660E+02	3.660E+02	3.660E+02	1.334E+01
butylbenzene	3.665E+02	3.650E+02	3.665E+02	3.665E+02	3.665E+02	6.465E-01
Carbazole	3.670E+02	3.650E+02	3.670E+02	3.670E+02	3.670E+02	4.715E-01
CarbonDiS	3.660E+02	3.650E+02	3.660E+02	3.660E+02	3.660E+02	3.475E+00
Carbontetchl	3.661E+02	3.650E+02	3.661E+02	3.661E+02	3.661E+02	5.119E-01
Chlordane	4.149E+02	3.650E+02	4.149E+02	4.150E+02	4.151E+02	3.328E-01
Chlorobenzene	3.661E+02	3.650E+02	3.661E+02	3.661E+02	3.661E+02	1.579E+00
Chloroform	3.660E+02	3.650E+02	3.660E+02	3.660E+02	3.660E+02	1.217E+00
Chlorometh	3.660E+02	3.650E+02	3.660E+02	3.660E+02	3.660E+02	1.905E+01
0-ChloroTu	3.664E+02	3.650E+02	3.664E+02	3.664E+02	3.664E+02	7.478E-01
m-cresol	3.660E+02	3.650E+02	3.660E+02	3.660E+02	3.660E+02	4.511E+00
o-cresol	3.660E+02	3.650E+02	3.660E+02	3.660E+02	3.660E+02	5.203E+00
p-cresol	3.660E+02	3.650E+02	3.660E+02	3.660E+02	3.660E+02	5.203E+00
Cumene	3.665E+02	3.650E+02	3.665E+02	3.665E+02	3.665E+02	6.465E-01
Cyanide	3.660E+02	3.650E+02	3.660E+02	3.665E+02	3.665E+02	1.507E+01
DDD	4.644E+02	3.650E+02	4.644E+02	4.645E+02	4.645E+02	4.006E-01
DDE	4.452E+02	3.650E+02	4.452E+02	4.452E+02	4.452E+02	3.899E-01
Dinbutylphthalat	4.283E+02	3.650E+02	4.283E+02	4.283E+02	4.283E+02	9.226E-02
Dibenz[ah]	1.350E+03	3.650E+02	1.350E+03	1.351E+03	1.356E+03	1.010E+00
Dibenzofuran	3.680E+02	3.650E+02	3.680E+02	3.681E+02	3.682E+02	3.307E-01
Dibromochloro	3.660E+02	3.650E+02	3.660E+02	3.660E+02	3.660E+02	3.475E+00
12Dichloro	3.664E+02	3.650E+02	3.664E+02	3.664E+02	3.664E+02	7.478E-01
13Dichloro	3.666E+02	3.650E+02	3.666E+02	3.666E+02	3.666E+02	5.817E-01
14Dichlorobenzen	3.664E+02	3.650E+02	3.664E+02	3.664E+02	3.664E+02	7.478E-01
12cisDichloro	3.660E+02	3.650E+02	3.660E+02	3.660E+02	3.660E+02	5.203E+00
12transDichl	3.660E+02	3.650E+02	3.660E+02	3.660E+02	3.660E+02	3.463E+01
Dichlorodiflo	3.660E+02	3.650E+02	3.660E+02	3.660E+02	3.660E+02	3.475E+00
12Dichlprop	3.660E+02	3.650E+02	3.660E+02	3.660E+02	3.660E+02	4.511E+00
Dieldrin	4.732E+02	3.650E+02	4.730E+02	4.732E+02	4.732E+02	2.392E+00

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  Diethylphth        3.660E+02 3.650E+02 3.660E+02 3.660E+02 3.660E+02 2.266E+00
  12DiMethylB        3.662E+02 3.650E+02 3.662E+02 3.662E+02 3.662E+02 1.069E+00
  24-Dimethylphe     3.660E+02 3.650E+02 3.660E+02 3.660E+02 3.660E+02 3.130E+00
  Dimethylphth       3.660E+02 3.650E+02 3.660E+02 3.660E+02 3.660E+02 7.798E+00
  24Dinitrotoluene   3.660E+02 3.650E+02 3.660E+02 3.660E+02 3.660E+02 4.511E+00
  26Dinitrotoluene   3.660E+02 3.650E+02 3.660E+02 3.660E+02 3.660E+02 6.760E+00
  EndosulfanII       3.665E+02 3.650E+02 3.665E+02 3.665E+02 3.665E+02 6.143E-01
  Endrin             3.721E+02 3.650E+02 3.721E+02 3.721E+02 3.721E+02 2.609E-01
  Aldehyde           3.721E+02 3.650E+02 3.721E+02 3.721E+02 3.721E+02 2.609E-01
  Ketone             3.721E+02 3.650E+02 3.721E+02 3.721E+02 3.721E+02 2.609E-01
  Ethylbenz          3.662E+02 3.650E+02 3.662E+02 3.662E+02 3.662E+02 1.084E+00
  Ethylchlorid       3.660E+02 3.650E+02 3.660E+02 3.660E+02 3.660E+02 1.022E+01
  Heptachlor         3.691E+02 3.650E+02 3.691E+02 3.691E+02 3.692E+02 2.962E-01
  Heptachlor-epoxd   4.051E+02 3.650E+02 4.051E+02 4.051E+02 4.051E+02 3.075E-01
  Hexachlorobenzen   3.971E+02 3.650E+02 3.971E+02 3.972E+02 3.972E+02 2.913E-01
  Hexachloroethane   3.672E+02 3.650E+02 3.672E+02 3.672E+02 3.672E+02 4.250E-01
  Nhexane            3.672E+02 3.650E+02 3.672E+02 3.672E+02 3.672E+02 4.250E-01
  1hexanol           3.660E+02 3.650E+02 3.660E+02 3.660E+02 3.660E+02 1.022E+01
  2hexanone          3.660E+02 3.650E+02 3.660E+02 3.660E+02 3.660E+02 1.022E+01
  Isophorone         3.661E+02 3.650E+02 3.660E+02 3.661E+02 3.661E+02 8.379E-01
  Lindane            3.668E+02 3.650E+02 3.668E+02 3.668E+02 3.668E+02 5.182E-01
  Methonal           3.661E+02 3.650E+02 3.660E+02 3.661E+02 3.661E+02 1.905E+02
  Methchloride       0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
  Methylcyclo        3.661E+02 3.650E+02 3.661E+02 3.661E+02 3.661E+02 1.459E+00
  MethylIso          3.660E+02 3.650E+02 3.660E+02 3.660E+02 3.660E+02 1.334E+01
  MMetacrylate       3.660E+02 3.650E+02 3.660E+02 3.660E+02 3.660E+02 1.161E+01
  MethylEthylB       3.665E+02 3.650E+02 3.665E+02 3.665E+02 3.665E+02 6.465E-01
  2Methylnaptha      3.672E+02 3.650E+02 3.672E+02 3.672E+02 3.672E+02 4.250E-01
  MethylPropylB      3.665E+02 3.650E+02 3.665E+02 3.665E+02 3.665E+02 6.465E-01
  Naphthalene        3.663E+02 3.650E+02 3.663E+02 3.664E+02 3.664E+02 8.304E-01
  4Nitrobenzenamin   3.660E+02 3.650E+02 3.660E+02 3.660E+02 3.660E+02 1.178E+01
  Nitrobenzene       3.660E+02 3.650E+02 3.660E+02 3.660E+02 3.660E+02 5.895E+00
  2Nitrophenol       3.660E+02 3.650E+02 3.660E+02 3.660E+02 3.660E+02 6.241E+00
  4Nitrophenol       3.660E+02 3.650E+02 3.660E+02 3.660E+02 3.660E+02 5.203E+00
  NnitroNpropyl      3.660E+02 3.650E+02 3.660E+02 3.660E+02 3.660E+02 1.022E+01
  NNitrosodiphen     3.662E+02 3.650E+02 3.662E+02 3.662E+02 3.662E+02 1.084E+00
  Phenol             3.660E+02 3.650E+02 3.660E+02 3.660E+02 3.660E+02 8.836E+00
  PropylB            3.665E+02 3.650E+02 3.665E+02 3.665E+02 3.665E+02 6.465E-01
  PropGlycol         3.662E+02 3.650E+02 3.662E+02 3.662E+02 3.662E+02 6.406E+02
  Pyridine           3.660E+02 3.650E+02 3.660E+02 3.660E+02 3.660E+02 1.161E+01
  Styrene            3.661E+02 3.650E+02 3.661E+02 3.661E+02 3.661E+02 1.391E+00
  1112Tetra          3.661E+02 3.650E+02 3.661E+02 3.661E+02 3.661E+02 1.220E+00
  1122Tetra          3.660E+02 3.650E+02 3.660E+02 3.660E+02 3.660E+02 2.611E+00
  Tetrachloroethen   3.661E+02 3.650E+02 3.661E+02 3.661E+02 3.661E+02 5.286E-01
  2346Tetrachlor     3.679E+02 3.650E+02 3.679E+02 3.681E+02 3.682E+02 3.501E-01
  Toluene            3.662E+02 3.650E+02 3.662E+02 3.662E+02 3.662E+02 4.605E-01
  124Trichlorb       3.669E+02 3.650E+02 3.669E+02 3.671E+02 3.671E+02 3.760E+01
  Trichloroethene    3.661E+02 3.650E+02 3.661E+02 3.661E+02 3.661E+02 7.174E-01
  TriChloFlo         3.660E+02 3.650E+02 3.660E+02 3.660E+02 3.660E+02 2.266E+00

**********  Image of Input Files  **********

-- Input File:  ABCDEF.DAT
pWAC HAZ - Organics-1 – Nov 2015 EMDF in UBCV
10, 0., 500.,600.,700.,800.,900.,1000.,1100.,1300.,1500.
99,0,2
1,2, 2,3,
0.0, 243.19, 427., 7.36E+05, 1., 476., 0.
1800., 47.6, 0., 0., 0.856, 0., 0.315, 0.
20, 2, 0, 1, 1, 0
3.35, 16.16, 1.68E+06, 0., 0., 1600., 0.40, 0.705, 0.90, 1.
1.0E-7, 8000., 0.705, 200., 1.0E+00, 0.01
240., 5.56E-04, 0.22, 0.02, 3.0E-4, 20., 0.01
4, 6.3, 0.23, 0., 1.1E-06, 0.01, 0., 0., 0., 0., 0.
0, 0, 0, 0, 0, 0, 0
1, 0, 0, 1
0.0109, 21.3, 0.04, 6.7, 0.000, 24.0, 0.00001, 1.0, 0., 0.438

-- Input File:  BRCDCF.DAT
501,24-D             0.00E+00,1.00E-02,0.00E+00,0.00E+00
502,245-TP(silvex)   0.00E+00,8.00E-03,0.00E+00,0.00E+00
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503,Acenaphthene      0.00E+00,6.00E-02,0.00E+00,0.00E+00
504,Acenaphthylene    0.00E+00,6.00E-02,0.00E+00,0.00E+00
505,Acetone           0.00E+00,9.00E-01,0.00E+00,0.00E+00
506,Acentonitrile     0.00E+00,0.00E+00,0.00E+00,0.00E+00
507,acetophenone      0.00E+00,1.00E-01,0.00E+00,0.00E+00
508,Acrolien          0.00E+00,5.00E-04,0.00E+00,0.00E+00
509,Acylonitrle       5.40E-01,4.00E-02,0.00E+00,0.00E+00
510,Aldrin            1.70E+01,3.00E-05,0.00E+00,0.00E+00
513,Aroclor1221       2.00E+00,0.00E+00,0.00E+00,0.00E+00
514,Aroclor1232       2.00E+00,0.00E+00,0.00E+00,0.00E+00
520,Benzene           5.50E-02,4.00E-03,0.00E+00,0.00E+00
526,Benzoic-acid      0.00E+00,4.00E+00,0.00E+00,0.00E+00
527,Benzyl-alcohol    0.00E+00,1.00E-01,0.00E+00,0.00E+00
528,benzidine         2.30E+02,3.00E-03,0.00E+00,0.00E+00
529,Alpha-BHC         6.30E+00,8.00E-03,0.00E+00,0.00E+00
530,Beta-BHC          1.80E+00,0.00E+00,0.00E+00,0.00E+00
531,Delta-BHC         1.80E+00,0.00E+00,0.00E+00,0.00E+00
533,Bromodichloro     6.20E-02,2.00E-02,0.00E+00,0.00E+00
534,Bromoform         7.90E-03,2.00E-02,0.00E+00,0.00E+00
535,Bromometh         0.00E+00,1.40E-03,0.00E+00,0.00E+00
537,butylbenzene      0.00E+00,5.00E-02,0.00E+00,0.00E+00
539,Carbazole         2.00E-02,0.00E+00,0.00E+00,0.00E+00
540,CarbonDiS         0.00E+00,1.00E-01,0.00E+00,0.00E+00
541,Carbontetchl      7.00E-02,4.00E-03,0.00E+00,0.00E+00
542,Chlordane         3.50E-01,5.00E-04,0.00E+00,0.00E+00
543,Chlorobenzene     0.00E+00,2.00E-02,0.00E+00,0.00E+00
544,Chloroform        3.10E-02,1.00E-02,0.00E+00,0.00E+00
545,Chlorometh        0.00E+00,0.00E+00,0.00E+00,0.00E+00
548,0-ChloroTu        0.00E+00,2.00E-02,0.00E+00,0.00E+00
550,m-cresol          0.00E+00,5.00E-02,0.00E+00,0.00E+00
551,o-cresol          0.00E+00,5.00E-02,0.00E+00,0.00E+00
552,p-cresol          0.00E+00,1.00E-01,0.00E+00,0.00E+00
553,Cumene            0.00E+00,1.00E-01,0.00E+00,0.00E+00
554,Cyanide           0.00E+00,6.00E-04,0.00E+00,0.00E+00
555,DDD               2.40E-01,0.00E+00,0.00E+00,0.00E+00
556,DDE               3.40E-01,0.00E+00,0.00E+00,0.00E+00
558,Dinbutylphthalat  0.00E+00,1.00E-01,0.00E+00,0.00E+00
560,Dibenz[ah]        7.30E+00,0.00E+00,0.00E+00,0.00E+00
561,Dibenzofuran      0.00E+00,1.00E-03,0.00E+00,0.00E+00
562,Dibromochloro     8.40E-02,2.00E-02,0.00E+00,0.00E+00
563,12Dichloro        0.00E+00,9.00E-02,0.00E+00,0.00E+00
564,13Dichloro        0.00E+00,8.90E-02,0.00E+00,0.00E+00
565,14Dichlorobenzen  5.40E-03,7.00E-02,0.00E+00,0.00E+00
571,12cisDichloro     0.00E+00,2.00E-03,0.00E+00,0.00E+00
572,12transDichl      0.00E+00,2.00E-02,0.00E+00,0.00E+00
573,Dichlorodiflo     0.00E+00,2.00E-01,0.00E+00,0.00E+00
574,12Dichlprop       3.60E-02,9.00E-02,0.00E+00,0.00E+00
575,Dieldrin          1.60E+01,5.00E-05,0.00E+00,0.00E+00
576,Diethylphth       0.00E+00,8.00E-01,0.00E+00,0.00E+00
577,12DiMethylB       0.00E+00,2.00E-01,0.00E+00,0.00E+00
579,24-Dimethylphe    0.00E+00,2.00E-02,0.00E+00,0.00E+00
580,Dimethylphth      0.00E+00,1.00E+01,0.00E+00,0.00E+00
582,24Dinitrotoluene  3.10E-01,2.00E-03,0.00E+00,0.00E+00
583,26Dinitrotoluene  0.00E+00,1.00E-03,0.00E+00,0.00E+00
585,EndosulfanII      0.00E+00,6.00E-03,0.00E+00,0.00E+00
586,Endrin            0.00E+00,3.00E-04,0.00E+00,0.00E+00
587,Aldehyde          0.00E+00,3.00E-04,0.00E+00,0.00E+00
588,Ketone            0.00E+00,3.00E-04,0.00E+00,0.00E+00
589,Ethylbenz         1.10E-02,1.00E-01,0.00E+00,0.00E+00
590,Ethylchlorid      0.00E+00,0.00E+00,0.00E+00,0.00E+00
593,Heptachlor        4.50E+00,5.00E-04,0.00E+00,0.00E+00
594,Heptachlor-epoxd  9.10E+00,1.30E-05,0.00E+00,0.00E+00
595,Hexachlorobenzen  1.60E+00,8.00E-04,0.00E+00,0.00E+00
596,Hexachloroethane  4.00E-02,7.00E-04,0.00E+00,0.00E+00
597,Nhexane           0.00E+00,6.00E-02,0.00E+00,0.00E+00
598,1hexanol          0.00E+00,4.00E-02,0.00E+00,0.00E+00
599,2hexanone         0.00E+00,5.00E-03,0.00E+00,0.00E+00
601,Isophorone        9.50E-04,2.00E-01,0.00E+00,0.00E+00
602,Lindane           1.10E+00,3.00E-04,0.00E+00,0.00E+00
603,Methonal          0.00E+00,5.00E-01,0.00E+00,0.00E+00
605,Methchloride      2.00E-03,6.00E-03,0.00E+00,0.00E+00
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606,Methylcyclo      0.00E+00,6.00E-02,0.00E+00,0.00E+00
607,MethylIso        0.00E+00,8.00E-02,0.00E+00,0.00E+00
608,MMetacrylate     0.00E+00,1.40E+00,0.00E+00,0.00E+00
609,MethylEthylB     0.00E+00,3.70E-02,0.00E+00,0.00E+00
610,2Methylnaptha    0.00E+00,4.00E-03,0.00E+00,0.00E+00
611,MethylPropylB    0.00E+00,3.70E-02,0.00E+00,0.00E+00
612,Naphthalene      0.00E+00,2.00E-02,0.00E+00,0.00E+00
614,4Nitrobenzenamin 2.00E-02,4.00E-03,0.00E+00,0.00E+00
615,Nitrobenzene     0.00E+00,2.00E-03,0.00E+00,0.00E+00
616,2Nitrophenol     0.00E+00,6.20E-02,0.00E+00,0.00E+00
617,4Nitrophenol     0.00E+00,6.20E-02,0.00E+00,0.00E+00
618,NnitroNpropyl    7.00E+00,0.00E+00,0.00E+00,0.00E+00
619,NNitrosodiphen   4.90E-03,0.00E+00,0.00E+00,0.00E+00
622,Phenol           0.00E+00,3.00E-01,0.00E+00,0.00E+00
623,PropylB          0.00E+00,3.70E-02,0.00E+00,0.00E+00
624,PropGlycol       0.00E+00,2.00E+01,0.00E+00,0.00E+00
626,Pyridine         0.00E+00,1.00E-03,0.00E+00,0.00E+00
627,Styrene          0.00E+00,2.00E-01,0.00E+00,0.00E+00
628,1112Tetra        2.60E-02,3.00E-02,0.00E+00,0.00E+00
629,1122Tetra        2.00E-01,2.00E-02,0.00E+00,0.00E+00
630,Tetrachloroethen 2.10E-03,6.00E-03,0.00E+00,0.00E+00
631,2346Tetrachlor   0.00E+00,3.00E-02,0.00E+00,0.00E+00
632,Toluene          0.00E+00,8.00E-02,0.00E+00,0.00E+00
634,124Trichlorb     2.90E-02,1.00E-02,0.00E+00,0.00E+00
637,Trichloroethene  4.60E-02,5.00E-04,0.00E+00,0.00E+00
639,TriChloFlo       0.00E+00,3.00E-01,0.00E+00,0.00E+00

-- Input File:  INVNTRY.DAT
501,  1.00E+10, 1.680E+06,         0,          0, 6.820E+02,         0,         24-D
502,  1.00E+10, 1.680E+06,         0,          0, 2.000E+02,         0,         245-TP(silvex)
503,  1.00E+10, 1.680E+06,         0,          0, 3.420E+00,         0,         Acenaphthene
504,  1.00E+10, 1.680E+06,         0,          0, 1.610E+01,         0,         Acenaphthylene
505,  1.00E+10, 1.680E+06,         0,          0, 0.000E+00,         0,         Acetone
506,  1.00E+10, 1.680E+06,         0,          0, 1.000E+06,         0,         Acentonitrile
507,  1.00E+10, 1.680E+06,         0,          0, 6.130E+03,         0,         acetophenone
508,  1.00E+10, 1.680E+06,         0,          0, 1.200E+04,         0,         Acrolien
509,  1.00E+10, 1.680E+06,         0,          0, 7.450E+04,         0,         Acylonitrle
510,  1.00E+10, 1.680E+06,         0,          0, 1.700E-02,         0,         Aldrin
513,  1.00E+10, 1.680E+06,         0,          0, 4.830E+00,         0,         Aroclor1221
514,  1.00E+10, 1.680E+06,         0,          0, 4.830E+00,         0,         Aroclor1232
520,  1.00E+10, 1.680E+06,         0,          0, 0.000E+00,         0,         Benzene
526,  1.00E+10, 1.680E+06,         0,          0, 3.400E+03,         0,         Benzolic
527,  1.00E+10, 1.680E+06,         0,          0, 4.290E+04,         0,         Benzyl
528,  1.00E+10, 1.680E+06,         0,          0, 3.220E+02,         0,         benzidine
529,  1.00E+10, 1.680E+06,         0,          0, 8.000E+00,         0,         Alpha-BHC
530,  1.00E+10, 1.680E+06,         0,          0, 8.000E+00,         0,         Beta-BHC
531,  1.00E+10, 1.680E+06,         0,          0, 8.000E+00,         0,         Delta-BHC
533,  1.00E+10, 1.680E+06,         0,          0, 3.030E+03,         0,         Bromodichloro
534,  1.00E+10, 1.680E+06,         0,          0, 1.000E+02,         0,         Bromoform
535,  1.00E+10, 1.680E+06,         0,          0, 5.200E+03,         0,         Bromometh
537,  1.00E+10, 1.680E+06,         0,          0, 6.130E+01,         0,         butylbenzene
539,  1.00E+10, 1.680E+06,         0,          0, 1.800E+00,         0,         Carbazole
540,  1.00E+10, 1.680E+06,         0,          0, 1.180E+03,         0,         CarbonDiS
541,  1.00E+10, 1.680E+06,         0,          0, 0.000E+00,         0,         Carbontetchl
542,  1.00E+10, 1.680E+06,         0,          0, 5.600E-02,         0,         Chlordane
543,  1.00E+10, 1.680E+06,         0,          0, 4.980E+02,         0,         Chlorobenzene
544,  1.00E+10, 1.680E+06,         0,          0, 0.000E+00,         0,         Chloroform
545,  1.00E+10, 1.680E+06,         0,          0, 5.320E+03,         0,         Chlorometh
548,  1.00E+10, 1.680E+06,         0,          0, 3.740E+02,         0,         0-ChloroTu
550,  1.00E+10, 1.680E+06,         0,          0, 2.270E+04,         0,         m-cresol
551,  1.00E+10, 1.680E+06,         0,          0, 2.590E+04,         0,         o-cresol
552,  1.00E+10, 1.680E+06,         0,          0, 2.150E+04,         0,         p-cresol
553,  1.00E+10, 1.680E+06,         0,          0, 6.130E+01,         0,         Cumene
554,  1.00E+10, 1.680E+06,         0,          0, 1.000E+06,         0,         Cyanide
555,  1.00E+10, 1.680E+06,         0,          0, 9.000E-02,         0,         DDD
556,  1.00E+10, 1.680E+06,         0,          0, 4.000E-02,         0,         DDE
558,  1.00E+10, 1.680E+06,         0,          0, 0.000E+00,         0,         Dinbutylphthalat
560,  1.00E+10, 1.680E+06,         0,          0, 1.030E-03,         0,         Dibenz[ah]
561,  1.00E+10, 1.680E+06,         0,          0, 3.100E+00,         0,         Dibenzofuran
562,  1.00E+10, 1.680E+06,         0,          0, 2.700E+03,         0,         Dibromochloro
563,  1.00E+10, 1.680E+06,         0,          0, 8.000E+01,         0,         12Dichloro
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564,  1.00E+10, 1.680E+06,         0,          0, 1.250E+02,         0,         13Dichloro
565,  1.00E+10, 1.680E+06,         0,          0, 8.130E+01,         0,         14Dichlorobenzen
571,  1.00E+10, 1.680E+06,         0,          0, 3.500E+03,         0,         12cisDichloro
572,  1.00E+10, 1.680E+06,         0,          0, 3.500E+03,         0,         12transDichl
573,  1.00E+10, 1.680E+06,         0,          0, 2.800E+02,         0,         Dichlorodiflo
574,  1.00E+10, 1.680E+06,         0,          0, 2.800E+03,         0,         12Dichlprop
575,  1.00E+10, 1.680E+06,         0,          0, 0.000E+00,         0,         Dieldrin
576,  1.00E+10, 1.680E+06,         0,          0, 1.080E+03,         0,         Diethylphth
577,  1.00E+10, 1.680E+06,         0,          0, 2.200E+02,         0,         12DiMethylB
579,  1.00E+10, 1.680E+06,         0,          0, 7.870E+03,         0,         24-Dimethylphe
580,  1.00E+10, 1.680E+06,         0,          0, 4.000E+03,         0,         Dimethylphth
582,  1.00E+10, 1.680E+06,         0,          0, 2.700E+02,         0,         24Dinitrotoluene
583,  1.00E+10, 1.680E+06,         0,          0, 3.520E+02,         0,         26Dinitrotoluene
585,  1.00E+10, 1.680E+06,         0,          0, 4.500E-01,         0,         EndosufanII
586,  1.00E+10, 1.680E+06,         0,          0, 2.500E-01,         0,         Endrin
587,  1.00E+10, 1.680E+06,         0,          0, 2.500E-01,         0,         Aldehyde
588,  1.00E+10, 1.680E+06,         0,          0, 2.500E-01,         0,         Ketone
589,  1.00E+10, 1.680E+06,         0,          0, 1.690E+02,         0,         Ethylbenz
590,  1.00E+10, 1.680E+06,         0,          0, 6.700E+03,         0,         Ethylchlorid
593,  1.00E+10, 1.680E+06,         0,          0, 1.800E-01,         0,         Heptachlor
594,  1.00E+10, 1.680E+06,         0,          0, 2.000E-01,         0,         Heptachlor
595,  1.00E+10, 1.680E+06,         0,          0, 6.200E-03,         0,         Hexachlorobenzen
596,  1.00E+10, 1.680E+06,         0,          0, 5.000E+01,         0,         Hexachloroethane
597,  1.00E+10, 1.680E+06,         0,          0, 9.500E+00,         0,         Nhexane
598,  1.00E+10, 1.680E+06,         0,          0, 5.900E+03,         0,         1hexanol
599,  1.00E+10, 1.680E+06,         0,          0, 5.900E+03,         0,         2hexanone
601,  1.00E+10, 1.680E+06,         0,          0, 0.000E+00,         0,         Isophorone
602,  1.00E+10, 1.680E+06,         0,          0, 8.000E+00,         0,         Lindane
603,  1.00E+10, 1.680E+06,         0,          0, 1.000E+06,         0,         Methonal
605,  1.00E+10, 1.680E+06,         0,          0, 1.300E+04,         0,         Methchloride
606,  1.00E+10, 1.680E+06,         0,          0, 1.400E+01,         0,         Methylcyclo
607,  1.00E+10, 1.680E+06,         0,          0, 1.900E+04,         0,         MethylIso
608,  1.00E+10, 1.680E+06,         0,          0, 1.500E+04,         0,         MMetacrylate
609,  1.00E+10, 1.680E+06,         0,          0, 6.100E+01,         0,         MethylEthylB
610,  1.00E+10, 1.680E+06,         0,          0, 2.460E+01,         0,         2Methylnaptha
611,  1.00E+10, 1.680E+06,         0,          0, 6.100E+01,         0,         MethylPropylB
612,  1.00E+10, 1.680E+06,         0,          0, 0.000E+00,         0,         Naphthalene
614,  1.00E+10, 1.680E+06,         0,          0, 1.070E-05,         0,         4Nitrobenzenamin
615,  1.00E+10, 1.680E+06,         0,          0, 2.090E+03,         0,         Nitrobenzene
616,  1.00E+10, 1.680E+06,         0,          0, 2.500E+03,         0,         2Nitrophenol
617,  1.00E+10, 1.680E+06,         0,          0, 1.160E+04,         0,         4Nitrophenol
618,  1.00E+10, 1.680E+06,         0,          0, 0.000E+00,         0,         NnitroNpropyl
619,  1.00E+10, 1.680E+06,         0,          0, 3.500E+01,         0,         NNitrosodiphen
622,  1.00E+10, 1.680E+06,         0,          0, 9.300E+04,         0,         Phenol
623,  1.00E+10, 1.680E+06,         0,          0, 6.100E+01,         0,         PropylB
624,  1.00E+10, 1.680E+06,         0,          0, 1.000E+06,         0,         PropGlycol
626,  1.00E+10, 1.680E+06,         0,          0, 1.000E+06,         0,         Pyridine
627,  1.00E+10, 1.680E+06,         0,          0, 3.100E+02,         0,         Styrene
628,  1.00E+10, 1.680E+06,         0,          0, 1.070E+03,         0,         1112Tetra
629,  1.00E+10, 1.680E+06,         0,          0, 2.870E+03,         0,         1122Tetra
630,  1.00E+10, 1.680E+06,         0,          0, 0.000E+00,         0,         Tetrachloroethen
631,  1.00E+10, 1.680E+06,         0,          0, 2.300E+01,         0,         2346Tetrachlor
632,  1.00E+10, 1.680E+06,         0,          0, 0.000E+00,         0,         Toluene
634,  1.00E+10, 1.680E+06,         0,          0, 5.700E+01,         0,         124Trichlorb
637,  1.00E+10, 1.680E+06,         0,          0, 0.000E+00,         0,         Trichloroethene
639,  1.00E+10, 1.680E+06,         0,          0, 1.100E+03,         0,         TriChloFlo

-- Input File:  RQSITE.DAT
501,-5.880E-02, 5.880E-03, 5.880E-02,       24-D
502,-1.608E-01, 1.608E-02, 1.608E-01,       245-TP(silvex)
503,-9.200E+01, 9.200E+00, 9.200E+01,       Acenaphthene
504,-1.220E+01, 1.220E+00, 1.220E+01,       Acenaphthylene
505,-4.400E-02, 0.000E+00, 4.400E-02,       Acetone
506,-1.540E-03, 1.540E-04, 1.540E-03,       Acentonitrile
507,-9.240E-02, 9.240E-03, 9.240E-02,       acetophenone
508,-2.780E-03, 2.780E-04, 2.780E-03,       Acrolien
509,-4.440E-03, 4.440E-04, 4.440E-03,       Acylonitrle
510,-9.740E+01, 9.740E+00, 9.740E+01,       Aldrin
513,-1.200E+02, 1.200E+02, 1.200E+02,       Aroclor1221
514,-1.500E+01, 1.500E+01, 1.500E+01,       Aroclor1232
520,-1.700E+00, 0.000E+00, 1.700E+00,       Benzene
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526,-1.200E-03, 1.200E-04, 1.200E-03,       Benzoic
527,-3.130E-02, 3.130E-03, 3.130E-02,       Benzyl
528,-5.480E+00, 5.480E-01, 5.480E+00,       benzidine
529,-3.520E+00, 3.520E-01, 3.520E+00,       Alpha-BHC
530,-4.280E+00, 4.280E-01, 4.280E+00,       Beta-BHC
531,-4.280E+00, 4.280E-01, 4.280E+00,       Delta-BHC
533,-1.080E-02, 1.080E-03, 1.080E-02,       Bromodichloro
534,-2.520E-01, 2.520E-02, 2.520E-01,       Bromoform
535,-2.830E-02, 2.830E-03, 2.830E-02,       Bromometh
537,-1.630E+00, 1.630E-01, 1.630E+00,       butylbenzene
539,-6.780E+00, 6.780E-01, 6.780E+00,       Carbazole
540,-1.030E-01, 1.030E-02, 1.030E-01,       CarbonDiS
541,-2.200E+00, 0.000E+00, 2.200E+00,       Carbontetchl
542,-1.730E+02, 1.730E+01, 1.730E+02,       Chlordane
543,-4.380E-01, 4.380E-02, 4.380E-01,       Chlorobenzene
544,-6.200E-01, 0.000E+00, 6.200E-01,       Chloroform
545,-2.860E-02, 2.860E-03, 2.860E-02,       Chlorometh
548,-8.860E-01, 8.860E-02, 8.860E-01,       0-ChloroTu
550,-9.560E-02, 9.560E-03, 9.560E-02,       m-cresol
551,-1.820E-01, 1.820E-02, 1.820E-01,       o-cresol
552,-9.220E-02, 9.220E-03, 9.220E-02,       p-cresol
553,-1.650E+00, 1.650E-01, 1.650E+00,       Cumene
554,-9.900E+00, 9.900E-01, 9.900E+00,       Cyanide
555,-9.160E+01, 9.160E+00, 9.160E+01,       DDD
556,-1.730E+00, 1.730E-01, 1.730E+00,       DDE
558,-1.000E-06, 0.000E+00, 1.000E-06,       Dinbutylphthalat
560,-3.580E+03, 3.580E+02, 3.580E+03,       Dibenz[ah]
561,-2.260E+02, 2.260E+01, 2.260E+02,       Dibenzofuran
562,-1.410E-01, 1.410E-02, 1.410E-01,       Dibromochloro
563,-7.580E-01, 7.580E-02, 7.580E-01,       12Dichloro
564,-1.606E+01, 1.606E+00, 1.606E+01,       13Dichloro
565,-1.232E+00, 1.232E-01, 1.232E+00,       14Dichlorobenzen
571,-9.960E-01, 9.960E-02, 9.960E-01,       12cisDichloro
572,-7.600E-02, 7.600E-03, 7.600E-02,       12transDichl
573,-1.370E-02, 1.370E-03, 1.370E-02,       Dichlorodiflo
574,-9.400E-02, 9.400E-03, 9.400E-02,       12Dichlprop
575,-3.400E+01, 0.000E+00, 3.400E+01,       Dieldrin
576,-2.520E-01, 2.520E-02, 2.520E-01,       Diethylphth
577,-4.800E-01, 4.800E-02, 4.800E-01,       12DiMethylB
579,-2.520E+00, 2.520E-01, 2.520E+00,       24-Dimethlphe
580,-7.420E-02, 7.420E-03, 7.420E-02,       Dimethylphth
582,-1.020E-01, 1.020E-02, 1.020E-01,       24Dinitrotoluene
583,-8.390E-02, 8.390E-03, 8.390E-02,       26Dinitrotoluene
585,-4.080E+00, 4.080E+00, 4.080E-01,       EndosulfanII
586,-2.160E+01, 2.160E+00, 2.160E+01,       Endrin
587,-2.160E+01, 2.160E+01, 2.160E+00,       Aldehyde
588,-2.160E+01, 2.160E+01, 2.160E+00,       Ketone
589,-4.080E-01, 4.080E-02, 4.080E-01,       Ethylbenz
590,-4.750E-02, 4.750E-03, 4.750E-02,       Ethylchlorid
593,-4.800E+01, 4.800E+00, 4.800E+01,       Heptachlor
594,-1.730E+01, 1.730E+00, 1.730E+01,       Heptachlor
595,-1.100E+02, 1.100E+01, 1.100E+02,       Hexachlorobenzen
596,-3.560E+00, 3.560E-01, 3.560E+00,       Hexachloroethane
597,-2.980E-01, 2.980E-02, 2.980E-01,       Nhexane
598,-2.600E-02, 2.600E-03, 2.600E-02,       1hexanol
599,-2.600E-02, 2.600E-03, 2.600E-02,       2hexanone
601,-1.700E+00, 0.000E+00, 1.700E+00,       Isophorone
602,-6.760E+00, 6.760E-01, 6.760E+00,       Lindane
603,-2.000E-03, 2.000E-04, 2.000E-03,       Methonal
605,-2.010E+03, 0.000E+00, 2.010E+03,       Methchloride
606,-1.990E-01, 0.000E+00, 0.000E+00,       Methylcyclo
607,-4.700E-03, 4.700E-04, 4.700E-03,       MethylIso
608,-2.000E-02, 2.000E-03, 2.000E-02,       MMetacrylate
609,-1.650E+00, 1.650E-01, 1.650E+00,       MethylEthylB
610,-5.940E+00, 5.940E-01, 5.940E+00,       2Methylnaptha
611,-1.650E+00, 1.650E-01, 1.650E+00,       MethylPropylB
612,-1.900E+01, 1.900E+00, 1.900E+01,       Naphthalene
614,-3.440E-01, 3.440E-02, 3.440E-01,       4Nitrobenzenamin
615,-1.290E-01, 1.290E-02, 1.290E-01,       Nitrobenzene
616,-7.100E-01, 7.100E-02, 7.100E-01,       2Nitrophenol
617,-8.740E-01, 8.740E-02, 8.740E-01,       4Nitrophenol
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618,-3.000E-01, 3.000E-02, 3.000E-01,       NnitroNpropyl
619,-6.540E-01, 6.540E-02, 6.540E-01,       NNitrosodiphen
622,-2.800E-01, 2.800E-02, 2.800E-01,       Phenol
623,-1.650E+00, 1.650E-01, 1.650E+00,       PropylB
624,-2.000E-03, 2.000E-04, 2.000E-03,       PropGlycol
626,-1.380E-02, 1.380E-03, 1.380E-02,       Pyridine
627,-1.820E+00, 1.820E-01, 1.820E+00,       Styrene
628,-3.180E-01, 3.180E-02, 3.180E-01,       1112Tetra
629,-1.580E-01, 1.560E-02, 1.560E-01,       1122Tetra
630,-7.200E+00, 0.000E+00, 7.200E+00,       Tetrachloroethen
631,-2.490E+02, 2.490E+01, 2.490E+02,       2346Tetrachlor
632,-6.000E+00, 0.000E+00, 6.000E+00,       Toluene
634,-1.440E+00, 1.440E-01, 1.440E+00,       124Trichlorb
637,-2.600E+00, 0.000E+00, 2.600E+00,       Trichloroethene
639,-2.680E-01, 2.680E-02, 2.680E-01,       TriChloFlo
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-- Input File:  UPTAKE.DAT
0.5,   0.2,    1.89
0.67,  0.65,   2.1E-3,   438.,   438.
0.0,   2160.,  24.,     1440.,     1.,  0.83
50.,   6.,     48.,      480.,    48.
.05,  0.0008,  60.,        8.,    50.
3.,     82., 169.,        0.,    52.,   365., 0.0
24-D                 0.25,  1.30E+00,  1.30E-01,  2.50E-06,         0,  7.90E-06,  0.00E+00,        501
245-TP(silvex)       0.25,  2.10E-01,  2.10E-02,  6.30E-05,         0,  2.00E-04,  0.00E+00,        502
Acenaphthene         0.25,  1.20E-01,  1.20E-02,  1.60E-04,         0,  5.00E-04,  1.10E+03,        503
Acenaphthylene       0.25,  2.70E-01,  2.70E-02,  4.00E-05,         0,  1.30E-04,  0.00E+00,        504
Acetone              0.25,  1.30E+01,  1.30E+00,  1.50E-08,         0,  1.50E-08,  1.50E-08,        505
Acentonitrile        0.25,  6.00E+01,  6.00E+00,  3.60E-09,         0,  1.10E-08,  0.00E+00,        506
acetophenone         0.25,  3.90E+00,  3.90E-01,  4.00E-07,         0,  1.30E-06,  0.00E+00,        507
Acrolien             0.25,  4.30E+01,  4.30E+00,  6.30E-09,         0,  2.00E-08,  0.00E+00,        508
Acylonitrle          0.25,  2.70E+01,  2.70E+00,  1.40E-08,         0,  4.40E-08,  0.00E+00,        509
Aldrin               0.25,  6.90E-01,  6.90E-02,  7.90E-06,         0,  2.50E-05,  0.00E+00,        510
Aroclor1221          0.25,  1.60E-01,  1.60E-02,  9.90E-05,         0,  3.10E-04,  0.00E+00,        513
Aroclor1232          0.25,  5.30E-01,  5.30E-02,  1.30E-05,         0,  4.00E-05,  0.00E+00,        514
Benzene              0.25,  5.80E-01,  5.80E-02,  3.30E-06,         0,  3.30E-06,  3.30E-06,        520
Benzoic-acid         0.25,  3.00E+00,  3.00E-01,  6.30E-07,         0,  2.00E-06,  0.00E+00,        526
Benzyl-alcohol       0.25,  8.70E+00,  8.70E-01,  9.90E-08,         0,  3.10E-07,  0.00E+00,        527
benzidine            0.25,  6.70E+00,  6.70E-01,  1.60E-07,         0,  5.00E-07,  0.00E+00,        528
Alpha-BHC            0.25,  2.10E-01,  2.10E-02,  6.30E-05,         0,  2.00E-04,  0.00E+00,        529
Beta-BHC             0.25,  1.80E-01,  1.80E-02,  7.90E-05,         0,  2.50E-04,  0.00E+00,        530
Delta-BHC            0.25,  9.00E-01,  9.00E-02,  5.00E-06,         0,  1.60E-05,  0.00E+00,        531
Bromodichloro        0.25,  2.30E+00,  2.30E-01,  9.90E-07,         0,  3.10E-06,  0.00E+00,        533
Bromoform            0.25,  1.50E+00,  1.50E-01,  2.00E-06,         0,  6.30E-06,  0.00E+00,        534
Bromometh            0.25,  7.70E+00,  7.70E-01,  1.30E-07,         0,  4.00E-07,  0.00E+00,        535
butylbenzene         0.25,  3.50E-01,  3.50E-02,  2.50E-05,         0,  7.90E-05,  0.00E+00,        537
Carbazole            0.25,  2.40E-01,  2.40E-02,  5.00E-05,         0,  1.60E-04,  4.50E+02,        539
CarbonDiS            0.25,  2.00E+00,  2.00E-01,  1.30E-06,         0,  4.00E-06,  0.00E+00,        540
Carbontetchl         0.25,  2.90E-01,  2.90E-02,  1.10E-05,         0,  1.10E-05,  1.10E-05,        541
Chlordane            0.25,  2.50E-02,  2.50E-03,  2.50E-03,         0,  7.90E-03,  0.00E+00,        542
Chlorobenzene        0.25,  9.00E-01,  9.00E-02,  5.00E-06,         0,  1.60E-05,  0.00E+00,        543
Chloroform           0.25,  7.00E-01,  7.00E-02,  2.30E-06,         0,  2.30E-06,  2.30E-06,        544
Chlorometh           0.25,  1.10E+01,  1.10E+00,  6.40E-08,         0,  2.00E-07,  0.00E+00,        545
0-ChloroTu           0.25,  4.10E-01,  4.10E-02,  2.00E-05,         0,  6.30E-05,  0.00E+00,        548
m-cresol             0.25,  2.60E+00,  2.60E-01,  7.90E-07,         0,  2.50E-06,  0.00E+00,        550
o-cresol             0.25,  3.00E+00,  3.00E-01,  6.30E-07,         0,  2.00E-06,  0.00E+00,        551
p-cresol             0.25,  3.00E+00,  3.00E-01,  6.30E-07,         0,  2.00E-06,  0.00E+00,        552
Cumene               0.25,  3.50E-01,  3.50E-02,  2.50E-05,         0,  7.90E-05,  0.00E+00,        553
Cyanide              0.25,  8.70E+00,  8.70E-01,  9.90E-08,         0,  3.10E-07,  3.50E+00,        554
DDD                  0.25,  1.60E-02,  1.60E-03,  5.00E-03,         0,  1.60E-02,  0.00E+00,        555
DDE                  0.25,  1.90E-02,  1.90E-03,  4.00E-03,         0,  1.30E-02,  0.00E+00,        556
Dinbutylphthalat     0.25,  5.60E-03,  5.60E-04,  3.20E-03,         0,  1.00E-02,  0.00E+00,        558
Dibenz[ah]           0.25,  4.30E-03,  4.30E-04,  5.00E-02,         0,  1.60E-01,  6.30E+00,        560
Dibenzofuran         0.25,  1.50E-01,  1.50E-02,  1.00E-04,         0,  3.30E-04,  0.00E+00,        561
Dibromochloro        0.25,  2.00E+00,  2.00E-01,  1.30E-06,         0,  4.00E-06,  0.00E+00,        562
12Dichloro           0.25,  4.10E-01,  4.10E-02,  2.00E-05,         0,  6.30E-05,  8.70E+01,        563
13Dichloro           0.25,  3.10E-01,  3.10E-02,  3.10E-05,         0,  1.00E-04,  1.00E+02,        564
14Dichlorobenzen     0.25,  4.10E-01,  4.10E-02,  2.00E-05,         0,  6.30E-05,  0.00E+00,        565
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12cisDichloro        0.25,  3.00E+00,  3.00E-01,  6.30E-07,          0,  2.00E-06,  0.00E+00,          571
12transDichl         0.25,  2.00E+01,  2.00E+00,  2.40E-08,          0,  7.50E-08,  0.00E+00,          572
Dichlorodiflo        0.25,  2.00E+00,  2.00E-01,  1.30E-06,          0,  4.00E-06,  0.00E+00,          573
12Dichlprop          0.25,  2.60E+00,  2.60E-01,  7.90E-07,          0,  2.50E-06,  0.00E+00,          574
Dieldrin             0.25,  9.20E-02,  9.20E-03,  7.90E-03,          0,  7.90E-03,  7.90E-03,          575
Diethylphth          0.25,  1.30E+00,  1.30E-01,  2.50E-06,          0,  7.90E-06,  0.00E+00,          576
12DiMethylB          0.25,  6.00E-01,  6.00E-02,  1.10E-05,          0,  3.40E-05,  0.00E+00,          577
24-Dimethylphe       0.25,  1.80E+00,  1.80E-01,  1.60E-06,          0,  5.00E-06,  0.00E+00,          579
Dimethylphth         0.25,  4.50E+00,  4.50E-01,  3.10E-07,          0,  1.00E-06,  0.00E+00,          580
24Dinitrotoluene     0.25,  2.60E+00,  2.60E-01,  7.90E-07,          0,  2.50E-06,  6.40E+00,          582
26Dinitrotoluene     0.25,  3.90E+00,  3.90E-01,  4.00E-07,          0,  1.30E-06,  6.20E+00,          583
EndosulfanII         0.25,  3.30E-01,  3.30E-02,  2.80E-05,          0,  8.90E-05,  0.00E+00,          585
Endrin               0.25,  8.20E-02,  8.20E-03,  3.10E-04,          0,  1.00E-03,  0.00E+00,          586
Aldehyde             0.25,  8.20E-02,  8.20E-03,  3.10E-04,          0,  1.00E-03,  0.00E+00,          587
Ketone               0.25,  8.20E-02,  8.20E-03,  3.10E-04,          0,  1.00E-03,  0.00E+00,          588
Ethylbenz            0.25,  6.10E-01,  6.10E-02,  9.90E-06,          0,  3.10E-05,  0.00E+00,          589
Ethylchlorid         0.25,  5.90E+00,  5.90E-01,  2.00E-07,          0,  6.30E-07,  0.00E+00,          590
Heptachlor           0.25,  1.20E-01,  1.20E-02,  1.60E-04,          0,  5.00E-04,  0.00E+00,          593
Heptachlor-epoxd     0.25,  2.80E-02,  2.80E-03,  2.00E-03,          0,  6.30E-03,  0.00E+00,          594
Hexachlorobenzen     0.25,  3.20E-02,  3.20E-03,  1.60E-03,          0,  5.00E-03,  0.00E+00,          595
Hexachloroethane     0.25,  2.10E-01,  2.10E-02,  6.30E-05,          0,  2.00E-04,  0.00E+00,          596
Nhexane              0.25,  2.10E-01,  2.10E-02,  6.30E-05,          0,  2.00E-04,  0.00E+00,          597
1hexanol             0.25,  5.90E+00,  5.90E-01,  2.00E-07,          0,  6.30E-07,  0.00E+00,          598
2hexanone            0.25,  5.90E+00,  5.90E-01,  2.00E-07,          0,  6.30E-07,  0.00E+00,          599
Isophorone           0.25,  4.80E-01,  4.80E-02,  4.60E-06,          0,  4.60E-06,  4.60E-06,          601
Lindane              0.25,  2.70E-01,  2.70E-02,  4.00E-05,          0,  1.30E-04,  0.00E+00,          602
Methonal             0.25,  1.10E+02,  1.10E+01,  1.30E-09,          0,  4.20E-09,  0.00E+00,          603
MethChoride          0.25,  6.70E+00,  6.70E-01,  1.60E-07,          0,  5.00E-07,  0.00E+00,          605
Methylcyclo          0.25,  8.30E-01,  8.30E-02,  5.70E-06,          0,  1.80E-05,  1.20E+02,          606
MethylIso            0.25,  7.70E+00,  7.70E-01,  1.30E-07,          0,  4.00E-07,  0.00E+00,          607
MMetacrylate         0.25,  6.70E+00,  6.70E-01,  1.60E-07,          0,  5.00E-07,  0.00E+00,          608
MethylEthylB         0.25,  3.50E-01,  3.50E-02,  2.50E-05,          0,  7.90E-05,  0.00E+00,          609
2Methylnaptha        0.25,  2.10E-01,  2.10E-02,  6.30E-05,          0,  2.00E-04,  0.00E+00,          610
MethylPropylB        0.25,  3.50E-01,  3.50E-02,  2.50E-05,          0,  7.90E-05,  0.00E+00,          611
Naphthalene          0.25,  4.60E-01,  4.60E-02,  1.60E-05,          0,  5.00E-05,  1.90E+02,          612
4Nitrobenzenamin     0.25,  6.80E+00,  6.80E-01,  2.00E-07,          0,  6.20E-07,  9.60E+02,          614
Nitrobenzene         0.25,  3.40E+00,  3.40E-01,  5.00E-07,          0,  1.60E-06,  0.00E+00,          615
2Nitrophenol         0.25,  3.60E+00,  3.60E-01,  4.90E-07,          0,  1.60E-06,  0.00E+00,          616
4Nitrophenol         0.25,  3.00E+00,  3.00E-01,  6.30E-07,          0,  2.00E-06,  3.10E+02,          617
NnitroNpropyl        0.25,  5.90E+00,  5.90E-01,  2.00E-07,          0,  6.30E-07,  6.80E+00,          618
NNitrosodiphen       0.25,  6.10E-01,  6.10E-02,  9.90E-06,          0,  3.00E-05,  5.30E+00,          619
Phenol               0.25,  5.10E+00,  5.10E-01,  2.50E-07,          0,  7.90E-07,  8.10E+00,          622
PropylB              0.25,  3.50E-01,  3.50E-02,  2.50E-05,          0,  7.90E-05,  0.00E+00,          623
PropGlycol           0.25,  3.70E+02,  3.70E+01,  1.60E-10,          0,  5.00E-10,  0.00E+00,          624
Pyridine             0.25,  6.70E+00,  6.70E-01,  1.60E-07,          0,  5.00E-07,  0.00E+00,          626
Styrene              0.25,  7.90E-01,  7.90E-02,  6.30E-06,          0,  2.00E-05,  0.00E+00,          627
1112Tetra            0.25,  6.90E-01,  6.90E-02,  7.90E-06,          0,  2.50E-05,  0.00E+00,          628
1122Tetra            0.25,  1.50E+00,  1.50E-01,  2.00E-06,          0,  6.30E-06,  0.00E+00,          629
Tetrachloroethen     0.25,  3.00E-01,  3.00E-02,  1.00E-05,          0,  1.00E-05,  1.00E-05,          630
2346Tetrachlor       0.25,  1.60E-01,  1.60E-02,  9.90E-05,          0,  3.10E-04,  0.00E+00,          631
Toluene              0.25,  2.60E-01,  2.60E-02,  1.30E-05,          0,  1.30E-05,  1.30E-05,          632
124Trichlorb         0.25,  2.44E-01,  2.44E+00,  4.80E-05,          0,  1.50E-04,  0.00E+00,          634
Trichloroethene      0.25,  4.10E-01,  4.10E-02,  6.00E-06,          0,  6.00E-06,  6.00E-06,          637
TriChloFlo           0.25,  1.30E+00,  1.30E-01,  2.50E-06,          0,  7.90E-06,  0.00E+00,          639

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**********  PATHRAE INPUT SUMMARY  **********

THERE ARE 99 CONTAMINANTS IN THE RISK FACTOR LIBRARY
NUMBER OF TIMES FOR CALCULATION IS 10
YEARS TO BE CALCULATED ARE ...

      .00   500.00   600.00   700.00   800.00
   900.00  1000.00  1100.00  1300.00  1500.00

THERE ARE  99 CONTAMINANTS IN THE INVENTORY FILE
THE VALUE OF IFLAG IS 0
NUMBER OF PATHWAYS IS  2
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          PATHWAY           TYPE OF USAGE
                          FOR UPTAKE FACTORS
   1  GROUNDWATER TO RIVER        2
   2  GROUNDWATER TO WELL         3

TIME OF OPERATION OF WASTE FACILITY IN YEARS                      0.
LENGTH OF REPOSITORY (M)                                        243.
WIDTH OF REPOSITORY (M)                                         427.
RIVER FLOW RATE (M**3/YR)                                         7.36E+05
STREAM FLOW RATE (M**3/YR)                                        1.00E+00
DISTANCE TO RIVER (M)                                           476.

OPERATIONAL SPILLAGE FRACTION                                     0.00E+00
DENSITY OF AQUIFER (KG/M**3)                                   1800.
LONGITUDINAL DISPERSIVITY (M)                                     4.76E+01
LATERAL DISPERSION COEFFICIENT -- Y AXIS (M**2/YR)                0.00E+00
NUMBER OF MESH POINTS FOR DISPERSION CALCULATION                 20
FLAG FOR ATMOSPHERIC PATHWAY                                      0

COVER THICKNESS OVER WASTE (M)                                    3.35
THICKNESS OF WASTE IN PITS (M)                                   16.16
TOTAL WASTE VOLUME (M**3)                                         1.680E+06
DISTANCE TO WELL -- X COORDINATE (M)                              0.
DISTANCE TO WELL -- Y COORDINATE (M)                              0.
DENSITY OF WASTE (KG/M**3)                                     1600.

FRACTION OF FOOD CONSUMED THAT IS GROWN ON SITE                    .400
FRACTION OF YEAR CONTAMINANTS CONTACT SKIN                         .705
AREA OF SKIN IN CONTACT WITH CONTAMINANTS (M**2)                   .0100
DEPTH OF PLANT ROOT ZONE (M)                                       .900
AREAL DENSITY OF PLANTS (KG/M**2)                                 1.000
AVERAGE DUST LOADING IN AIR (KG/M**3)                             1.00E-07

ANNUAL ADULT BREATHING RATE (M**3/YR)                          8000.
FRACTION OF YEAR EXPOSED TO DUST                                   .705
CANISTER LIFETIME (YEARS)                                       200.
INVENTORY SCALING FACTOR                                          1.00E+00
HEIGHT OF ROOMS IN RECLAIMER HOUSE (CM)                         240.
AIR CHANGE RATE IN RECLAIMER HOUSE (CHANGES/SEC)                  5.56E-04

ATMOSPHERIC STABILITY CLASS                                       4
AVERAGE WIND SPEED (M/S)                                          6.30
FRACTION OF TIME WIND BLOWS TOWARD RECEPTOR                        .2300
RECEPTOR DISTANCE FOR ATMOSPHERIC PATHWAY (M)                      .0
DUST RESUSPENSION RATE FOR OFFSITE TRANSPORT (M**3/S)             1.10E-06
DEPOSITION VELOCITY (M/S)                                          .0100

STACK HEIGHT (M)                                                   .0
STACK INSIDE DIAMETER (M)                                          .00
STACK GAS VELOCITY (M/S)                                           .0
HEAT EMISSION RATE FROM BURNING (CAL/S)                           0.00E+00
FLAGS FOR DEGRADATION SERIES              0   0   0   0   0   0   0

FLAG FOR INPUT SUMMARY PRINTOUT                                   1
FLAG FOR DIRECTION OF TRENCH FILLING                              0
FLAG FOR GROUNDWATER PATHWAY OPTIONS                              1
AMOUNT OF WATER PERCOLATING THROUGH WASTE ANNUALLY (M)             1.09E-02
DEGREE OF SOIL SATURATION                                          .856
RESIDUAL SOIL SATURATION                                           .000

PERMEABILITY OF VERTICAL ZONE (M/YR)                               .32
SOIL NUMBER                                                        .000
POROSITY OF AQUIFER                                                .04
POROSITY OF UNSATURATED ZONE                                       .44
DISTANCE FROM AQUIFER TO WASTE (M)                                6.7
AVERAGE VERTICAL GROUNDWATER VELOCITY (M/YR)                      2.91E-02

HORIZONTAL VELOCITY OF AQUIFER (M/YR)                             2.13E+01
LENGTH OF PERFORATED WELL CASING (M)                             24.000
SURFACE EROSION RATE (M/YR)                                       1.000E-05
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LEACH RATE SCALING FACTOR 1.000E+00
ANNUAL RUNOFF OF PRECIPITATION (M) 0.00E+00

	-------- INGESTION -----------		-------- INHALATION ----------		
CONTAMINANT	UNIT RISK FACTORS (KG-DAY/MG)	ALLOWABLE DAILY INTAKES (MG/KG-DAY)	UNIT RISK FACTORS (KG-DAY/MG)	ALLOWABLE DAILY INTAKES (MG/KG-DAY)	HALF LIFE (YR)
24-D	0.000E+00	1.000E-02	0.000E+00	0.000E+00	1.000E+10
245-TP(silvex)	0.000E+00	8.000E-03	0.000E+00	0.000E+00	1.000E+10
Acenaphthene	0.000E+00	6.000E-02	0.000E+00	0.000E+00	1.000E+10
Acenaphthylene	0.000E+00	6.000E-02	0.000E+00	0.000E+00	1.000E+10
Acetone	0.000E+00	9.000E-01	0.000E+00	0.000E+00	1.000E+10
Acentonitrile	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.000E+10
acetophenone	0.000E+00	1.000E-01	0.000E+00	0.000E+00	1.000E+10
Acrolien	0.000E+00	5.000E-04	0.000E+00	0.000E+00	1.000E+10
Acylonitrle	5.400E-01	4.000E-02	0.000E+00	0.000E+00	1.000E+10
Aldrin	1.700E+01	3.000E-05	0.000E+00	0.000E+00	1.000E+10
Aroclor1221	2.000E+00	0.000E+00	0.000E+00	0.000E+00	1.000E+10
Aroclor1232	2.000E+00	0.000E+00	0.000E+00	0.000E+00	1.000E+10
Benzene	5.500E-02	4.000E-03	0.000E+00	0.000E+00	1.000E+10
Benzoic-acid	0.000E+00	4.000E+00	0.000E+00	0.000E+00	1.000E+10
Benzyl-alcohol	0.000E+00	1.000E-01	0.000E+00	0.000E+00	1.000E+10
benzidine	2.300E+02	3.000E-03	0.000E+00	0.000E+00	1.000E+10
Alpha-BHC	6.300E+00	8.000E-03	0.000E+00	0.000E+00	1.000E+10
Beta-BHC	1.800E+00	0.000E+00	0.000E+00	0.000E+00	1.000E+10
Delta-BHC	1.800E+00	0.000E+00	0.000E+00	0.000E+00	1.000E+10
Bromodichloro	6.200E-02	2.000E-02	0.000E+00	0.000E+00	1.000E+10
Bromoform	7.900E-03	2.000E-02	0.000E+00	0.000E+00	1.000E+10
Bromometh	0.000E+00	1.400E-03	0.000E+00	0.000E+00	1.000E+10
butylbenzene	0.000E+00	5.000E-02	0.000E+00	0.000E+00	1.000E+10
Carbazole	2.000E-02	0.000E+00	0.000E+00	0.000E+00	1.000E+10
CarbonDiS	0.000E+00	1.000E-01	0.000E+00	0.000E+00	1.000E+10
Carbontetchl	7.000E-02	4.000E-03	0.000E+00	0.000E+00	1.000E+10
Chlordane	3.500E-01	5.000E-04	0.000E+00	0.000E+00	1.000E+10
Chlorobenzene	0.000E+00	2.000E-02	0.000E+00	0.000E+00	1.000E+10
Chloroform	3.100E-02	1.000E-02	0.000E+00	0.000E+00	1.000E+10
Chlorometh	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.000E+10
0-ChloroTu	0.000E+00	2.000E-02	0.000E+00	0.000E+00	1.000E+10
m-cresol	0.000E+00	5.000E-02	0.000E+00	0.000E+00	1.000E+10
o-cresol	0.000E+00	5.000E-02	0.000E+00	0.000E+00	1.000E+10
p-cresol	0.000E+00	1.000E-01	0.000E+00	0.000E+00	1.000E+10
Cumene	0.000E+00	1.000E-01	0.000E+00	0.000E+00	1.000E+10
Cyanide	0.000E+00	6.000E-04	0.000E+00	0.000E+00	1.000E+10
DDD	2.400E-01	0.000E+00	0.000E+00	0.000E+00	1.000E+10
DDE	3.400E-01	0.000E+00	0.000E+00	0.000E+00	1.000E+10
Dinbutylphthalat	0.000E+00	1.000E-01	0.000E+00	0.000E+00	1.000E+10
Dibenz[ah]	7.300E+00	0.000E+00	0.000E+00	0.000E+00	1.000E+10
Dibenzofuran	0.000E+00	1.000E-03	0.000E+00	0.000E+00	1.000E+10
Dibromochloro	8.400E-02	2.000E-02	0.000E+00	0.000E+00	1.000E+10
12Dichloro	0.000E+00	9.000E-02	0.000E+00	0.000E+00	1.000E+10
13Dichloro	0.000E+00	8.900E-02	0.000E+00	0.000E+00	1.000E+10
14Dichlorobenzen	5.400E-03	7.000E-02	0.000E+00	0.000E+00	1.000E+10
12cisDichloro	0.000E+00	2.000E-03	0.000E+00	0.000E+00	1.000E+10
12transDichl	0.000E+00	2.000E-02	0.000E+00	0.000E+00	1.000E+10
Dichlorodiflo	0.000E+00	2.000E-01	0.000E+00	0.000E+00	1.000E+10
12Dichlprop	3.600E-02	9.000E-02	0.000E+00	0.000E+00	1.000E+10
Dieldrin	1.600E+01	5.000E-05	0.000E+00	0.000E+00	1.000E+10
Diethylphth	0.000E+00	8.000E-01	0.000E+00	0.000E+00	1.000E+10
12DiMethylB	0.000E+00	2.000E-01	0.000E+00	0.000E+00	1.000E+10
24-Dimethylphe	0.000E+00	2.000E-02	0.000E+00	0.000E+00	1.000E+10
Dimethylphth	0.000E+00	1.000E+01	0.000E+00	0.000E+00	1.000E+10
24Dinitrotoluene	3.100E-01	2.000E-03	0.000E+00	0.000E+00	1.000E+10
26Dinitrotoluene	0.000E+00	1.000E-03	0.000E+00	0.000E+00	1.000E+10
EndosulfanII	0.000E+00	6.000E-03	0.000E+00	0.000E+00	1.000E+10
Endrin	0.000E+00	3.000E-04	0.000E+00	0.000E+00	1.000E+10
Aldehyde	0.000E+00	3.000E-04	0.000E+00	0.000E+00	1.000E+10
Ketone	0.000E+00	3.000E-04	0.000E+00	0.000E+00	1.000E+10
Ethylbenz	1.100E-02	1.000E-01	0.000E+00	0.000E+00	1.000E+10

Ethylchlorid	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.000E+10
Heptachlor	4.500E+00	5.000E-04	0.000E+00	0.000E+00	1.000E+10
Heptachlor-epoxd	9.100E+00	1.300E-05	0.000E+00	0.000E+00	1.000E+10
Hexachlorobenzen	1.600E+00	8.000E-04	0.000E+00	0.000E+00	1.000E+10
Hexachloroethane	4.000E-02	7.000E-04	0.000E+00	0.000E+00	1.000E+10
Nhexane	0.000E+00	6.000E-02	0.000E+00	0.000E+00	1.000E+10
1hexanol	0.000E+00	4.000E-02	0.000E+00	0.000E+00	1.000E+10
2hexanone	0.000E+00	5.000E-03	0.000E+00	0.000E+00	1.000E+10
Isophorone	9.500E-04	2.000E-01	0.000E+00	0.000E+00	1.000E+10
Lindane	1.100E+00	3.000E-04	0.000E+00	0.000E+00	1.000E+10
Methonal	0.000E+00	5.000E-01	0.000E+00	0.000E+00	1.000E+10
Methchloride	2.000E-03	6.000E-03	0.000E+00	0.000E+00	1.000E+10
Methylcyclo	0.000E+00	6.000E-02	0.000E+00	0.000E+00	1.000E+10
MethylIso	0.000E+00	8.000E-02	0.000E+00	0.000E+00	1.000E+10
MMetacrylate	0.000E+00	1.400E+00	0.000E+00	0.000E+00	1.000E+10
MethylEthylB	0.000E+00	3.700E-02	0.000E+00	0.000E+00	1.000E+10
2Methylnaptha	0.000E+00	4.000E-03	0.000E+00	0.000E+00	1.000E+10
MethylPropylB	0.000E+00	3.700E-02	0.000E+00	0.000E+00	1.000E+10
Naphthalene	0.000E+00	2.000E-02	0.000E+00	0.000E+00	1.000E+10
4Nitrobenzenamin	2.000E-02	4.000E-03	0.000E+00	0.000E+00	1.000E+10
Nitrobenzene	0.000E+00	2.000E-03	0.000E+00	0.000E+00	1.000E+10
2Nitrophenol	0.000E+00	6.200E-02	0.000E+00	0.000E+00	1.000E+10
4Nitrophenol	0.000E+00	6.200E-02	0.000E+00	0.000E+00	1.000E+10
NnitroNpropyl	7.000E+00	0.000E+00	0.000E+00	0.000E+00	1.000E+10
NNitrosodiphen	4.900E-03	0.000E+00	0.000E+00	0.000E+00	1.000E+10
Phenol	0.000E+00	3.000E-01	0.000E+00	0.000E+00	1.000E+10
PropylB	0.000E+00	3.700E-02	0.000E+00	0.000E+00	1.000E+10
PropGlycol	0.000E+00	2.000E+01	0.000E+00	0.000E+00	1.000E+10
Pyridine	0.000E+00	1.000E-03	0.000E+00	0.000E+00	1.000E+10
Styrene	0.000E+00	2.000E-01	0.000E+00	0.000E+00	1.000E+10
1112Tetra	2.600E-02	3.000E-02	0.000E+00	0.000E+00	1.000E+10
1122Tetra	2.000E-01	2.000E-02	0.000E+00	0.000E+00	1.000E+10
Tetrachloroethen	2.100E-03	6.000E-03	0.000E+00	0.000E+00	1.000E+10
2346Tetrachlor	0.000E+00	3.000E-02	0.000E+00	0.000E+00	1.000E+10
Toluene	0.000E+00	8.000E-02	0.000E+00	0.000E+00	1.000E+10
124Trichlorb	2.900E-02	1.000E-02	0.000E+00	0.000E+00	1.000E+10
Trichloroethene	4.600E-02	5.000E-04	0.000E+00	0.000E+00	1.000E+10
TriChloFlo	0.000E+00	3.000E-01	0.000E+00	0.000E+00	1.000E+10

CONTAMINANT	VOLATILITY FRACTION	VAPORIZATION RATE (1/S)	SKIN ABSORPTION (M/HR)
24-D	0.000E+00	0.000E+00	0.000E+00
245-TP(silvex)	0.000E+00	0.000E+00	0.000E+00
Acenaphthene	0.000E+00	0.000E+00	0.000E+00
Acenaphthylene	0.000E+00	0.000E+00	0.000E+00
Acetone	0.000E+00	0.000E+00	0.000E+00
Acentonitrile	0.000E+00	0.000E+00	0.000E+00
acetophenone	0.000E+00	0.000E+00	0.000E+00
Acrolien	0.000E+00	0.000E+00	0.000E+00
Acylonitrle	0.000E+00	0.000E+00	0.000E+00
Aldrin	0.000E+00	0.000E+00	0.000E+00
Aroclor1221	0.000E+00	0.000E+00	0.000E+00
Aroclor1232	0.000E+00	0.000E+00	0.000E+00
Benzene	0.000E+00	0.000E+00	0.000E+00
Benzoic-acid	0.000E+00	0.000E+00	0.000E+00
Benzyl-alcohol	0.000E+00	0.000E+00	0.000E+00
benzidine	0.000E+00	0.000E+00	0.000E+00
Alpha-BHC	0.000E+00	0.000E+00	0.000E+00
Beta-BHC	0.000E+00	0.000E+00	0.000E+00
Delta-BHC	0.000E+00	0.000E+00	0.000E+00
Bromodichloro	0.000E+00	0.000E+00	0.000E+00
Bromoform	0.000E+00	0.000E+00	0.000E+00
Bromometh	0.000E+00	0.000E+00	0.000E+00
butylbenzene	0.000E+00	0.000E+00	0.000E+00
Carbazole	0.000E+00	0.000E+00	0.000E+00
CarbonDiS	0.000E+00	0.000E+00	0.000E+00
Carbontetchl	0.000E+00	0.000E+00	0.000E+00
Chlordane	0.000E+00	0.000E+00	0.000E+00

Chlorobenzene	0.000E+00	0.000E+00	0.000E+00
Chloroform	0.000E+00	0.000E+00	0.000E+00
Chlorometh	0.000E+00	0.000E+00	0.000E+00
0-ChloroTu	0.000E+00	0.000E+00	0.000E+00
m-cresol	0.000E+00	0.000E+00	0.000E+00
o-cresol	0.000E+00	0.000E+00	0.000E+00
p-cresol	0.000E+00	0.000E+00	0.000E+00
Cumene	0.000E+00	0.000E+00	0.000E+00
Cyanide	0.000E+00	0.000E+00	0.000E+00
DDD	0.000E+00	0.000E+00	0.000E+00
DDE	0.000E+00	0.000E+00	0.000E+00
Dinbutylphthalat	0.000E+00	0.000E+00	0.000E+00
Dibenz[ah]	0.000E+00	0.000E+00	0.000E+00
Dibenzofuran	0.000E+00	0.000E+00	0.000E+00
Dibromochloro	0.000E+00	0.000E+00	0.000E+00
12Dichloro	0.000E+00	0.000E+00	0.000E+00
13Dichloro	0.000E+00	0.000E+00	0.000E+00
14Dichlorobenzen	0.000E+00	0.000E+00	0.000E+00
12cisDichloro	0.000E+00	0.000E+00	0.000E+00
12transDichl	0.000E+00	0.000E+00	0.000E+00
Dichlorodiflo	0.000E+00	0.000E+00	0.000E+00
12Dichlprop	0.000E+00	0.000E+00	0.000E+00
Dieldrin	0.000E+00	0.000E+00	0.000E+00
Diethylphth	0.000E+00	0.000E+00	0.000E+00
12DiMethylB	0.000E+00	0.000E+00	0.000E+00
24-Dimethylphe	0.000E+00	0.000E+00	0.000E+00
Dimethylphth	0.000E+00	0.000E+00	0.000E+00
24Dinitrotoluene	0.000E+00	0.000E+00	0.000E+00
26Dinitrotoluene	0.000E+00	0.000E+00	0.000E+00
EndosulfanII	0.000E+00	0.000E+00	0.000E+00
Endrin	0.000E+00	0.000E+00	0.000E+00
Aldehyde	0.000E+00	0.000E+00	0.000E+00
Ketone	0.000E+00	0.000E+00	0.000E+00
Ethylbenz	0.000E+00	0.000E+00	0.000E+00
Ethylchlorid	0.000E+00	0.000E+00	0.000E+00
Heptachlor	0.000E+00	0.000E+00	0.000E+00
Heptachlor-epoxd	0.000E+00	0.000E+00	0.000E+00
Hexachlorobenzen	0.000E+00	0.000E+00	0.000E+00
Hexachloroethane	0.000E+00	0.000E+00	0.000E+00
Nhexane	0.000E+00	0.000E+00	0.000E+00
1hexanol	0.000E+00	0.000E+00	0.000E+00
2hexanone	0.000E+00	0.000E+00	0.000E+00
Isophorone	0.000E+00	0.000E+00	0.000E+00
Lindane	0.000E+00	0.000E+00	0.000E+00
Methonal	0.000E+00	0.000E+00	0.000E+00
Methchloride	0.000E+00	0.000E+00	0.000E+00
Methylcyclo	0.000E+00	0.000E+00	0.000E+00
MethylIso	0.000E+00	0.000E+00	0.000E+00
MMetacrylate	0.000E+00	0.000E+00	0.000E+00
MethylEthylB	0.000E+00	0.000E+00	0.000E+00
2Methylnaptha	0.000E+00	0.000E+00	0.000E+00
MethylPropylB	0.000E+00	0.000E+00	0.000E+00
Naphthalene	0.000E+00	0.000E+00	0.000E+00
4Nitrobenzenamin	0.000E+00	0.000E+00	0.000E+00
Nitrobenzene	0.000E+00	0.000E+00	0.000E+00
2Nitrophenol	0.000E+00	0.000E+00	0.000E+00
4Nitrophenol	0.000E+00	0.000E+00	0.000E+00
NnitroNpropyl	0.000E+00	0.000E+00	0.000E+00
NNitrosodiphen	0.000E+00	0.000E+00	0.000E+00
Phenol	0.000E+00	0.000E+00	0.000E+00
PropylB	0.000E+00	0.000E+00	0.000E+00
PropGlycol	0.000E+00	0.000E+00	0.000E+00
Pyridine	0.000E+00	0.000E+00	0.000E+00
Styrene	0.000E+00	0.000E+00	0.000E+00
1112Tetra	0.000E+00	0.000E+00	0.000E+00
1122Tetra	0.000E+00	0.000E+00	0.000E+00
Tetrachloroethen	0.000E+00	0.000E+00	0.000E+00
2346Tetrachlor	0.000E+00	0.000E+00	0.000E+00
Toluene	0.000E+00	0.000E+00	0.000E+00
124Trichlorb	0.000E+00	0.000E+00	0.000E+00
Trichloroethene	0.000E+00	0.000E+00	0.000E+00

TriChloFlo	0.000E+00	0.000E+00	0.000E+00	

CONTAMINANT	INPUT LEACH (1/YR)	FINAL LEACH (1/YR)	SOLUBILITY (MG/L)	INPUT INVENTORY (KG)
24-D	-5.880E-02	4.595E-04	6.820E+02	1.680E+06
245-TP(silvex)	-1.608E-01	1.347E-04	2.000E+02	1.680E+06
Acenaphthene	-9.200E+01	2.304E-06	3.420E+00	1.680E+06
Acenaphthylene	-1.220E+01	1.085E-05	1.610E+01	1.680E+06
Acetone	-4.400E-02	1.327E-03	0.000E+00	1.680E+06
Acentonitrile	-1.540E-03	1.531E-03	1.000E+06	1.680E+06
acetophenone	-9.240E-02	1.151E-03	6.130E+03	1.680E+06
Acrolien	-2.780E-03	1.524E-03	1.200E+04	1.680E+06
Acylonitrle	-4.440E-03	1.515E-03	7.450E+04	1.680E+06
Aldrin	-9.740E+01	1.145E-08	1.700E-02	1.680E+06
Aroclor1221	-1.200E+02	3.254E-06	4.830E+00	1.680E+06
Aroclor1232	-1.500E+01	3.254E-06	4.830E+00	1.680E+06
Benzene	-1.700E+00	2.136E-04	0.000E+00	1.680E+06
Benzoic-acid	-1.200E-03	1.533E-03	3.400E+03	1.680E+06
Benzyl-alcohol	-3.130E-02	1.382E-03	4.290E+04	1.680E+06
benzidine	-5.480E+00	7.327E-05	3.220E+02	1.680E+06
Alpha-BHC	-3.520E+00	5.390E-06	8.000E+00	1.680E+06
Beta-BHC	-4.280E+00	5.390E-06	8.000E+00	1.680E+06
Delta-BHC	-4.280E+00	5.390E-06	8.000E+00	1.680E+06
Bromodichloro	-1.080E-02	1.482E-03	3.030E+03	1.680E+06
Bromoform	-2.520E-01	6.737E-05	1.000E+02	1.680E+06
Bromometh	-2.830E-02	1.396E-03	5.200E+03	1.680E+06
butylbenzene	-1.630E+00	4.130E-05	6.130E+01	1.680E+06
Carbazole	-6.780E+00	1.213E-06	1.800E+00	1.680E+06
CarbonDiS	-1.030E-01	7.950E-04	1.180E+03	1.680E+06
Carbontetchl	-2.200E+00	1.704E-04	0.000E+00	1.680E+06
Chlordane	-1.730E+02	3.773E-08	5.600E-02	1.680E+06
Chlorobenzene	-4.380E-01	3.355E-04	4.980E+02	1.680E+06
Chloroform	-6.200E-01	4.717E-04	0.000E+00	1.680E+06
Chlorometh	-2.860E-02	1.394E-03	5.320E+03	1.680E+06
0-ChloroTu	-8.860E-01	2.520E-04	3.740E+02	1.680E+06
m-cresol	-9.560E-02	1.141E-03	2.270E+04	1.680E+06
o-cresol	-1.820E-01	9.250E-04	2.590E+04	1.680E+06
p-cresol	-9.220E-02	1.152E-03	2.150E+04	1.680E+06
Cumene	-1.650E+00	4.130E-05	6.130E+01	1.680E+06
Cyanide	-9.900E+00	4.144E-05	1.000E+06	1.680E+06
DDD	-9.160E+01	6.064E-08	9.000E-02	1.680E+06
DDE	-1.730E+00	2.695E-08	4.000E-02	1.680E+06
Dinbutylphthalat	-1.000E-06	1.540E-03	0.000E+00	1.680E+06
Dibenz[ah]	-3.580E+03	6.939E-10	1.030E-03	1.680E+06
Dibenzofuran	-2.260E+02	1.863E-06	3.100E+00	1.680E+06
Dibromochloro	-1.410E-01	1.016E-03	2.700E+03	1.680E+06
12Dichloro	-7.580E-01	5.390E-05	8.000E+01	1.680E+06
13Dichloro	-1.606E+01	2.581E-05	1.250E+02	1.680E+06
14Dichlorobenzen	-1.232E+00	5.477E-05	8.130E+01	1.680E+06
12cisDichloro	-9.960E-01	3.320E-04	3.500E+03	1.680E+06
12transDichl	-7.600E-02	1.205E-03	3.500E+03	1.680E+06
Dichlorodiflo	-1.370E-02	1.886E-04	2.800E+02	1.680E+06
12Dichlprop	-9.400E-02	1.146E-03	2.800E+03	1.680E+06
Dieldrin	-3.400E+01	1.230E-05	0.000E+00	1.680E+06
Diethylphth	-2.520E-01	7.276E-04	1.080E+03	1.680E+06
12DiMethylB	-4.800E-01	1.482E-04	2.200E+02	1.680E+06
24-Dimethylphe	-2.520E+00	1.509E-04	7.870E+03	1.680E+06
Dimethylphth	-7.420E-02	1.212E-03	4.000E+03	1.680E+06
24Dinitrotoluene	-1.020E-01	1.819E-04	2.700E+02	1.680E+06
26Dinitrotoluene	-8.390E-02	2.372E-04	3.520E+02	1.680E+06
EndosulfanII	-4.080E+00	3.032E-07	4.500E-01	1.680E+06
Endrin	-2.160E+01	1.684E-07	2.500E-01	1.680E+06
Aldehyde	-2.160E+01	1.684E-07	2.500E-01	1.680E+06
Ketone	-2.160E+01	1.684E-07	2.500E-01	1.680E+06
Ethylbenz	-4.080E-01	1.139E-04	1.690E+02	1.680E+06
Ethylchlorid	-4.750E-02	1.312E-03	6.700E+03	1.680E+06
Heptachlor	-4.800E+01	1.213E-07	1.800E-01	1.680E+06
Heptachlor-epoxd	-1.730E+01	1.347E-07	2.000E-01	1.680E+06
Hexachlorobenzen	-1.100E+02	4.177E-09	6.200E-03	1.680E+06

Hexachloroethane	-3.560E+00	3.369E-05	5.000E+01	1.680E+06
Nhexane	-2.980E-01	6.401E-06	9.500E+00	1.680E+06
1hexanol	-2.600E-02	1.406E-03	5.900E+03	1.680E+06
2hexanone	-2.600E-02	1.406E-03	5.900E+03	1.680E+06
Isophorone	-1.700E+00	2.136E-04	0.000E+00	1.680E+06
Lindane	-6.760E+00	5.390E-06	8.000E+00	1.680E+06
Methonal	-2.000E-03	1.529E-03	1.000E+06	1.680E+06
Methchloride	-2.010E+03	2.097E-07	1.300E+04	1.680E+06
Methylcyclo	-1.990E-01	9.432E-06	1.400E+01	1.680E+06
MethylIso	-4.700E-03	1.514E-03	1.900E+04	1.680E+06
MMetacrylate	-2.000E-02	1.435E-03	1.500E+04	1.680E+06
MethylEthylB	-1.650E+00	4.110E-05	6.100E+01	1.680E+06
2Methylnaptha	-5.940E+00	1.657E-05	2.460E+01	1.680E+06
MethylPropylB	-1.650E+00	4.110E-05	6.100E+01	1.680E+06
Naphthalene	-1.900E+01	2.187E-05	0.000E+00	1.680E+06
4Nitrobenzenamin	-3.440E-01	7.209E-12	1.070E-05	1.680E+06
Nitrobenzene	-1.290E-01	1.047E-03	2.090E+03	1.680E+06
2Nitrophenol	-7.100E-01	4.285E-04	2.500E+03	1.680E+06
4Nitrophenol	-8.740E-01	3.673E-04	1.160E+04	1.680E+06
NnitroNpropyl	-3.000E-01	7.348E-04	0.000E+00	1.680E+06
NNitrosodiphen	-6.540E-01	2.358E-05	3.500E+01	1.680E+06
Phenol	-2.800E-01	7.613E-04	9.300E+04	1.680E+06
PropylB	-1.650E+00	4.110E-05	6.100E+01	1.680E+06
PropGlycol	-2.000E-03	1.529E-03	1.000E+06	1.680E+06
Pyridine	-1.380E-02	1.466E-03	1.000E+06	1.680E+06
Styrene	-1.820E+00	2.013E-04	3.100E+02	1.680E+06
1112Tetra	-3.180E-01	7.124E-04	1.070E+03	1.680E+06
1122Tetra	-1.580E-01	9.764E-04	2.870E+03	1.680E+06
Tetrachloroethen	-7.200E+00	5.641E-05	0.000E+00	1.680E+06
2346Tetrachlor	-2.490E+02	1.691E-06	2.300E+01	1.680E+06
Toluene	-6.000E+00	6.720E-05	0.000E+00	1.680E+06
124Trichlorb	-1.440E+00	3.840E-05	5.700E+01	1.680E+06
Trichloroethene	-2.600E+00	1.467E-04	0.000E+00	1.680E+06
TriChloFlo	-2.680E-01	7.411E-04	1.100E+03	1.680E+06

CONTAMINANT	AQUIFER SORPTION	AQUIFER RETARDATION	VERTICAL SORPTION	VERTICAL RETARDATION
24-D	5.880E-03	1.265E+00	5.880E-02	1.282E+00
245-TP(silvex)	1.608E-02	1.724E+00	1.608E-01	1.772E+00
Acenaphthene	9.200E+00	4.150E+02	9.200E+01	4.427E+02
Acenaphthylene	1.220E+00	5.590E+01	1.220E+01	5.957E+01
Acetone	0.000E+00	1.000E+00	4.400E-02	1.211E+00
Acentonitrile	1.540E-04	1.007E+00	1.540E-03	1.007E+00
acetophenone	9.240E-03	1.416E+00	9.240E-02	1.444E+00
Acrolien	2.780E-04	1.013E+00	2.780E-03	1.013E+00
Acylonitrle	4.440E-04	1.020E+00	4.440E-03	1.021E+00
Aldrin	9.740E+00	4.393E+02	9.740E+01	4.686E+02
Aroclor1221	1.200E+02	5.401E+03	1.200E+02	5.771E+02
Aroclor1232	1.500E+01	6.760E+02	1.500E+01	7.301E+01
Benzene	0.000E+00	1.000E+00	1.700E+00	9.162E+00
Benzoic-acid	1.200E-04	1.005E+00	1.200E-03	1.006E+00
Benzyl-alcohol	3.130E-03	1.141E+00	3.130E-02	1.150E+00
benzidine	5.480E-01	2.566E+01	5.480E+00	2.731E+01
Alpha-BHC	3.520E-01	1.684E+01	3.520E+00	1.790E+01
Beta-BHC	4.280E-01	2.026E+01	4.280E+00	2.155E+01
Delta-BHC	4.280E-01	2.026E+01	4.280E+00	2.155E+01
Bromodichloro	1.080E-03	1.049E+00	1.080E-02	1.052E+00
Bromoform	2.520E-02	2.134E+00	2.520E-01	2.210E+00
Bromometh	2.830E-03	1.127E+00	2.830E-02	1.136E+00
butylbenzene	1.630E-01	8.335E+00	1.630E+00	8.826E+00
Carbazole	6.780E-01	3.151E+01	6.780E+00	3.355E+01
CarbonDiS	1.030E-02	1.464E+00	1.030E-01	1.494E+00
Carbontetchl	0.000E+00	1.000E+00	2.200E+00	1.156E+01
Chlordane	1.730E+01	7.795E+02	1.730E+02	8.316E+02
Chlorobenzene	4.380E-02	2.971E+00	4.380E-01	3.103E+00
Chloroform	0.000E+00	1.000E+00	6.200E-01	3.977E+00
Chlorometh	2.860E-03	1.129E+00	2.860E-02	1.137E+00
0-ChloroTu	8.860E-02	4.987E+00	8.860E-01	5.254E+00
m-cresol	9.560E-03	1.430E+00	9.560E-02	1.459E+00

BIOACCUMULATION FACTORS

	SOIL-PLANT	SOIL-PLANT	FORAGE-MILK	FORAGE-MEAT
o-cresol	1.820E-02	1.819E+00	1.820E-01	1.874E+00
p-cresol	9.220E-03	1.415E+00	9.220E-02	1.443E+00
Cumene	1.650E-01	8.425E+00	1.650E+00	8.922E+00
Cyanide	9.900E-01	4.555E+01	9.900E+00	4.853E+01
DDD	9.160E+00	4.132E+02	9.160E+01	4.408E+02
DDE	1.730E-01	8.785E+00	1.730E+00	9.306E+00
Dinbutylphthalat	0.000E+00	1.000E+00	1.000E-06	1.000E+00
Dibenz[ah]	3.580E+02	1.611E+04	3.580E+03	1.719E+04
Dibenzofuran	2.260E+01	1.018E+03	2.260E+02	1.086E+03
Dibromochloro	1.410E-02	1.635E+00	1.410E-01	1.677E+00
12Dichloro	7.580E-02	4.411E+00	7.580E-01	4.639E+00
13Dichloro	1.606E+00	7.327E+01	1.606E+01	7.810E+01
14Dichlorobenzen	1.232E-01	6.544E+00	1.232E+00	6.915E+00
12cisDichloro	9.960E-02	5.482E+00	9.960E-01	5.782E+00
12transDichl	7.600E-03	1.342E+00	7.600E-02	1.365E+00
Dichlorodiflo	1.370E-03	1.062E+00	1.370E-02	1.066E+00
12Dichlprop	9.400E-03	1.423E+00	9.400E-02	1.451E+00
Dieldrin	0.000E+00	1.000E+00	3.400E+01	1.642E+02
Diethylphth	2.520E-02	2.134E+00	2.520E-01	2.210E+00
12DiMethylB	4.800E-02	3.160E+00	4.800E-01	3.304E+00
24-Dimethylphe	2.520E-01	1.234E+01	2.520E+00	1.310E+01
Dimethylphth	7.420E-03	1.334E+00	7.420E-02	1.356E+00
24Dinitrotoluene	1.020E-02	1.459E+00	1.020E-01	1.490E+00
26Dinitrotoluene	8.390E-03	1.378E+00	8.390E-02	1.403E+00
EndosulfanII	4.080E+00	1.846E+02	4.080E-01	2.959E+00
Endrin	2.160E+00	9.820E+01	2.160E+01	1.047E+02
Aldehyde	2.160E+01	9.730E+02	2.160E+00	1.137E+01
Ketone	2.160E+01	9.730E+02	2.160E+00	1.137E+01
Ethylbenz	4.080E-02	2.836E+00	4.080E-01	2.959E+00
Ethylchlorid	4.750E-03	1.214E+00	4.750E-02	1.228E+00
Heptachlor	4.800E+00	2.170E+02	4.800E+01	2.314E+02
Heptachlor-epoxd	1.730E+00	7.885E+01	1.730E+01	8.406E+01
Hexachlorobenzen	1.100E+01	4.960E+02	1.100E+02	5.291E+02
Hexachloroethane	3.560E-01	1.702E+01	3.560E+00	1.809E+01
Nhexane	2.980E-02	2.341E+00	2.980E-01	2.431E+00
1hexanol	2.600E-03	1.117E+00	2.600E-02	1.125E+00
2hexanone	2.600E-03	1.117E+00	2.600E-02	1.125E+00
Isophorone	0.000E+00	1.000E+00	1.700E+00	9.162E+00
Lindane	6.760E-01	3.142E+01	6.760E+00	3.345E+01
Methonal	2.000E-04	1.009E+00	2.000E-03	1.010E+00
Methchloride	0.000E+00	1.000E+00	2.010E+03	9.651E+03
Methylcyclo	0.000E+00	1.000E+00	0.000E+00	1.000E+00
MethylIso	4.700E-04	1.021E+00	4.700E-03	1.023E+00
MMetacrylate	2.000E-03	1.090E+00	2.000E-02	1.096E+00
MethylEthylB	1.650E-01	8.425E+00	1.650E+00	8.922E+00
2Methylnaptha	5.940E-01	2.773E+01	5.940E+00	2.952E+01
MethylPropylB	1.650E-01	8.425E+00	1.650E+00	8.922E+00
Naphthalene	1.900E+00	8.650E+01	1.900E+01	9.222E+01
4Nitrobenzenamin	3.440E-02	2.548E+00	3.440E-01	2.652E+00
Nitrobenzene	1.290E-02	1.581E+00	1.290E-01	1.619E+00
2Nitrophenol	7.100E-02	4.195E+00	7.100E-01	4.409E+00
4Nitrophenol	8.740E-02	4.933E+00	8.740E-01	5.196E+00
NnitroNpropyl	3.000E-02	2.350E+00	3.000E-01	2.440E+00
NNitrosodiphen	6.540E-02	3.943E+00	6.540E-01	4.140E+00
Phenol	2.800E-02	2.260E+00	2.800E-01	2.344E+00
PropylB	1.650E-01	8.425E+00	1.650E+00	8.922E+00
PropGlycol	2.000E-04	1.009E+00	2.000E-03	1.010E+00
Pyridine	1.380E-03	1.062E+00	1.380E-02	1.066E+00
Styrene	1.820E-01	9.190E+00	1.820E+00	9.738E+00
1112Tetra	3.180E-02	2.431E+00	3.180E-01	2.527E+00
1122Tetra	1.560E-02	1.702E+00	1.560E-01	1.749E+00
Tetrachloroethen	0.000E+00	1.000E+00	7.200E+00	3.557E+01
2346Tetrachlor	2.490E+01	1.122E+03	2.490E+02	1.196E+03
Toluene	0.000E+00	1.000E+00	6.000E+00	2.981E+01
124Trichlorb	1.440E-01	7.480E+00	1.440E+00	7.913E+00
Trichloroethene	0.000E+00	1.000E+00	2.600E+00	1.348E+01
TriChloFlo	2.680E-02	2.206E+00	2.680E-01	2.287E+00

CONTAMINANT	Bv	Br	Fm (D/L)	Ff (D/KG)
24-D	1.300E+00	1.300E-01	2.500E-06	7.900E-06
245-TP(silvex)	2.100E-01	2.100E-02	6.300E-05	2.000E-04
Acenaphthene	1.200E-01	1.200E-02	1.600E-04	5.000E-04
Acenaphthylene	2.700E-01	2.700E-02	4.000E-05	1.300E-04
Acetone	1.300E+01	1.300E+00	1.500E-08	1.500E-08
Acentonitrile	6.000E+01	6.000E+00	3.600E-09	1.100E-08
acetophenone	3.900E+00	3.900E-01	4.000E-07	1.300E-06
Acrolien	4.300E+01	4.300E+00	6.300E-09	2.000E-08
Acylonitrle	2.700E+01	2.700E+00	1.400E-08	4.400E-08
Aldrin	6.900E-01	6.900E-02	7.900E-06	2.500E-05
Aroclor1221	1.600E-01	1.600E-02	9.900E-05	3.100E-04
Aroclor1232	5.300E-01	5.300E-02	1.300E-05	4.000E-05
Benzene	5.800E-01	5.800E-02	3.300E-06	3.300E-06
Benzoic-acid	3.000E+00	3.000E-01	6.300E-07	2.000E-06
Benzyl-alcohol	8.700E+00	8.700E-01	9.900E-08	3.100E-07
benzidine	6.700E+00	6.700E-01	1.600E-07	5.000E-07
Alpha-BHC	2.100E-01	2.100E-02	6.300E-05	2.000E-04
Beta-BHC	1.800E-01	1.800E-02	7.900E-05	2.500E-04
Delta-BHC	9.000E-01	9.000E-02	5.000E-06	1.600E-05
Bromodichloro	2.300E+00	2.300E-01	9.900E-07	3.100E-06
Bromoform	1.500E+00	1.500E-01	2.000E-06	6.300E-06
Bromometh	7.700E+00	7.700E-01	1.300E-07	4.000E-07
butylbenzene	3.500E-01	3.500E-02	2.500E-05	7.900E-05
Carbazole	2.400E-01	2.400E-02	5.000E-05	1.600E-04
CarbonDiS	2.000E+00	2.000E-01	1.300E-06	4.000E-06
Carbontetchl	2.900E-01	2.900E-02	1.100E-05	1.100E-05
Chlordane	2.500E-02	2.500E-03	2.500E-03	7.900E-03
Chlorobenzene	9.000E-01	9.000E-02	5.000E-06	1.600E-05
Chloroform	7.000E-01	7.000E-02	2.300E-06	2.300E-06
Chlorometh	1.100E+01	1.100E+00	6.400E-08	2.000E-07
0-ChloroTu	4.100E-01	4.100E-02	2.000E-05	6.300E-05
m-cresol	2.600E+00	2.600E-01	7.900E-07	2.500E-06
o-cresol	3.000E+00	3.000E-01	6.300E-07	2.000E-06
p-cresol	3.000E+00	3.000E-01	6.300E-07	2.000E-06
Cumene	3.500E-01	3.500E-02	2.500E-05	7.900E-05
Cyanide	8.700E+00	8.700E-01	9.900E-08	3.100E-07
DDD	1.600E-02	1.600E-03	5.000E-03	1.600E-02
DDE	1.900E-02	1.900E-03	4.000E-03	1.300E-02
Dinbutylphthalat	5.600E-03	5.600E-04	3.200E-03	1.000E-02
Dibenz[ah]	4.300E-03	4.300E-04	5.000E-02	1.600E-01
Dibenzofuran	1.500E-01	1.500E-02	1.000E-04	3.300E-04
Dibromochloro	2.000E+00	2.000E-01	1.300E-06	4.000E-06
12Dichloro	4.100E-01	4.100E-02	2.000E-05	6.300E-05
13Dichloro	3.100E-01	3.100E-02	3.100E-05	1.000E-04
14Dichlorobenzen	4.100E-01	4.100E-02	2.000E-05	6.300E-05
12cisDichloro	3.000E+00	3.000E-01	6.300E-07	2.000E-06
12transDichl	2.000E+01	2.000E+00	2.400E-08	7.500E-08
Dichlorodiflo	2.000E+00	2.000E-01	1.300E-06	4.000E-06
12Dichlprop	2.600E+00	2.600E-01	7.900E-07	2.500E-06
Dieldrin	9.200E-02	9.200E-03	7.900E-03	7.900E-03
Diethylphth	1.300E+00	1.300E-01	2.500E-06	7.900E-06
12DiMethylB	6.000E-01	6.000E-02	1.100E-05	3.400E-05
24-Dimethylphe	1.800E+00	1.800E-01	1.600E-06	5.000E-06
Dimethylphth	4.500E+00	4.500E-01	3.100E-07	1.000E-06
24Dinitrotoluene	2.600E+00	2.600E-01	7.900E-07	2.500E-06
26Dinitrotoluene	3.900E+00	3.900E-01	4.000E-07	1.300E-06
EndosulfanII	3.300E-01	3.300E-02	2.800E-05	8.900E-05
Endrin	8.200E-02	8.200E-03	3.100E-04	1.000E-03
Aldehyde	8.200E-02	8.200E-03	3.100E-04	1.000E-03
Ketone	8.200E-02	8.200E-03	3.100E-04	1.000E-03
Ethylbenz	6.100E-01	6.100E-02	9.900E-06	3.100E-05
Ethylchlorid	5.900E+00	5.900E-01	2.000E-07	6.300E-07
Heptachlor	1.200E-01	1.200E-02	1.600E-04	5.000E-04
Heptachlor-epoxd	2.800E-02	2.800E-03	2.000E-03	6.300E-03
Hexachlorobenzen	3.200E-02	3.200E-03	1.600E-03	5.000E-03
Hexachloroethane	2.100E-01	2.100E-02	6.300E-05	2.000E-04
Nhexane	2.100E-01	2.100E-02	6.300E-05	2.000E-04
1hexanol	5.900E+00	5.900E-01	2.000E-07	6.300E-07
2hexanone	5.900E+00	5.900E-01	2.000E-07	6.300E-07

Isophorone	4.800E-01	4.800E-02	4.600E-06	4.600E-06
Lindane	2.700E-01	2.700E-02	4.000E-05	1.300E-04
Methonal	1.100E+02	1.100E+01	1.300E-09	4.200E-09
Methchloride	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Methylcyclo	8.300E-01	8.300E-02	5.700E-06	1.800E-05
MethylIso	7.700E+00	7.700E-01	1.300E-07	4.000E-07
MMetacrylate	6.700E+00	6.700E-01	1.600E-07	5.000E-07
MethylEthylB	3.500E-01	3.500E-02	2.500E-05	7.900E-05
2Methylnaptha	2.100E-01	2.100E-02	6.300E-05	2.000E-04
MethylPropylB	3.500E-01	3.500E-02	2.500E-05	7.900E-05
Naphthalene	4.600E-01	4.600E-02	1.600E-05	5.000E-05
4Nitrobenzenamin	6.800E+00	6.800E-01	2.000E-07	6.200E-07
Nitrobenzene	3.400E+00	3.400E-01	5.000E-07	1.600E-06
2Nitrophenol	3.600E+00	3.600E-01	4.900E-07	1.600E-06
4Nitrophenol	3.000E+00	3.000E-01	6.300E-07	2.000E-06
NnitroNpropyl	5.900E+00	5.900E-01	2.000E-07	6.300E-07
NNitrosodiphen	6.100E-01	6.100E-02	9.900E-06	3.000E-05
Phenol	5.100E+00	5.100E-01	2.500E-07	7.900E-07
PropylB	3.500E-01	3.500E-02	2.500E-05	7.900E-05
PropGlycol	3.700E+02	3.700E+01	1.600E-10	5.000E-10
Pyridine	6.700E+00	6.700E-01	1.600E-07	5.000E-07
Styrene	7.900E-01	7.900E-02	6.300E-06	2.000E-05
1112Tetra	6.900E-01	6.900E-02	7.900E-06	2.500E-05
1122Tetra	1.500E+00	1.500E-01	2.000E-06	6.300E-06
Tetrachloroethen	3.000E-01	3.000E-02	1.000E-05	1.000E-05
2346Tetrachlor	1.600E-01	1.600E-02	9.900E-05	3.100E-04
Toluene	2.600E-01	2.600E-02	1.300E-05	1.300E-05
124Trichlorb	2.440E-01	2.440E+00	4.800E-05	1.500E-04
Trichloroethene	4.100E-01	4.100E-02	6.000E-06	6.000E-06
TriChloFlo	1.300E+00	1.300E-01	2.500E-06	7.900E-06

***** PEAK CONCENTRATIONS AND TIMES FOR PATHWAY 1 *****
***** RIVER AT 476.0 M *****

CONTAMINANT	PEAK CONCENTRATION (MG/L)	PEAK TIME (YR)	AVERAGE DOSE AT PEAK TIME (MG/KG-DAY)	AVERAGE RISK AT PEAK TIME (HE/LIFE)	FRACTION OF ADI
24-D	1.05E+00	786.2	1.50E-02		1.50E+00
245-TP(silvex)	3.08E-01	971.1	4.42E-03		5.53E-01
Acenaphthene		> 15000.0			
Acenaphthylene		> 15000.0			
Acetone	3.03E+00	752.7	4.34E-02		4.82E-02
Acentonitrile	3.50E+00	682.4	5.01E-02		
acetophenone	2.63E+00	847.1	3.76E-02		3.76E-01
Acrolien	3.48E+00	684.7	4.98E-02		9.97E+01
Acylonitrle	3.46E+00	687.7	4.96E-02	2.68E-02	1.24E+00
Aldrin		> 15000.0			
Aroclor1221		> 15000.0			
Aroclor1232		> 15000.0			
Benzene	4.88E-01	3501.0	6.98E-03	3.84E-04	1.75E+00
Benzoic-acid	3.50E+00	681.8	5.01E-02		1.25E-02
Benzyl-alcohol	3.15E+00	736.4	4.52E-02		4.52E-01
benzidine	1.67E-01	11495.9	2.40E-03	5.51E-01	7.99E-01
Alpha-BHC	1.23E-02	7059.3	1.77E-04	1.11E-03	2.21E-02
Beta-BHC	1.23E-02	9139.8	1.77E-04	3.19E-04	
Delta-BHC	1.23E-02	9139.8	1.76E-04	3.17E-04	
Bromodichloro	3.38E+00	699.2	4.84E-02	3.00E-03	2.42E+00
Bromoform	1.54E-01	1136.4	2.20E-03	1.74E-05	1.10E-01
Bromometh	3.19E+00	730.9	4.56E-02		3.26E+01
butylbenzene	9.43E-02	4239.5	1.35E-03		2.70E-02
Carbazole	2.77E-03	14048.4	3.98E-05	7.95E-07	
CarbonDiS	1.81E+00	866.3	2.60E-02		2.60E-01
Carbontetchl	3.89E-01	3609.0	5.57E-03	3.90E-04	1.39E+00
Chlordane		> 15000.0			
Chlorobenzene	7.66E-01	1473.5	1.10E-02		5.49E-01
Chloroform	1.08E+00	1708.6	1.54E-02	4.78E-04	1.54E+00

Chlorometh	3.18E+00	731.5	4.56E-02		
0-ChloroTu	5.75E-01	2285.4	8.25E-03		4.12E-01
m-cresol	2.61E+00	852.9	3.73E-02		7.46E-01
o-cresol	2.11E+00	1009.5	3.02E-02		6.05E-01
p-cresol	2.63E+00	846.7	3.77E-02		3.77E-01
Cumene	9.43E-02	4281.8	1.35E-03		1.35E-02
Cyanide	9.46E-02	20174.3	1.35E-03		2.26E+00
DDD		> 15000.0			
DDE	6.15E-05	3815.1	1.07E-06	3.64E-07	
Dinbutylphthalat	3.52E+00	679.6	5.89E-02		5.89E-01
Dibenz[ah]		> 15000.0			
Dibenzofuran		> 15000.0			
Dibromochloro	2.32E+00	935.2	3.32E-02	2.79E-03	1.66E+00
12Dichloro	1.23E-01	2053.4	1.76E-03		1.96E-02
13Dichloro		> 15000.0			
14Dichlorobenzen	1.25E-01	2912.5	1.79E-03	9.68E-06	2.56E-02
12cisDichloro	7.58E-01	2691.9	1.09E-02		5.43E+00
12transDichl	2.75E+00	817.4	3.94E-02		1.97E+00
Dichlorodiflo	4.31E-01	704.5	6.17E-03		3.08E-02
12Dichlprop	2.62E+00	850.0	3.75E-02	1.35E-03	4.16E-01
Dieldrin		> 15000.0			
Diethylphth	1.66E+00	1136.4	2.38E-02		2.97E-02
12DiMethylB	3.38E-01	1549.6	4.85E-03		2.42E-02
24-Dimethylphe	3.44E-01	5684.1	4.93E-03		2.47E-01
Dimethylphth	2.77E+00	814.1	3.96E-02		3.96E-03
24Dinitrotoluene	4.15E-01	864.5	5.95E-03	1.84E-03	2.97E+00
26Dinitrotoluene	5.41E-01	831.7	7.75E-03		7.75E+00
EndosulfanII	6.92E-04	30359.4	9.93E-06		1.65E-03
Endrin		> 15000.0			
Aldehyde		> 15000.0			
Ketone		> 15000.0			
Ethylbenz	2.60E-01	1419.1	3.72E-03	4.10E-05	3.72E-02
Ethylchlorid	3.00E+00	765.7	4.29E-02		
Heptachlor		> 15000.0			
Heptachlor-epoxd		> 15000.0			
Hexachlorobenzen		> 15000.0			
Hexachloroethane	7.69E-02	7131.8	1.11E-03	4.42E-05	1.58E+00
Nhexane	1.46E-02	1219.7	2.10E-04		3.50E-03
1hexanol	3.21E+00	726.8	4.60E-02		1.15E+00
2hexanone	3.21E+00	726.8	4.60E-02		9.20E+00
Isophorone	4.88E-01	3501.0	6.98E-03	6.64E-06	3.49E-02
Lindane	1.23E-02	12931.5	1.77E-04	1.94E-04	5.89E-01
Methonal	3.49E+00	683.3	5.00E-02		1.00E-01
Methchloride		> 15000.0			
Methylcyclo	2.15E-02	679.6	3.09E-04		5.14E-03
MethylIso	3.46E+00	688.2	4.95E-02		6.19E-01
MMetacrylate	3.28E+00	715.9	4.69E-02		3.35E-02
MethylEthylB	9.38E-02	3670.1	1.35E-03		3.64E-02
2Methylnaptha	3.78E-02	11445.3	5.44E-04		1.36E-01
MethylPropylB	9.38E-02	3670.1	1.35E-03		3.64E-02
Naphthalene		> 15000.0			
4Nitrobenzenamin	1.65E-08	1303.1	2.36E-10	4.71E-12	5.89E-08
Nitrobenzene	2.39E+00	913.4	3.42E-02		1.71E+01
2Nitrophenol	9.78E-01	1966.4	1.40E-02		2.26E-01
4Nitrophenol	8.38E-01	2263.7	1.20E-02		1.94E-01
NnitroNpropyl	1.68E+00	1223.4	2.40E-02	1.68E-01	
NNitrosodiphen	5.38E-02	1865.0	7.71E-04	3.78E-06	
Phenol	1.74E+00	1187.1	2.49E-02		8.30E-02
PropylB	9.38E-02	3670.1	1.35E-03		3.64E-02
PropGlycol	3.49E+00	683.3	5.00E-02		2.50E-03
Pyridine	3.35E+00	704.7	4.79E-02		4.79E+01
Styrene	4.60E-01	4309.7	6.59E-03		3.29E-02
1112Tetra	1.63E+00	1256.0	2.33E-02	6.06E-04	7.77E-01
1122Tetra	2.23E+00	962.4	3.19E-02	6.39E-03	1.60E+00
Tetrachloroethen	1.29E-01	10524.2	1.85E-03	3.87E-06	3.08E-01
2346Tetrachlor		> 15000.0			
Toluene	1.53E-01	8864.5	2.20E-03		2.75E-02
124Trichlorb	8.77E-02	3289.5	1.26E-03	3.65E-05	1.26E-01
Trichloroethene	3.35E-01	4162.2	4.80E-03	2.21E-04	9.60E+00
TriChloFlo	1.69E+00	1165.4	2.42E-02		8.08E-02

***** PEAK CONCENTRATIONS AND TIMES FOR PATHWAY 2 *****
***** WELL AT .0 M *****

CONTAMINANT	PEAK CONCENTRATION (MG/L)		PEAK TIME (YR)	AVERAGE DOSE AT PEAK TIME (MG/KG-DAY)	AVERAGE RISK AT PEAK TIME (HE/LIFE)	FRACTION OF ADI
24-D	8.84E+01		743.8	1.26E+00		1.26E+02
245-TP(silvex)	2.59E+01		913.3	3.70E-01		4.63E+01
Acenaphthene		>	15000.0			
Acenaphthylene	2.09E+00		20917.1	2.98E-02		4.97E-01
Acetone	2.55E+02		719.1	3.65E+00		4.05E+00
Acentonitrile	2.95E+02		648.7	4.21E+00		
acetophenone	2.22E+02		799.6	3.16E+00		3.16E+01
Acrolien	2.93E+02		650.7	4.19E+00		8.38E+03
Acylonitrle	2.92E+02		653.5	4.17E+00	2.25E+00	1.04E+02
Aldrin		>	15000.0			
Aroclor1221		>	15000.0			
Aroclor1232		>	15000.0			
Benzene	4.11E+01		3467.5	5.87E-01	3.23E-02	1.47E+02
Benzoic-acid	2.95E+02		648.1	4.21E+00		1.05E+00
Benzyl-alcohol	2.66E+02		698.1	3.80E+00		3.80E+01
benzidine	1.41E+01		9751.5	2.01E-01	4.63E+01	6.71E+01
Alpha-BHC	1.04E+00		6494.8	1.48E-02	9.33E-02	1.85E+00
Beta-BHC	1.04E+00		7757.6	1.48E-02	2.67E-02	
Delta-BHC	1.04E+00		7757.6	1.48E-02	2.67E-02	
Bromodichloro	2.85E+02		664.1	4.07E+00	2.52E-01	2.04E+02
Bromoform	1.30E+01		1064.8	1.85E-01	1.46E-03	9.26E+00
Bromometh	2.69E+02		693.1	3.84E+00		2.74E+03
butylbenzene	7.95E+00		3354.5	1.14E-01		2.27E+00
Carbazole	2.33E-01		11911.5	3.33E-03	6.67E-05	
CarbonDiS	1.53E+02		817.3	2.19E+00		2.19E+01
Carbontetchl	3.28E+01		3581.1	4.68E-01	3.28E-02	1.17E+02
Chlordane		>	15000.0			
Chlorobenzene	6.46E+01		1373.9	9.22E-01		4.61E+01
Chloroform	9.08E+01		1675.1	1.30E+00	4.02E-02	1.30E+02
Chlorometh	2.68E+02		693.6	3.83E+00		
0-ChloroTu	4.85E+01		2118.3	6.93E-01		3.46E+01
m-cresol	2.20E+02		805.0	3.14E+00		6.27E+01
o-cresol	1.78E+02		948.5	2.54E+00		5.09E+01
p-cresol	2.22E+02		799.3	3.17E+00		3.17E+01
Cumene	7.95E+00		3387.7	1.14E-01		1.14E+00
Cyanide	7.97E+00		17095.6	1.14E-01		1.90E+02
DDD		>	15000.0			
DDE	5.19E-03		3520.6	7.41E-05	2.52E-05	
Dinbutylphthalat	2.96E+02		646.1	4.23E+00		4.23E+01
Dibenz[ah]		>	15000.0			
Dibenzofuran		>	15000.0			
Dibromochloro	1.96E+02		880.4	2.79E+00	2.35E-01	1.40E+02
12Dichloro	1.04E+01		1905.6	1.48E-01		1.65E+00
13Dichloro		>	15000.0			
14Dichlorobenzen	1.05E+01		2693.2	1.51E-01	8.13E-04	2.15E+00
12cisDichloro	6.39E+01		2301.0	9.13E-01		4.56E+02
12transDichl	2.32E+02		772.4	3.31E+00		1.66E+02
Dichlorodiflo	3.63E+01		668.9	5.19E-01		2.59E+00
12Dichlprop	2.21E+02		802.3	3.15E+00	1.13E-01	3.50E+01
Dieldrin		>	15000.0			
Diethylphth	1.40E+02		1064.8	2.00E+00		2.50E+00
12DiMethylB	2.85E+01		1443.7	4.07E-01		2.04E+00
24-Dimethylphe	2.90E+01		4833.2	4.15E-01		2.07E+01
Dimethylphth	2.33E+02		769.4	3.33E+00		3.33E-01
24Dinitrotoluene	3.50E+01		815.6	5.00E-01	1.55E-01	2.50E+02
26Dinitrotoluene	4.56E+01		785.5	6.52E-01		6.52E+02
EndosulfanII	5.83E-02		21027.9	8.33E-04		1.39E-01
Endrin		>	15000.0			
Aldehyde	3.24E-02		99137.9	4.63E-04		1.54E+00
Ketone	3.24E-02		99137.9	4.63E-04		1.54E+00

Ethylbenz	2.19E+01		1324.0	3.13E-01	3.44E-03	3.13E+00
Ethylchlorid	2.52E+02		725.0	3.61E+00		
Heptachlor		>	15000.0			
Heptachlor-epoxd		>	15000.0			
Hexachlorobenzen		>	15000.0			
Hexachloroethane	6.48E+00		6561.3	9.26E-02	3.70E-03	1.32E+02
Nhexane	1.23E+00		1141.3	1.76E-02		2.93E-01
1hexanol	2.71E+02		689.3	3.87E+00		9.66E+01
2hexanone	2.71E+02		689.3	3.87E+00		7.73E+02
Isophorone	4.11E+01		3467.5	5.87E-01	5.58E-04	2.94E+00
Lindane	1.04E+00		11878.3	1.48E-02	1.63E-02	4.94E+01
Methonal	2.94E+02		649.4	4.20E+00		8.40E+00
Methchloride		>	15000.0			
Methylcyclo	1.81E+00		646.1	2.59E-02		4.32E-01
MethylIso	2.91E+02		653.9	4.16E+00		5.20E+01
MMetacrylate	2.76E+02		679.3	3.94E+00		2.82E+00
MethylEthylB	7.91E+00		3387.7	1.13E-01		3.05E+00
2Methylnaptha	3.19E+00		10515.8	4.56E-02		1.14E+01
MethylPropylB	7.91E+00		3387.7	1.13E-01		3.05E+00
Naphthalene		>	15000.0			
4Nitrobenzenamin	1.39E-06		1217.7	1.98E-08	3.96E-10	4.95E-06
Nitrobenzene	2.01E+02		860.5	2.88E+00		1.44E+03
2Nitrophenol	8.25E+01		1825.8	1.18E+00		1.90E+01
4Nitrophenol	7.07E+01		2098.3	1.01E+00		1.63E+01
NnitroNpropyl	1.41E+02		1144.6	2.02E+00	1.41E+01	
NNitrosodiphen	4.54E+00		1732.8	6.48E-02	3.18E-04	
Phenol	1.46E+02		1111.4	2.09E+00		6.98E+00
PropylB	7.91E+00		3387.7	1.13E-01		3.05E+00
PropGlycol	2.94E+02		649.4	4.20E+00		2.10E-01
Pyridine	2.82E+02		669.0	4.03E+00		4.03E+03
Styrene	3.87E+01		3670.2	5.53E-01		2.77E+00
1112Tetra	1.37E+02		1174.5	1.96E+00	5.09E-02	6.53E+01
1122Tetra	1.88E+02		905.3	2.68E+00	5.37E-01	1.34E+02
Tetrachloroethen	1.09E+01		10496.2	1.55E-01	3.26E-04	2.58E+01
2346Tetrachlor		>	15000.0			
Toluene	1.29E+01		8836.6	1.85E-01		2.31E+00
124Trichlorb	7.39E+00		3038.8	1.06E-01	3.06E-03	1.06E+01
Trichloroethene	2.82E+01		4134.3	4.03E-01	1.85E-02	8.06E+02
TriChloFlo	1.43E+02		1091.4	2.04E+00		6.79E+00

APPENDIX I:
COST ESTIMATES FOR ON-SITE AND OFF-SITE DISPOSAL ALTERNATIVES

CONTENTS

FIGURES

TABLES

ACRONYMS

ABC	articulated built container
CD	Critical Decision
CEES	Cost Engineering Estimating System
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
DOE	U.S. Department of Energy
EBCV	East Bear Creek Valley
EMDF	Environmental Management Disposal Facility
EMWMF	Environmental Management Waste Management Facility
EPA	U.S. Environmental Protection Agency
ETTP	East Tennessee Technology Park
FFS	Focused Feasibility Study
FY	Fiscal Year
G&A	General and Administrative
IDIQ	Indefinite Delivery Indefinite Quantity
IWM	Integrated Water Management
K	Thousand
LF	linear foot/feet
LLW	low-level waste
M	Million
NNSS	Nevada National Security Site
NT	Northern Tributary
OMB	Office of Management and Budget
ORR	Oak Ridge Reservation
RAWP	Remedial Action Work Plan
RCRA	Resource Conservation and Recovery Act of 1976
RDR	Remedial Design Report
RI/FS	Remedial Investigation/Feasibility Study
S&M	surveillance and maintenance
TSCA	Toxic Substances Control Act of 1976
UCOR	URS|CH2M Oak Ridge LLC
U.S.	United States
VR	volume reduction
WAC	Waste Acceptance Criteria
WBCV	West Bear Creek Valley
WBS	Work Breakdown Structure

WCS	Waste Control Specialists
WFG	Waste Forecast Generation
Y-12	Y-12 National Security Complex

1. INTRODUCTION

This Appendix provides cost estimates, supporting assumptions, summary cost information, and material pricing for the disposal of future-generated Oak Ridge Reservation (ORR) Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) waste after the existing Environmental Management Waste Management Facility (EMWMF) reaches maximum capacity. Under the On-site Disposal Alternative (various proposed sites, including an Option that provides two small landfill footprints), waste would be disposed in a newly constructed on-site disposal facility(ies) at ORR referred to as the Environmental Management Disposal Facility (EMDF). Under the Off-site Disposal Alternative, waste would be disposed at existing off-site facilities. Two options were defined for off-site disposal:

Option 1 (Major Destination NNSS):

- All classified waste disposed by Nevada National Security Site (NNSS).
- All mixed waste disposed by Energy*Solutions* and/or Waste Control Specialists (WCS).
- All low-level waste (LLW) and LLW/Toxic Substances Control Act of 1976 (TSCA) disposed by NNSS.

Option 2 (Major Destination Energy*Solutions*):

- All classified waste disposed by NNSS.
- All mixed waste disposed by Energy*Solutions* and/or WCS.
- All LLW and LLW/TSCA disposed by Energy*Solutions.*

Lastly, a Hybrid Disposal Alternative combines a small on-site facility (proposed location is Site 6b of the Dual Site Option) with off-site disposal.

CERCLA waste will be generated from environmental restoration activities on the ORR and associated sites. Individual demolition and remediation projects are responsible for any treatment of waste to meet Waste Acceptance Criteria (WAC) (e.g., to meet Land Disposal Restrictions) and transport of waste to the new disposal facility for the On-site/Hybrid Disposal Alternatives and/or to a centrally located transfer station for the Off-site/Hybrid Disposal Alternatives. The cost of this transportation (project to alternative) is therefore not included in either estimate as it is currently assumed this cost is equivalent for all alternatives. An unfunded risk to the Off-site Disposal Alternative has been identified concerning transportation to the rail transloading station at the East Tennessee Technology Park (ETTP), which will become a public industrial park in the future. As a public site, stringent transportation requirements would become applicable to this transfer (from demolition site to transloading station) with associated costs.

Candidate waste streams addressed under these disposal alternatives are LLW and mixed waste with components of radiological and other regulated waste such as Resource Conservation and Recovery Act of 1976 (RCRA) hazardous waste and TSCA-regulated waste (LLW/RCRA, LLW/TSCA). For the Remedial Investigation/Feasibility Study (RI/FS) evaluation, material types are defined as either soil or debris. See Chapter 2 of the RI/FS for additional information about candidate waste streams.

Major cost elements for the On-site Disposal Alternative Options are design and construction of the landfill and supporting infrastructure, operation and management of the disposal cells, capping and closure, and post-closure monitoring and maintenance. Major cost elements of the Off-site Disposal Alternative are packaging and transportation of waste to the off-site facilities and fees for disposal. All costs associated with treatment of wastes to meet facility WAC are assumed to be covered under specific project scope/funds, and so are not included in these costs. In the case of the Hybrid Disposal Alternative, it is assumed to have elements of on-site disposal and off-site disposal, and major cost elements for that alternative are similar to the “only” on-site and “only” off-site alternatives.

Waste volumes estimated to be generated and disposed are fundamental assumptions in determining the cost for all disposal alternatives. Details about the as-generated and as-disposed waste volume estimates that are used in the cost estimates are provided in Chapter 2 and Appendix A of the RI/FS. A summary of those volumes is given in Table I-1.

Contingency has been added for both the On-site and Off-site Disposal Alternative cost estimates based on guidance provided in the United States (U.S.) Environmental Protection Agency's (EPA's) *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study*, July 2000. Likewise, for the Hybrid Disposal Alternative, contingency is applied for each portion, using the same contingencies as the on- and off-site alternatives. Contingency on a cost estimate is typically applied as two elements: scope contingency and bid contingency. Scope contingency accounts for unknowns concerning the design: costs that are unforeseen/undocumented at the time of estimating due to lack of clarity/granularity. Bid contingency accounts for unforeseen conditions: weather, material cost increases, and situations outside the control of a project.

Table I-1. As-generated Waste Volume Estimate with Uncertainty

Material Type	**Waste Type**		**TOTAL by Material Type (yd^3)**
	LLW (includes LLW/TSCA)	**Mixed (LLW/RCRA, LLW/RCRA/TSCA)**	
25% Uncertainty applied to As-generated Estimates			
Debris	1,151,440	149,418	1,300,858
Debris/Classified[a]	35,612	4,621	40,233
Soil	540,115	67,353	607,468
Total	**1,727,167**	**221,391**	**1,948,559**

[a] Some percentage of debris waste is expected to be classified, but is currently not specified as such in the Waste Generation Forecast. Three percent of generated debris is assumed to be classified for purposes of off-site disposal evaluation (based on 3% of waste from ETTP considered classified in the WGF).

For the on-site cost estimates a 22% contingency was applied to all elements except operations, based on 7% scope contingency, and 15% bid contingency. EPA recommends a 5–10% scope contingency for clay caps, 5–10% scope contingency for surface grading/diking, and 10–20% scope contingency for synthetic caps. A lower end 7% scope contingency was selected based on the fact that needed design considerations have been readily available from the existing EMWMF design. A mid-range bid contingency (EPA recommends 10–20%) was applied, 15%, to account for changing conditions (e.g. material pricing and weather disruptions). Contingency on operations was held to 5% since the U.S. Department of Energy (DOE) currently operates an existing and very similar landfill, and those costs are very well known. Operations that have not previously been performed (e.g., landfill water treatment) carry the 22% contingency.

For the off-site estimate, the scope contingency was estimated at 12%, toward the higher value recommended by EPA (off-site disposal 5–15% contingency range) since the scope (e.g., disposal cost per volume of waste) used in the estimate is not adjusted for surcharges that are likely to be leveled (e.g., those for fuel, over-sized equipment disposal, water content of soils). A mid-value bid contingency of 15% is applied due to the significant risk inherent in an alternative that might be affected by external uncontrollable influences such as travel across state lines, potential for modified off-site availability, and the unusually long timeframe in which waste is expected to be generated. Therefore a total 27% contingency is applied to the off-site alternative.

Additionally, the waste volume contingency of 25% that is accounted for in both on-site and off-site alternatives is part of the analysis, and therefore is present in both estimates as additional contingency. Table I-1 summarizes the volumes considered for all alternatives including the 25% volume contingency. For the On-site Disposal Alternative, this 1.95 Million (M) yd^3 as-generated volume results in 2.18 M yd^3 as-disposed volume (required disposal capacity) as demonstrated in Chapter 2 (see Tables 2-3 and 2-4 in Chapter 2). This is the capacity provided by five cells in both the East Bear Creek Valley (EBCV) Site Option and West Bear Creek Valley (WBCV) Site Option, whereas the conceptual designs for both those facilities are six cell designs. The Dual Site Option (Sites 6b and 7a) provides a 2.25 M yd^3 capacity. The costs developed for the EMDF at the EBCV and WBCV proposed locations throughout this Appendix are for the whole conceptual design capacity of six cells as well as the five cell buildout. Because only five cells are currently projected to be required (per the volume estimate), and that is the volume of waste assumed for the Off-site Disposal Alternative, a five cell estimated cost for the On-site Disposal Alternative EBCV and WBCV Options is used to compare to the Off-site Disposal Alternative cost.

Table I-2 summarizes the costs for the On-site, Hybrid, and Off-site Disposal Alternatives in Fiscal Year (FY) 2012 and 2016 dollars, future (escalated) cost, and present worth project cost for FY 2016. Details regarding the estimates are found in the subsequent sections. In terms of comparing costs, it is best to compare the Present Worth estimates, which are given in FY 2016 dollars; and on a cost basis of dollars per yd^3 of waste, those numbers are the last entries in Table I-2. As shown, the on-site disposal costs are lowest, followed by hybrid disposal, with off-site disposal being the most costly.

1.1 ALTERNATIVE DESCRIPTIONS

Summary descriptions of the On-site, Hybrid, and Off-site Disposal Alternatives that were developed for analysis in the RI/FS are provided below.

1.1.1 On-site Disposal Alternative

The On-site Disposal Alternative proposes the consolidated disposal of CERCLA waste in a newly constructed disposal facility on the ORR. Several possible site locations are examined; costs are provided for all sites. Sites proposed include:

- EBCV Site Option, a site just east of the existing EMWMF (Option 5 in Appendix D).
- WBCV Site Option, a site located approximately 2.5 miles west of the existing EMWMF (Option 14 in Appendix D).
- Dual Site Option, which includes a site beside and to the west of the existing EMWMF (6b) and a second site (7a), located 1.5 miles west of the existing EMWMF (Options 6b/7a in Appendix D).

The scope of actions for these alternative Options includes early actions (i.e., pre-design investigations and required CERCLA and DOE order documentation and reviews); design and construction of all facilities; design support during construction, quality assurance, quality controls; operations for receiving waste, meeting the WAC, unloading the waste and placing it into the disposal cells; decontaminating any containers, equipment, or vehicles leaving the site; managing the waste and the disposal cells during construction, operations, closure, and post-closure; and final capping (design and construction) and closure of the facility.

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Table I-2. Summary of Estimated Costs for CERCLA Waste Disposal Alternatives based on 1.948 M yd^3 of Waste Disposed

Description of Cost	On-site Disposal Alternative			Hybrid Disposal Alternative	Off-site Disposal Alternative	
	EBCV Site Option (Five Cell Buildout)	WBCV Site Option (Five Cell Buildout)	Dual Site Option Site 6b and Site 7a	On-site (Site 6b) and Off-site	Option 1	Option 2
Life-cycle Cost (FY 2012 $)	$613,373,017	$625,360,532	$760,232,876	$1,075,342,439	$1,355,288,173	$1,180,298,901
Contingency	$72,474,440	$75,725,320	$100,790,134	$235,374,342	$365,927,807	$318,680,703
Life-cycle Cost with Contingency (FY 2012 $)	$685,847,457	$701,085,853	$861,023,011	$1,310,716,781	$1,721,215,979	$1,498,979,605
Life-cycle Cost with Contingency (FY 2016 $)	$716,532,116	$732,614,611	$899,626,030	$1,369,645,965	$1,799,014,941	$1,566,733,483
Escalated Cost with Contingency	$1,036,797,696	$1,048,899,789	$1,305,877,368	$2,016,877,739	$2,650,519,526	$2,273,455,268
Present Worth[a] Cost with Contingency	$542,869,155	$557,681,735	$676,224,167	$1,144,179,105	$1,494,358,468	$1,315,127,421
Disposal Cost ($/yd^3) FY 2012 $ with Contingency	$352	$360	$442	$673	$883	$769
Disposal Cost ($/yd^3) FY 2016 $ with Contingency	$368	$376	$462	$703	$923	$804
Disposal Cost ($/yd^3) Escalated Cost with Contingency	$532	$538	$670	$1035	$1,360	$1,167
Disposal Cost ($/yd^3) Present Worth[a,b] with Contingency	$279	$286	$347	$587	$767	$675
	On-site Disposal Alternative (all sites): Lifecycle: • 1,948,559 yd^3 of waste disposed • DOE Orders and CERCLA compliance • 22 years of operation (base operations; leachate treatment; security) • All capital costs for phased construction (three phases, each option) • Five of six cells buildout for EBCV and WBCV sites; Dual Site Option full buildout • Includes final capping of landfill • Demolition of structures Long-term Care: • 1,000 years • Routine and non-routine surveillance and maintenance, 5-year reviews, monitoring, etc.			**Hybrid Disposal Alternative:** • 1,948,559 yd^3 of waste disposed • DOE Orders and CERCLA compliance • Packaging in Intermodal/sealands/super gondolas for off-site portion • Volume reduction (VR) implemented in on-site portion • Transloading to rail in full off-site portion • On-site portion has a 12 year operation life • Transporting to Off-site Disposal Site via Off-site Disposal Alternative Option 2	**Off-site Disposal Alternative:** • 1,948,559 yd^3 of waste disposed • DOE Orders and CERCLA compliance • Packaging in Intermodal/sealands/super gondolas • Volume reduction implemented in Option 2 only • Transloading to rail • Transporting to disposal site (NNSS in Option 1 and primarily Energy*Solutions* in Option 2)	

[a] Present Worth in FY 2016 dollars, discount rate of 1.5%.

[b] Present Worth includes long-term care surveillance and maintenance and cap repair. See Section 3.3 for details.

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The envisioned on-site EMDF would consist of an engineered waste disposal facility or facilities (i.e., landfill[s]) with sufficient capacity to accept the anticipated volume of CERCLA waste and ancillary facilities to support operations. As discussed in Chapter 2 of the RI/FS, the estimated needed future capacity varies with changes in actual disposed volumes and future waste volume projections, as well as projected uncertainty. An on-site facility(ies) is estimated to receive waste for approximately 22 years (i.e., FY 2022 through FY 2043) followed by closure (through FY 2047). Support facilities required for initial operations would include those needed for staging of waste, receiving and unloading waste, and management of landfill wastewater. Siting near EMWMF would allow many of the support facilities already constructed for EMWMF to be shared with EMDF (see Section 6.2.2.5 of the RI/FS). New support infrastructure would be required for the proposed sites (WBCV and Site 7a), which are located some distance from EMWMF. The conceptual design of EMDF at the EBCV and WBCV sites would provide a disposal capacity of approximately 2.5 or 2.8 M yd^3, respectively, and it is projected that only five cells will be filled at either site based on the current Waste Generation Forecast (WGF). For the Dual Site Option (two landfills) a combined disposal capacity of 2.25 M yd^3 is estimated, and would be fully utilized; therefore the estimate for this On-site Option is the full buildout of those footprints.The representative process option for the On-site Disposal Alternative Options is construction of an engineered waste disposal facility for on-site disposal of radioactive or mixed wastes and implementation of long-term institutional controls for this EMDF. Key elements of the proposed disposal facilities include an underdrain (of varying sizes based on topography of individual sites) beneath the landfill to intercept and drain ground water; a compacted clay geobuffer; a multilayer liner with a double leachate collection detection system; a dike constructed of clean fill material to contain the waste laterally; upgradient geomembrane-lined diversion ditch with shallow french drain to divert upgradient surface water and shallow perched ground water around the landfill; and a multilayer cap that contains layers of clay, geosynthetic liner, sand, and cobblestones to minimize infiltration and isolate the waste from human and environmental receptors. Section 6.2 of the RI/FS provides a more-detailed description of the proposed facility and the possible locations for the On-site Disposal Alternative. The conceptual site layout plans for EMDF are shown in Figures I-1 through I-4.

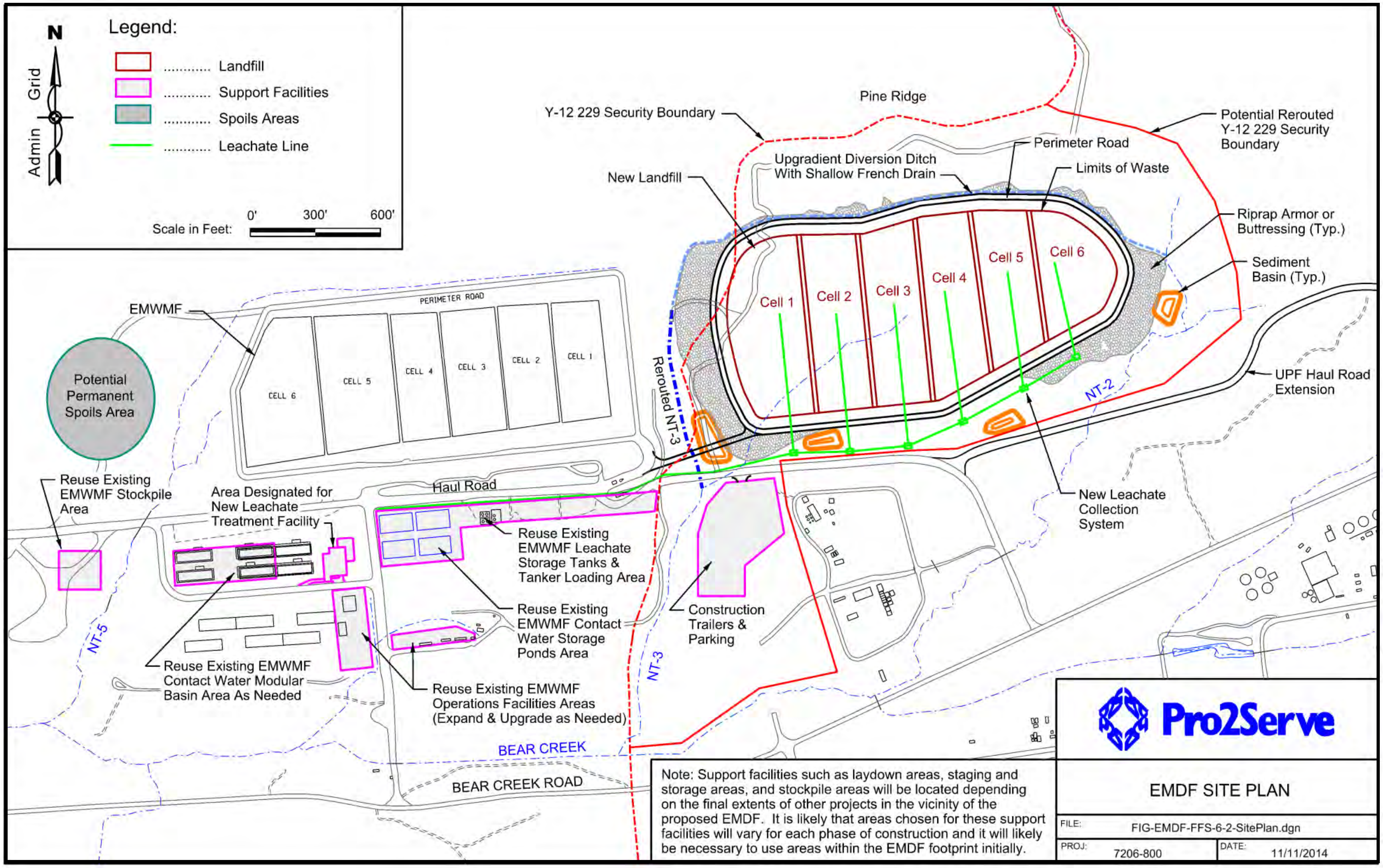

Figure I-1. On-site EMDF Conceptual Site Layout Plan at EBCV Site

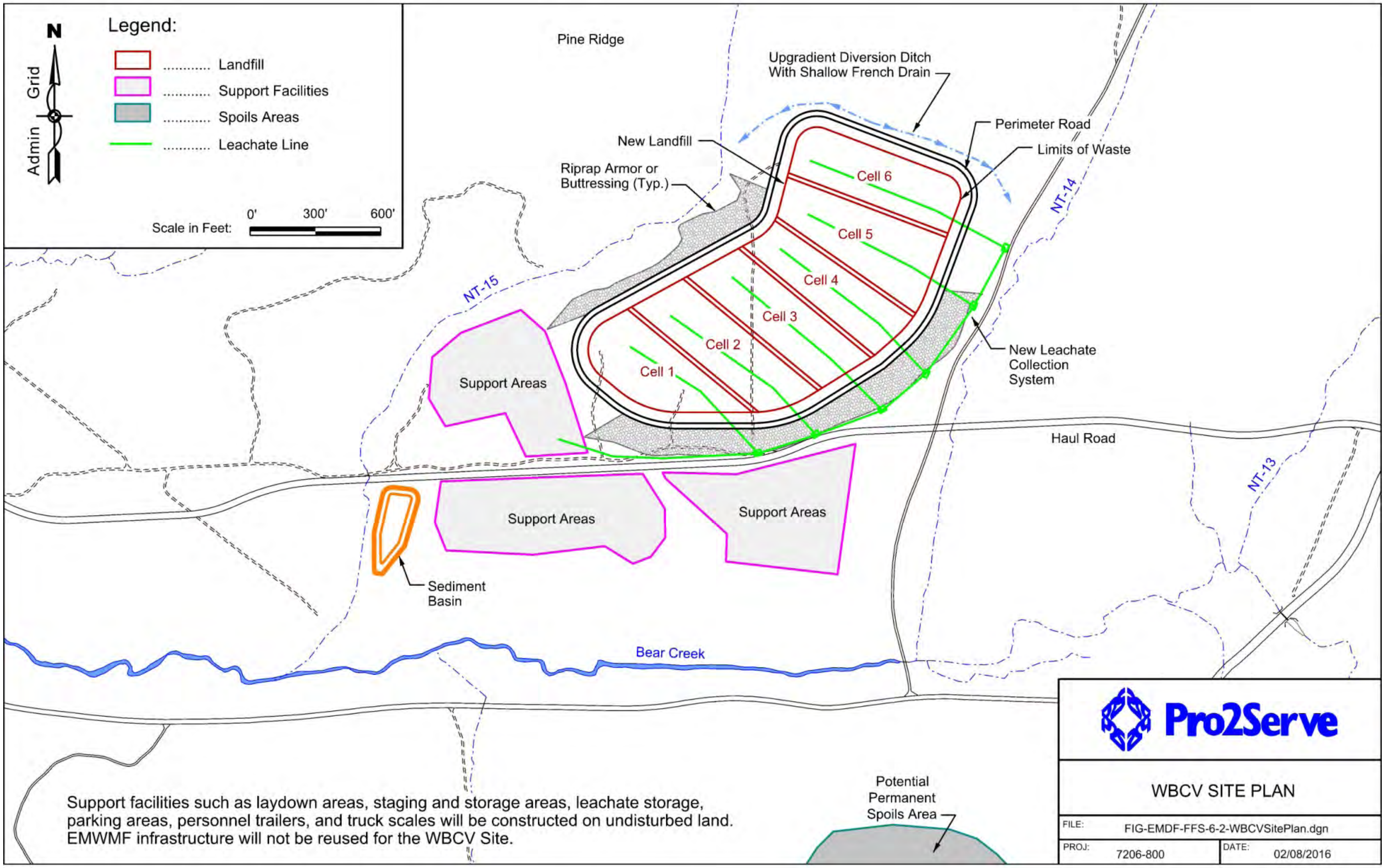

Figure I-2. On-site EMDF Conceptual Site Layout Plan at WBCV Site

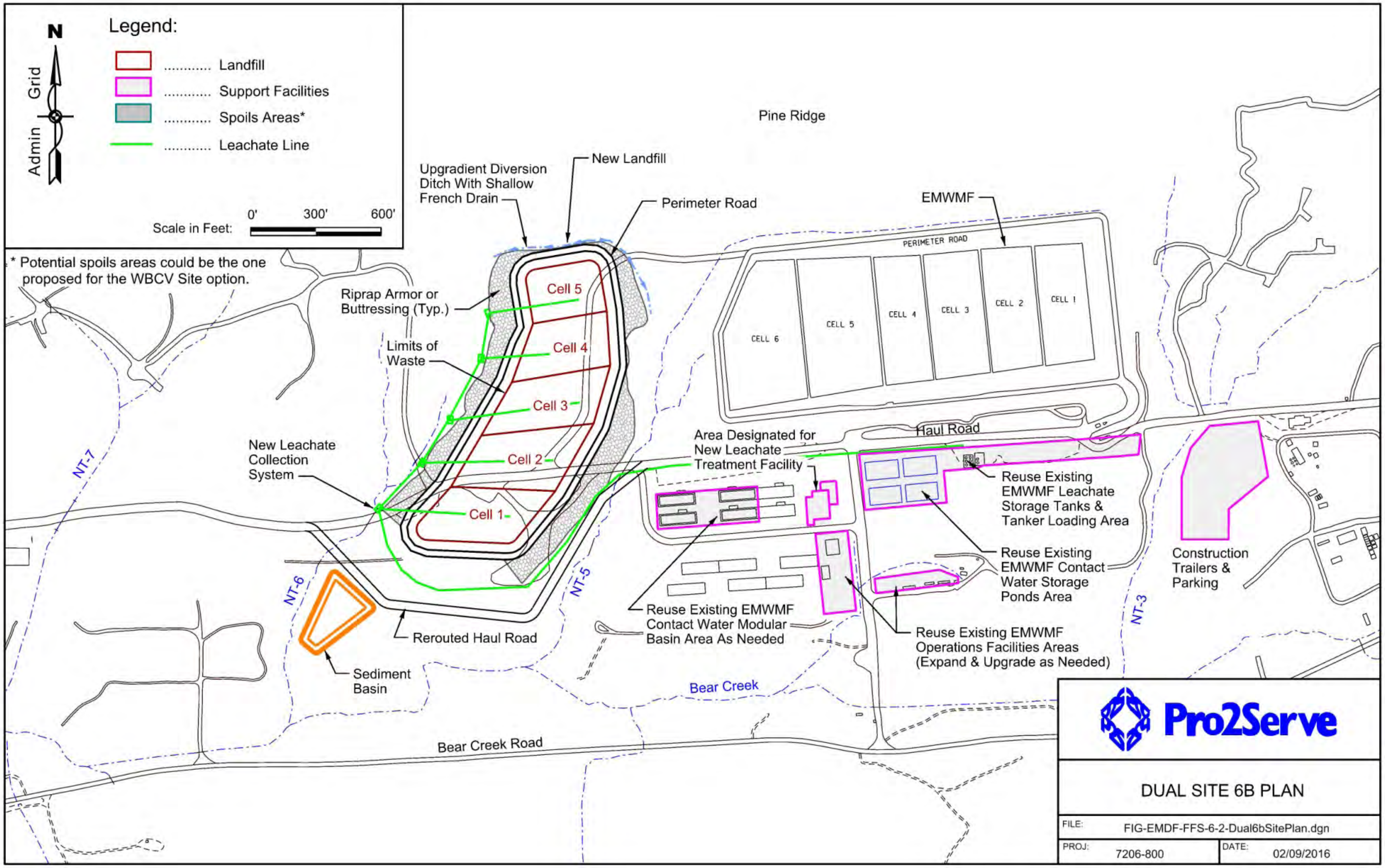

Figure I-3. On-site EMDF Conceptual Site Layout Plan at Site 6b of the Dual Site Option or Hybrid Alternative

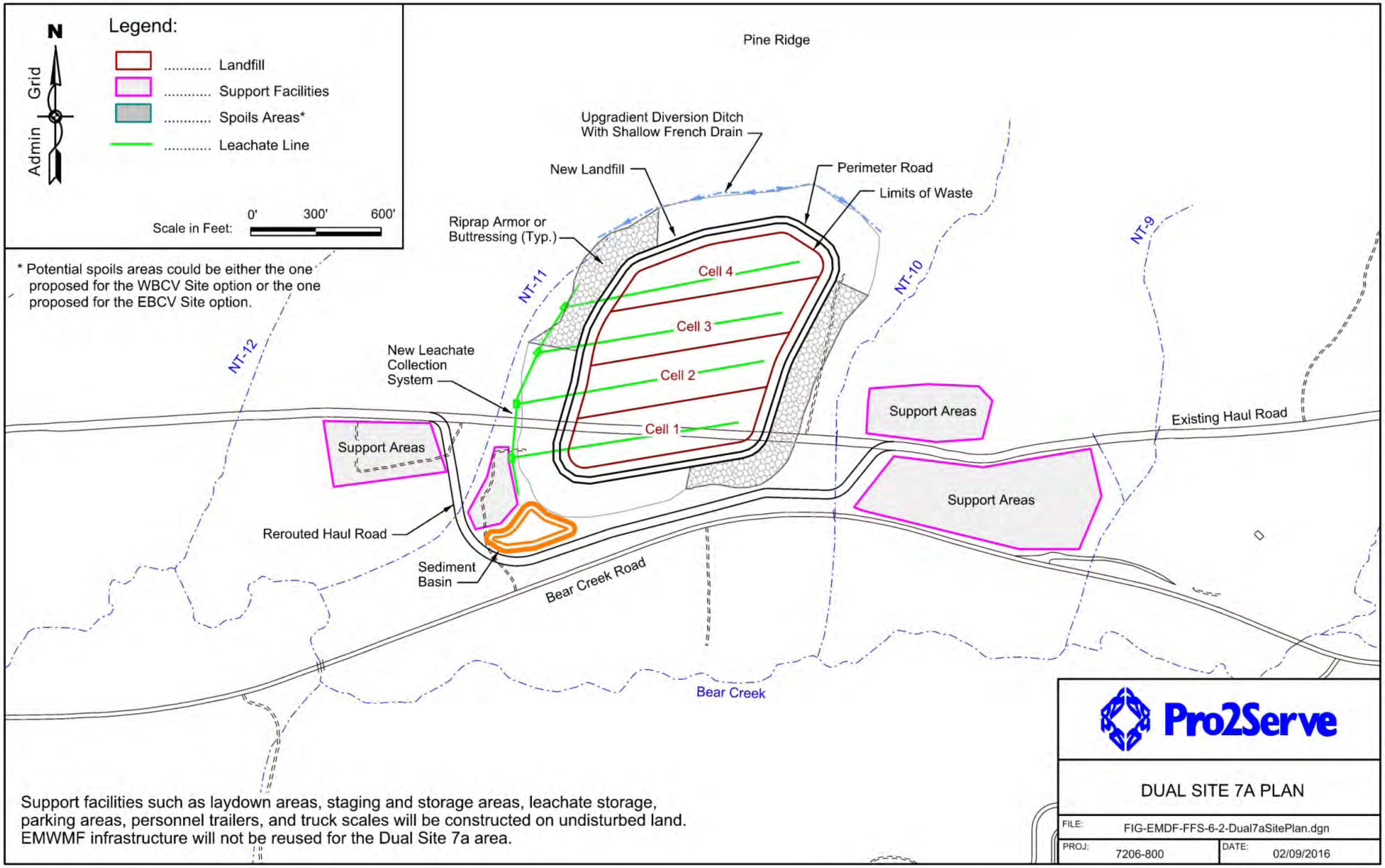

Figure I-4. On-site EMDF Conceptual Site Layout Plan at Site 7a of the Dual Site Option

1.1.2 Off-site Disposal Alternative

This alternative provides for the transportation of future candidate waste streams off the ORR to approved disposal facilities and placement of the wastes in those facilities. For purposes of the cost estimate, two options are examined: non-classified LLW and LLW/TSCA waste would be shipped to either NNSS in Nye County, Nevada, or Energy*Solutions* in Clive, Utah. Any classified LLW or LLW/TSCA waste would be shipped for disposal at NNSS in Nye County. Classified mixed waste would be treated by the generator to meet the NNSS WAC prior to shipment to NNSS. Any mixed (LLW/RCRA) waste requiring treatment (e.g., the mercury-contaminated debris) is assumed to go to either Energy*Solutions* or WCS in Andrews, Texas, where it would undergo treatment to meet land disposal restrictions and be disposed. However, costs for that treatment are assumed to be covered by the generator (project generating the waste) and are therefore not included. Any other waste generator costs for treatment of waste to meet the facility WAC are not included in the Off-site Disposal Alternative estimate.

All non-classified waste would be shipped by rail to Energy*Solutions* or NNSS. For transfer to NNSS, rail transport would end in Kingman, Arizona, where intermodals would be transferred to trucks for the final transport to NNSS. Thus two options are considered. VR, in a facility assumed to be located close to the transloading station at ETTP would be implemented for Option 1 only, as Option 2 is a weight-limited transportation scenario (e.g., reducing volume will not change the weight transport analysis). Appendix B contains the details regarding the assumed VR. The cost savings is applied within this Appendix (see Chapter 4 of this Appendix). The two options are:

Option 1 (Major Destination NNSS):

- All classified waste disposed by NNSS.
- All mixed waste disposed by Energy*Solutions* and/or WCS.
- All non-classified LLW and LLW/TSCA disposed by NNSS.

Option 2 (Major Destination Energy*Solutions*):

- All classified waste disposed by NNSS.
- All mixed waste disposed by Energy*Solutions* and/or WCS.
- All non-classified LLW and LLW/TSCA disposed by Energy*Solutions*.[1]

1.1.3 Hybrid Disposal Alternative

The Hybrid Disposal Alternative is a combination of on-site disposal and off-site disposal. A small on-site facility is proposed to be constructed at Site 6b. VR will be implemented to conserve on-site capacity. Future CERCLA waste generated that exceeds the capacity of the on-site facility will be disposed off-site via the same assumptions as the Off-site Disposal Alternative, Option 2. During operation of the on-site facility, 10% of the debris waste will be disposed of off-site. During operation of the on-site facility, all classified waste generated will be disposed of on-site.

1.1.4 Project Schedules

Project schedules for the Hybrid and On- and Off-site Disposal Alternatives are based on the estimated future waste-generation rates. It is assumed that waste would be disposed of on-site or off-site in the same

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[1] Note this assumption that all (non-classified) LLW and LLW/TSCA waste is disposed at Energy*Solutions* necessarily also assumes that all non-classified LLW and LLW/TSCA waste is Class A waste. There will likely be a small portion of waste that will exceed Class A, and require disposal at NNSS, which would proportionally increase the cost of this option.

year it is generated. The schedule for the Off-site Disposal Alternative is directly linked to the as-generated waste volume estimate, and occurs from FY 2022 to FY 2043. No adjustment to the off-site schedule (and thus cost) has been made to account for additional funding demands this alternative, if fully implemented, would require on an annual basis. The off-site schedule/cost assumes that the DOE ORR Program would receive correspondingly increased annual budgets to accommodate the additional funding demands. However, if the assumption were made that annual appropriations to the ORR Cleanup Program are not adjusted to accommodate off-site disposal, then a minimum schedule extension of 5-10 years would be required to complete the ORR cleanup, and result in a much higher estimate for the Off-site Disposal Alternative.

Figure I-2 shows the project schedule for the On-site Disposal Alternative (EBCV and WBCV Site Options; the Dual Site Option will require overlap of Site 6b and 7a operations, and require additional characterization and design durations. Phased construction will take place, in four phases rather than three). Operation of the on-site disposal facility would be expected to continue through FY 2043 with closure activities completed by FY 2047. Long-term surveillance and maintenance (S&M) and monitoring would continue after facility closure.

2. ELEMENTS COMMON TO THE ON-SITE AND OFF-SITE DISPOSAL ALTERNATIVES

Key elements common to the On- and Off-site and Hybrid Disposal Alternatives that affect cost estimates include contractual mechanisms, assumptions about excluding cost of the DOE activities, and assumptions regarding responsibilities of the waste generators. Volumes, and therefore costs for off-site shipment of waste not meeting an on-site disposal facility WAC or shipped off-site due to other project-specific factors, are excluded for all disposal alternatives (see Section 2.1.3 of the RI/FS).

For purposes of the estimates for all alternatives, costs for DOE activities are excluded from the estimates for both disposal alternatives as they would be comparable. Cost contingency was added to the On-site or Off-site Disposal Alternative cost estimates, 22% for the on-site estimate applied to all elements except active operations (which received a 5% contingency) and 27% applied to the off-site estimate. Integrating prime contractor General and Administrative (G&A) and fee is applied to the on-site estimate at 15%. The Hybrid Disposal Alternative uses the appropriate on- or off-site contingency for each portion of the alternative.

The waste generators are considered to be responsible for removal of waste during cleanup actions; waste characterization and certification; waste segregation, compaction, or shredding; transport of waste to treatment facilities; treatment as necessary to meet disposal-facility WAC; placement of waste into containers; transport to either the on-site disposal facility or the transfer station at ETTP for off-site shipment; and interim storage, if required, for waste not meeting the disposal facilities' WAC. As waste generator responsibilities that are required regardless of the destination, the costs of these activities are not included in either estimate as they would not represent a discriminating element between the alternatives. Discriminating costs, such as purchasing waste containers and liners for transport to off-site facilities, are included. For classified waste and hazardous waste to be treated at the disposal facility, purchase and single use of containers is assumed. Purchase of liners and a limited number of containers for LLW and LLW/TSCA waste disposal at off-site facilities is assumed for the off-site alternative; containers are assumed to be reused for a 10-year lifetime.

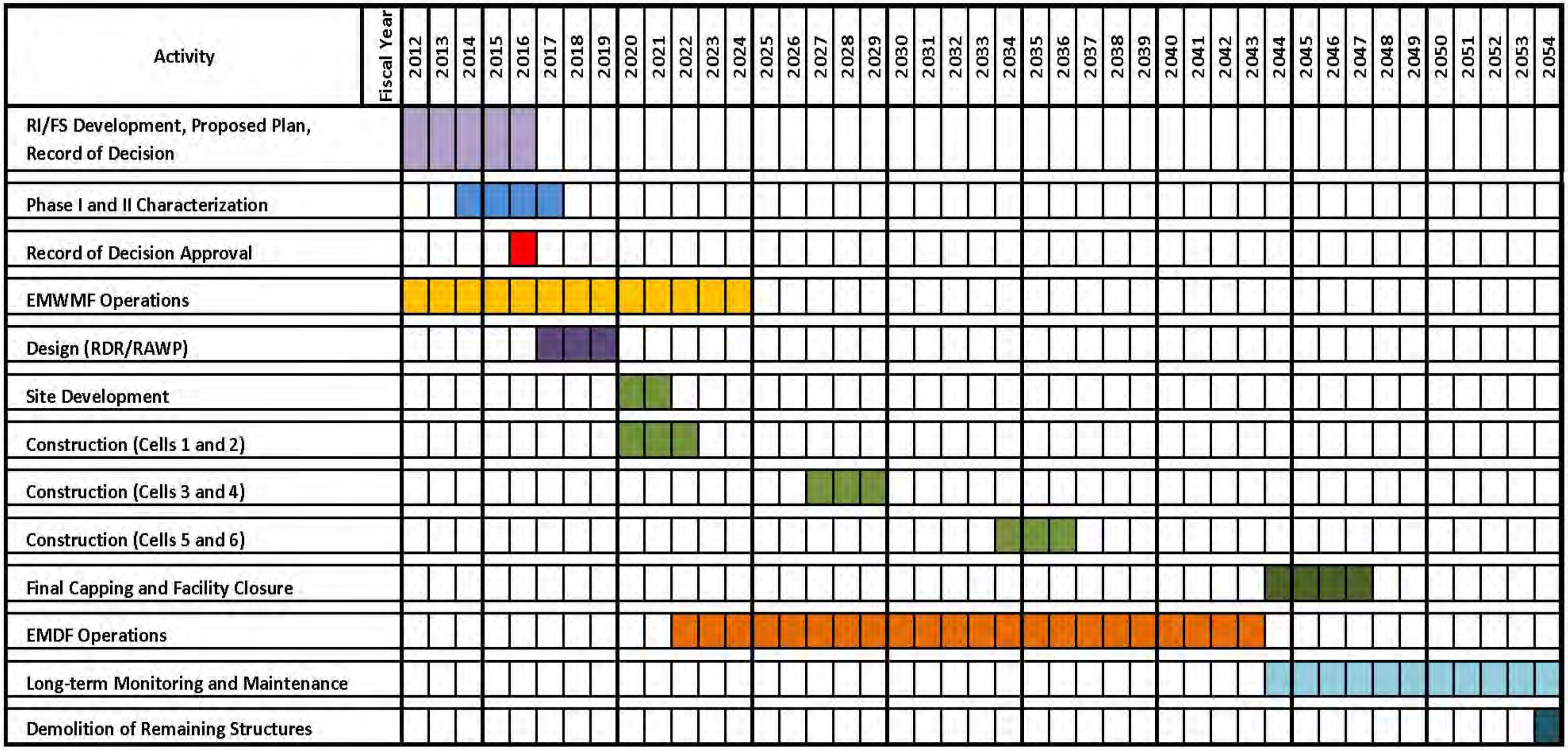

Figure I-5. On-site Disposal Alternative Schedule

3. ON-SITE DISPOSAL ALTERNATIVE COST ESTIMATE

This chapter provides the key assumptions for the On-site Disposal Alternative (all Options) cost estimates, the basis for the estimates, and summary results.

3.1 COST ESTIMATE CONDITIONS AND ASSUMPTIONS

A cost estimate was prepared for the On-site Disposal Alternative with a proposed EMDF sited in EBCV immediately east of EMWMF (see Figure I-1). That estimate was taken and reworked to result in estimates for the WBCV Site Option, and the two facilities (one at Site 6b and one at Site 7a) for the Dual Site Option. All material quantities were based on individual conceptual designs, and updated for each estimate (P2S 2016). This section provides the conditions and assumptions for the on-site EMDF estimate. Elements common to both the On-site and Off-site Disposal Alternative (see Chapter 2 above) are not included in the On-site Disposal Alternative cost estimate.

The On-site Disposal Alternative (all Site Options) would be implemented and managed by a prime contractor to DOE. This contractor would self-perform a portion of the work such as operations and subcontract other work activities as needed. Cost estimates for the On-site Disposal Alternative include early actions, including pre-design characterization and engineering studies along with CERCLA and DOE required documentation/review; remedial design; site development; construction for the entire facility, including waste cell and support facilities; receiving, unloading, and placing of waste into the disposal cell; all operations including placement of waste, daily cover, landfill water management and treatment as needed, and site monitoring; final capping and closure of the landfill; post-closure monitoring and maintenance; and management of all aspects and phases of the project. A Cost Engineering Estimating System (CEES) project value file for materials and labor was used to develop the estimate for each site. No allowance is included for overtime during any phase of the project.

The key assumptions for the On-site Disposal Alternative cost estimate (all sites) are as follows:

- Costs for DOE activities are not included.
- Waste is sequenced and the facility built and operated under the FY 2016 Target Funding Baseline Case ($420M).
- DOE funds all activities for the On-site Disposal Alternative (e.g., construction, operation, and closure).
- Management and Operations Contractor fees and G&A are assumed for all elements at 15%.
- All costs are presented in FY 2012 dollars, escalated dollars, and present worth (present worth given in FY 2016 dollars). Present worth discount rate of 1.5% is used (OMB 2016).
- Escalation calculations assume a 4.52% escalation rate for the whole period 2012 to 2016, and a 2.3% escalation rate thereafter (CPI 2016).
- Assume EMWMF capacity is filled in FY 2024. EMDF (all sites) would have an operational lifespan of approximately 22 years from FY 2022 through FY 2043 and waste would be generated during the 22 years of operation. This schedule assumes approximately two years of operational overlap of the two facilities. The Dual Site Option has two overlap time frames (one between EMWMF and Site 6b operations, and one between Site 6b and 7a operations).
- Activities for the On-site Disposal Alternative began in FY 2012, and will complete in FY 2054 in the current schedule; this is a total life-cycle of 43 years.
- No remediation would be required to construct the new facility.
- The site would be free of radiological materials/contamination during construction activities.

- Review and approval protocols for CERCLA documents would be per the ORR Federal Facility Agreement.
- The total capacity of EMDF at EBCV would be approximately 2.5M yd^3. The disposal facility would be constructed in three phases. Each phase would include the construction of two disposal cells; the entire facility would include six cells.
- The total capacity of EMDF at WBCV would be approximately 2.8M yd^3. The disposal facility would be constructed in three phases. Each phase would include the construction of two disposal cells; the entire facility would include six cells.
- The total capacity of EMDF at Site 6b would be approximately 0.85M yd^3. The disposal facility would be constructed in a single phase.
- The total capacity of EMDF at Site 7a would be approximately 1.4M yd^3. The disposal facility would be constructed in two phases. Phase I would construct 2 cells as would Phase II.
- Site development activities would be performed to prepare the site and provide/modify support facilities and utilities prior to landfill construction. These activities are described in Section 3.2.2.2. Some support facilities would be shared with the existing EMWMF.
- The first phase of landfill construction would include the construction of two waste disposal cells at sites EBCV and WBCV. The Dual Site first phase will construct all of Site 6b.) and the associated structural features necessary for operation of those cells, and future disposal cells. Construction of the first phase would be implemented so that the EMDF is ready to receive waste for approximately two years prior to reaching capacity at EMWMF.
- Phase II (EBCV and WBCV) construction would include the construction of two waste disposal cells (Cells 3 and 4) and the soil contour layer for interim capping of Cells 1 and 2. This construction would occur simultaneously with the operation of the disposal cells.
- Phase II (Dual Site) will construct Cells 1 and 2 of Site 7a.
- Phase III construction (EBCV and WBCV) would include the construction of two waste disposal cells (Cells 5 and 6) and the soil contour layer for interim capping of Cells 3 and 4. This construction would occur simultaneously with the operation of the disposal cells.
- Phase III construction (Dual Site) would include the construction of two waste disposal cells (Cells 3 and 4) and the soil contour layer for interim capping of Cells 3 and 4. This construction would occur simultaneously with the operation of the disposal cells.
- Capping for the Dual Site will be accomplished in a single phase (both sites capped at the same time) at completion of filling both landfills. This would require that Site 6b not be capped for a period of time, but it would require a temporary cover provided by the interim cover.
- The EMDF would be closed with a final cap that would be placed at the conclusion of operation in the final cells including an interim cap (soil contour layer) on those final cells.
- The new disposal facility would be a stand-alone facility. Complete self-supporting infrastructure (e.g., access roads, utilities, disposal cells, leachate collection, treatment facilities, staging, truck scales, etc.) would be constructed or shared with EMWMF (see Section 6.2.2.5 of the RI/FS).
- Waste would be transported from the Y-12 National Security Complex (Y-12) and Oak Ridge National Laboratory to the EMDF on dedicated Haul Roads and not over state maintained roadways.
- EMDF and support facilities would be located in close proximity to one another. Mobile fire and safety equipment/services would be provided by existing DOE ORR facilities.
- All monitoring and alarms would be maintained on-site.
- Davis-Bacon Act regulations regarding local prevailing wage rates would be in effect for all construction and operation activities.

- Borrow areas within 25 miles of the project site would be used for landfill construction and to provide suitable clean fill material for void space reduction in the waste cells.
- No additional verification, sampling, or analysis of incoming waste would be required other than visual inspection, review of manifest, and waste fingerprinting. Verification and documenting meeting WAC attainment requirements is considered part of operations.
- New storage capacity for landfill wastewater is provided, as well as bypass piping for the existing EMWMF and new EMDF.
- Landfill wastewater would be managed by collecting in existing leachate collection tanks and contact water basins located at the EMWMF site as well as new tanks. The Integrated Water Management (IWM) Focused Feasibility Study (FFS) (UCOR 2016) contains the details as to the proposed system for treatment. Existing collection systems would be maintained as necessary for EMDF utilization.
- Operation of the leachate collection system would continue three years after disposal operations cease. Reduced operation of the leachate collection system would continue for ten years after closure.
- Waste would not be highly radioactive; therefore, would not require personnel shielding or special handling.
- Operations costs are based on actual EMWMF operations data.
- Post-closure care is considered to be a ten-year period following closure.
- The long-term monitoring and maintenance for EMDF would continue after closure of the facility. Estimates for this cost are calculated separately in Section 3.3.
- No assumption as to the performer of the long-term maintenance is made in this document.

3.2 ON-SITE DISPOSAL ALTERNATIVE ESTIMATE DEVELOPMENT

The key components of the On-site Disposal Alternative cost estimate include pre-construction activities (includes design); site development and construction; operations (including security); final capping and facility closure; and post-closure care. A detailed basis of estimate has been prepared (P2S 2015, P2S 2016), with references and vendor quotes. The detailed estimate was developed in CEES. This document summarizes costs and assumptions taken from that CEES detailed estimate and Basis of Estimate document with references. Section 3.3 details the estimate of lon-term care based on several optional methods of accomplishment.

Table I-3 is a summary of the EMDF Conceptual Design estimate for each Site Option (EBCV, WBCV, and Dual Site 7a/6b). The following sections summarize the activities/elements of the estimate and give major assumptions. Each section points to the specific elements of Table I-3 that are described.

3.2.1 Financial Basis of Estimate

3.2.1.1 Material and Labor Pricing

The site development and construction estimates are based on preliminary bills of materials developed for each anticipated activity, for each site. Each activity was estimated with regard to the material cost and labor cost. Material and labor rates productivity were based on similar recent job history, as applicable, and R.S. Means cost data (Means 2012). Special work situations and job conditions that would result in additional material and/or labor work hours were identified and included in the estimate. Examples of special considerations include safety requirements, special materials, specialized training, supporting items, and cleanup.

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Table I-3. Summary of EMDF Conceptual Design Cost Estimate

Element Number	WBS Element	EBCV Site Option		WBCV Site Option		Dual Site Option	Hybrid Disposal
		6 Cell Cost (FY 2012 Dollars)	5 Cell Cost (FY 2012 Dollars)	6 Cell Cost (FY 2012 Dollars)	5 Cell Cost (FY 2012 Dollars)	Sites 6b and 7a (FY 2012 Dollars)	Site 6b (FY 2012 Dollars)
1	**Pre-Construction and Engineering**	**$31,946,437**	**$31,946,437**	**$30,034,414**	**$30,034,414**	**$50,210,193**	**$26,733,741**
	Project Management	**$1,692,070**	**$1,692,070**	**$1,692,070**	**$1,692,070**	**$2,793,258**	**$1,692,070**
	Site Characterization (Early Actions)	**$6,064,500**	**$6,064,500**	**$4,152,476**	**$4,152,476**	**$10,041,266**	**$4,807,279**
	Engineering (DOE Order/CERCLA compliance; Design) pre-ROD[a]	**$3,537,686**	**$3,537,686**	**$3,537,687**	**$3,537,687**	**$3,537,687**	**$3,537,687**
	Engineering (DOE Order/CERCLA compliance; Design) post-ROD	**$20,652,181**	**$20,652,181**	**$20,652,181**	**$20,652,181**	**$33,837,982**	**$16,696,705**
2	**Operations**	**$298,696,922**	**$298,696,922**	**$298,624,546**	**$298,624,546**	**$316,784,163**	**$164,313,460**
	Base Operations	**$265,650,000**	**$265,650,000**	**$265,650,000**	**$265,650,000**	**$280,073,588**	**$144,900,000**
	Interim Capping (all cells, material only)	**$749,602**	**$749,602**	**$677,226**	**$677,226**	**$781,667**	**$300,487**
	Water Treatment Operations	**$28,640,275**	**$28,640,275**	**$28,640,275**	**$28,640,275**	**$32,271,862**	**$17,184,165**
	Security Operations	**$3,657,045**	**$3,657,045**	**$3,657,045**	**$3,657,045**	**$3,657,046**	**$1,928,808**
3	**Post-closure Care Operations**	**$29,428,090**	**$29,428,090**	**$29,428,090**	**$29,428,090**	**$32,795,330**	**$19,795,330**
	Perpetual Care Fee	**$22,000,000**	**$22,000,000**	**$22,000,000**	**$22,000,000**	**$25,000,000**	**$12,000,000**
	Post-closure Care Operations	**$7,428,090**	**$7,428,090**	**$7,428,090**	**$7,428,090**	**$7,795,330**	**$7,795,330**
4	**EMDF Engineering Phase I (Cells 1 & 2, Cells 1-5 for Site 6b)**	**$1,946,798**	**$1,946,798**	**$1,946,799**	**$1,946,799**	**$1,946,799**	**$1,946,799**
	Engineering	**$1,946,798**	**$1,946,798**	**$1,946,799**	**$1,946,799**	**$1,946,799**	**$1,946,799**
	Requests for proposals/review/award	*$696,162*	*$696,162*	*$696,162*	*$696,162*	*$696,162*	*$696,162*
	Documentation	*$502,313*	*$502,313*	*$715,014*	*$715,014*	*$715,014*	*$715,014*
	Operational readiness and startup	*$715,014*	*$715,014*	*$535,623*	*$535,623*	*$535,623*	*$535,623*
5	**EMDF Construction Phase I (Cells 1 & 2, Cells 1-5 for Site 6b)**	**$106,997,351**	**$106,997,351**	**$111,544,265**	**$111,544,265**	**$108,070,467**	**$105,656,804**
	Project Management	**$6,149,114**	**$6,149,114**	**$6,149,114**	**$6,149,114**	**$5,620,993**	**$5,620,993**
	Site Development	**$7,216,340**	**$7,216,340**	**$9,270,613**	**$9,270,613**	**$6,597,964**	**$6,597,964**
	Construction Management	*$852,225*	*$852,225*	*$852,225*	*$852,225*	*$599,815*	*$599,815*
	Mobilization/demobilization	*$1,658,851*	*$1,658,851*	*$1,658,851*	*$1,658,851*	*$1,658,851*	*$1,658,851*
	Work packages/lift plan	*$136,499*	*$136,499*	*$136,499*	*$136,499*	*$136,499*	*$136,499*
	Wetlands/stream replacement	*$841,101*	*$841,101*	*$309,120*	*$309,120*	*$294,400*	*$294,400*
	Contact water basin	*$0*	*$0*	*$1,766,254*	*$1,766,254*	*$0*	*$0*
	Clearing/grading	*$353,964*	*$353,964*	*$571,709*	*$571,709*	*$225,375*	*$225,375*
	Initial sediment control	*$123,579*	*$123,579*	*$123,579*	*$123,579*	*$123,579*	*$123,579*
	Access roads/laydown areas	*$338,228*	*$338,228*	*$471,400*	*$471,400*	*$775,871*	*$775,871*
	229 Boundary	*$312,775*	*$312,775*	*$0*	*$0*	*$0*	*$0*
	Utility install/distribute	*$2,711,472*	*$2,711,472*	*$3,380,976*	*$3,380,976*	*$2,711,472*	*$2,711,472*
	Culvert work	*$34,846*	*$34,846*	*$0*	*$0*	*$72,102*	*$72,102*
	Support Facilities	**$18,202,168**	**$18,202,168**	**$19,354,975**	**$19,354,975**	**$20,084,991**	**$17,671,328**
	Personnel facilities	*$462,743*	*$462,743*	*$610,519*	*$610,519*	*$1,084,829*	*$462,743*
	Truck scale	*$147,732*	*$147,732*	*$147,732*	*$147,732*	*$295,464*	*$147,732*
	Guard station	*$107,972*	*$107,972*	*$107,972*	*$107,972*	*$215,944*	*$107,972*
	Leachate/contact water treatment facilities	*$13,413,951*	*$13,413,951*	*$13,413,949*	*$13,413,949*	*$13,413,951*	*$13,413,951*
	Leachate storage and transfer systems	*$4,069,770*	*$4,069,770*	*$5,074,803*	*$5,074,803*	*$5,074,803*	*$3,538,930*

Table I-3. Summary of EMDF Conceptual Design Cost Estimate (Continued)

Element Number	WBS Element	EBCV Site Option		WBCV Site Option		Dual Site Option	Hybrid Disposal
		6 Cell Cost (FY 2012 Dollars)	5 Cell Cost (FY 2012 Dollars)	6 Cell Cost (FY 2012 Dollars)	5 Cell Cost (FY 2012 Dollars)	Sites 6b and 7a (FY 2012 Dollars)	Site 6b (FY 2012 Dollars)
	Construct Phase I	$75,429,706	$75,429,706	$76,769,563	$76,769,563	$75,766,519	$75,766,519
	Construction Management	***$4,713,300***	***$4,713,300***	***$4,713,300***	***$4,713,300***	***$4,538,734***	***$4,538,734***
	Oversight and Quality Assurance	***$5,406,093***	***$5,406,093***	***$5,406,093***	***$5,406,093***	***$5,406,093***	***$5,406,093***
	Mobilization/demobilization	***$1,852,349***	***$1,852,349***	***$1,852,348***	***$1,852,348***	***$1,781,873***	***$1,781,873***
	· Pre-mob submittals	$245,824	$245,824	$245,824	$245,824	$245,824	$245,824
	· Work packages & lift plan	$136,499	$136,499	$136,499	$136,499	$136,499	$136,499
	· Personnel training	$164,275	$164,275	$164,275	$164,275	$164,275	$164,275
	· Temporary facilities	$215,472	$215,472	$215,472	$215,472	$215,472	$215,472
	· Support equipment and services	$634,533	$634,533	$634,533	$634,533	$564,058	$564,058
	· Site restoration	$42,522	$42,522	$42,522	$42,522	$42,522	$42,522
	· Mobilization/demobilization	$413,223	$413,223	$413,223	$413,223	$413,223	$413,223
	Phase I Preparations	***$21,445,582***	***$21,445,582***	***$20,840,821***	***$20,840,821***	***$11,237,064***	***$11,237,064***
	· Clearing/grading	$661,815	$661,815	$784,791	$784,791	$435,092	$435,092
	· Underdrain construction	$1,400,575	$1,400,575	$445,853	$445,853	$124,300	$124,300
	· Excavation and fill (includes clean fill dikes)	$18,846,701	$18,846,701	$19,073,686	$19,073,686	$9,627,653	$9,627,653
	· Test pads	$536,491	$536,491	$536,491	$536,491	$1,050,019	$1,050,019
	Phase I Buffer and Liner Systems	***$26,952,075***	***$26,952,075***	***$26,430,002***	***$26,430,002***	***$30,799,935***	***$30,799,935***
	· Geologic buffer	$13,119,253	$13,119,253	$14,898,732	$14,898,732	$14,211,070	$14,211,070
	· Compacted clay liner	$9,676,967	$9,676,967	$7,772,209	$7,772,209	$10,663,322	$10,663,322
	· Secondary geomembrane liner	$470,250	$470,250	$377,555	$377,555	$545,421	$545,421
	· Geocomposite leak detection	$92,377	$92,377	$117,762	$117,762	$194,048	$194,048
	· Primary geomembrane liner	$516,099	$516,099	$414,367	$414,367	$540,865	$540,865
	· Geotextile cushion layer	$50,717	$50,717	$65,106	$65,106	$106,536	$106,536
	· Geosynthetic clay liner	$569,368	$569,368	$463,702	$463,702	$636,063	$636,063
	· Leachate collection drainage layer	$637,075	$637,075	$814,901	$814,901	$1,335,591	$1,335,591
	· Geotextile separator layer	$33,510	$33,510	$42,718	$42,718	$70,390	$70,390
	· Geocomposite drainage leachate collection	$377,642	$377,642	$259,608	$259,608	$323,544	$323,544
	· Protective soil layer	$665,610	$665,610	$535,445	$535,445	$738,125	$738,125
	· Leachate collection window	$258,948	$258,948	$209,678	$209,678	$302,827	$302,827
	· Liner trench/penetration boxes	$484,259	$484,259	$458,219	$458,219	$1,132,133	$1,132,133
	Phase I Construction	***$15,060,308***	***$15,060,308***	***$17,526,999***	***$17,526,999***	***$22,002,820***	***$22,002,820***
	· Side slope riprap armour (3:1 side slopes)	$0	$0	$427,262	$427,262	$230,254	$230,254
	· Side slope riprap buttress (2:1 side slopes)	$9,789,721	$9,789,721	$10,932,846	$10,932,846	$13,247,097	$13,247,097
	· Perimeter road/ditch construction	$524,207	$524,207	$451,089	$451,089	$893,145	$893,145
	· Upgradient ditch/French drain	$432,516	$432,516	$0	$0	$302,969	$302,969
	· Sediment basin construction	$61,179	$61,179	$61,179	$61,179	$118,693	$118,693
	· Security fencing/lighting	$524,326	$524,326	$596,036	$596,036	$830,892	$830,892
	· Drainage and erosion controls	$619,902	$619,902	$619,902	$619,902	$553,374	$553,374
	· Leachate piping	$540,482	$540,482	$1,870,710	$1,870,710	$1,141,467	$1,141,467
	· Lift stations	$73,600	$73,600	$73,600	$73,600	$73,600	$73,600
	· Power to alarm controls	$66,004	$66,004	$66,004	$66,004	$132,008	$132,008
	· Engineering & Testing	$2,428,371	$2,428,371	$2,428,371	$2,428,371	$4,479,321	$4,479,321

Table I-3. Summary of EMDF Conceptual Design Cost Estimate (Continued)

Element Number	WBS Element	EBCV Site Option		WBCV Site Option		Dual Site Option	Hybrid Disposal
		6 Cell Cost (FY 2012 Dollars)	5 Cell Cost (FY 2012 Dollars)	6 Cell Cost (FY 2012 Dollars)	5 Cell Cost (FY 2012 Dollars)	Sites 6b and 7a (FY 2012 Dollars)	Site 6b (FY 2012 Dollars)
6	**EMDF Engineering Phase II (Cells 3 & 4, Cells 1&2 Site 7a)**	**$2,102,443**	**$2,102,443**	**$2,102,442**	**$2,102,442**	**$1,598,718**	
	Engineering	**$2,102,443**	**$2,102,443**	**$2,102,442**	**$2,102,442**	**$1,598,718**	
	Requests for proposals/review/award	*$418,357*	*$418,357*	*$418,357*	*$418,357*	*(costs included in Phase I*	
	DOE Order, CERCLA compliance; design addendum	*$1,558,506*	*$1,558,506*	*$1,684,085*	*$1,684,085*	*Engineering above)*	
7	**EMDF Construction Phase II (Cells 3 & 4, Cells 1&2 Site 7a)**	**$42,225,549**	**$42,225,549**	**$57,699,649**	**$57,699,649**	**$86,569,044**	
	Project Management	**$5,319,745**	**$5,319,745**	**$3,475,586**	**$3,475,586**	**$5,614,409**	
	Site Development (Dual Site 7b only)	**NA**	**NA**	**NA**	**NA**	**$10,214,041**	
	Construction Management					*$871,296*	
	Mobilization/demobilization					*$1,658,851*	
	Work packages/lift plan					*$136,499*	
	Wetlands/stream replacement					*$662,400*	
	Contact water basin					*$1,766,254*	
	Clearing/grading					*$584,446*	
	Initial sediment control					*$123,579*	
	Access roads/laydown areas					*$1,546,060*	
	229 Boundary					*$0*	
	Utility install/distribute					*$2,737,164*	
	Culvert work					*$127,492*	
	Construct Phase II	**$36,905,804**	**$36,905,804**	**$54,224,063**	**$54,224,063**	**$70,740,594**	
	Construction Management	***$4,538,734***	***$4,538,734***	***$4,015,034***	***$4,015,034***	***$4,895,380***	
	Oversight and Quality Assurance	***$2,969,358***	***$2,969,358***	***$2,969,358***	***$2,969,358***	***$3,735,212***	
	Mobilization/demobilization	***$1,609,267***	***$1,609,267***	***$1,609,267***	***$1,609,267***	***$1,922,823***	
	· Pre-mob submittals	$245,824	$245,824	$245,824	$245,824	$245,824	
	· Work packages & lift plan	$136,673	$136,673	$136,673	$136,673	$136,499	
	· Personnel training	$164,275	$164,275	$164,275	$164,275	$164,275	
	· Temporary facilities	$190,703	$190,703	$190,703	$190,703	$215,472	
	· Support equipment and services	$423,108	$423,108	$423,108	$423,108	$705,008	
	· Site restoration	$38,547	$38,547	$38,547	$38,547	$42,522	
	· Mobilization/demobilization	$410,137	$410,137	$410,137	$410,137	$413,223	
	Phase II Preparations	***$1,816,538***	***$1,816,538***	***$13,418,376***	***$13,418,376***	***$23,019,279***	
	· Clearing/grading	$201,113	$201,113	$417,538	$417,538	$708,612	
	· Underdrain construction	$126,002	$126,002	$682,573	$682,573	$532,283	
	· Excavation and fill	$975,895	$975,895	$11,804,737	$11,804,737	$21,241,893	
	· Test pads	$513,528	$513,528	$513,528	$513,528	$536,491	
	Phase II Buffer and Liner Systems	***$22,328,541***	***$22,328,541***	***$21,160,859***	***$21,160,859***	***$22,142,757***	
	· Geologic buffer	$8,265,033	$8,265,033	$9,004,674	$9,004,674	$10,046,155	
	· Compacted clay liner	$9,603,239	$9,603,239	$7,600,393	$7,600,393	$7,758,106	
	· Secondary geomembrane liner	$449,885	$449,885	$404,913	$404,913	$376,830	
	· Geocomposite leak detection	$179,976	$179,976	$215,420	$215,420	$167,000	
	· Primary geomembrane liner	$409,918	$409,918	$368,941	$368,941	$516,099	
	· Geotextile cushion layer	$98,810	$98,810	$118,271	$118,271	$91,686	
	· Geosynthetic clay liner	$496,278	$496,278	$453,122	$453,122	$456,736	
	· Leachate collection drainage layer	$1,239,329	$1,239,329	$1,490,124	$1,490,124	$1,152,946	
	· Geotextile separator layer	$65,286	$65,286	$78,143	$78,143	$60,579	
	· Geocomposite drainage leachate collection	$229,740	$229,740	$153,347	$153,347	$209,637	
	· Protective soil layer	$584,000	$584,000	$528,423	$528,423	$534,572	
	· Leachate collection window	$237,459	$237,459	$268,953	$268,953	$290,254	
	· Liner trench/penetration boxes	$469,590	$469,590	$476,135	$476,135	$482,157	

Table I-3. Summary of EMDF Conceptual Design Cost Estimate (Continued)

Element Number	WBS Element	EBCV Site Option		WBCV Site Option		Dual Site Option	Hybrid Disposal
		6 Cell Cost (FY 2012 Dollars)	5 Cell Cost (FY 2012 Dollars)	6 Cell Cost (FY 2012 Dollars)	5 Cell Cost (FY 2012 Dollars)	Sites 6b and 7a (FY 2012 Dollars)	Site 6b (FY 2012 Dollars)
	Phase II Construction	***$3,643,364***	***$3,643,364***	***$11,051,169***	***$11,051,169***	***$15,025,144***	
	· Side slope riprap armour (3:1 side slopes)	$0	$0	$691,841	$691,841	$862,361	
	· Side slope riprap buttress	$151,195	$151,195	$6,749,335	$6,749,335	$8,278,404	
	· Perimeter road/ditch construction	$153,044	$153,044	$214,515	$214,515	$672,115	
	· Upgradient ditch/french drain	$46,828	$46,828	$46,828	$46,828	$0	
	· Sediment basin construction	$57,514	$57,514	$57,514	$57,514	$61,179	
	· Security fencing/lighting	$306,566	$306,566	$349,381	$349,381	$640,211	
	· Drainage and erosion controls	$327,967	$327,967	$327,967	$327,967	$619,902	
	· Leachate piping	$407,812	$407,812	$421,350	$421,350	$1,322,997	
	· Lift stations	$0	$0	$0	$0	$73,600	
	· Power to alarm controls	$66,004	$66,004	$66,004	$66,004	$66,004	
	· Engineering & Testing	$2,126,434	$2,126,434	$2,126,434	$2,126,434	$2,428,371	
8	**EMDF Engineering Phase III (Cells 5 & 6, Cells 3&4 Site 7a)**	**$2,102,443**	**$2,102,443**	**$2,102,442**	**$2,102,442**	**$2,102,442**	
	Engineering	**$2,102,443**	**$2,102,443**	**$2,102,442**	**$2,102,442**	**$2,102,442**	
	Requests for proposals/review/award	*$418,357*	*$418,357*	*$418,357*	*$418,357*	*$418,357*	
	DOE Order, CERCLA compliance; design addendum	*$1,684,085*	*$1,684,085*	*$1,684,085*	*$1,684,085*	*$1,684,085*	
9	**EMDF Construction Phase III (Cells 5 & 6, Cells 3&4 Site 7a)**	**$47,649,458**	**$28,848,064**	**$45,704,929**	**$27,953,140**	**$64,211,941**	
	Project Management	**$5,327,856**	**$3,622,942**	**$5,327,856**	**$3,622,942**	**$3,208,233**	
	Construct Phase III	**$42,321,602**	**$25,225,122**	**$40,377,073**	**$24,330,198**	**$61,003,708**	
	Construction Management	***$3,142,200***	***$2,356,650***	***$4,015,034***	***$3,011,276***	***$3,324,280***	
	Oversight and Quality Assurance	***$2,969,358***	***$2,227,019***	***$2,969,358***	***$2,227,019***	***$2,686,188***	
	Mobilization/demobilization	***$1,613,176***	***$1,613,177***	***$1,613,177***	***$1,613,177***	***$1,574,030***	
	· Pre-mob submittals	$245,824	$245,824	$245,824	$245,824	$245,824	
	· Work packages & lift plan	$136,673	$136,673	$136,673	$136,673	$136,673	
	· Personnel training	$164,275	$164,275	$164,275	$164,275	$164,275	
	· Temporary facilities	$191,277	$191,277	$191,277	$191,277	$190,703	
	· Support equipment and services	$423,108	$423,108	$423,108	$423,108	$387,871	
	· Site restoration	$38,833	$38,833	$38,833	$38,833	$38,547	
	· Mobilization/demobilization	$413,186	$413,186	$413,186	$413,186	$410,137	
	Phase III Preparations	***$5,443,382***	***$2,993,860***	***$8,854,112***	***$4,869,762***	***$29,781,700***	
	· Clearing/grading	$334,722	$184,097	$334,722	$184,097	$313,607	
	· Underdrain construction	$544,568	$299,512	$0	$0	$0	
	· Excavation and fill	$4,027,601	$2,215,181	$7,982,899	$4,390,594	$28,954,565	
	· Test pads	$536,491	$295,070	$536,491	$295,070	$513,528	
	Phase III Buffer and Liner Systems	***$18,938,029***	***$10,415,915***	***$18,265,545***	***$10,046,050***	***$13,315,473***	
	· Geologic buffer	$8,870,563	$4,878,810	$5,480,186	$3,014,102	$1,103,599	
	· Compacted clay liner	$6,669,006	$3,667,954	$8,506,481	$4,678,565	$7,777,350	
	· Secondary geomembrane liner	$349,301	$192,116	$445,252	$244,889	$414,657	
	· Geocomposite leak detection	$118,726	$65,299	$168,087	$92,448	$179,762	
	· Primary geomembrane liner	$349,301	$192,116	$445,252	$244,889	$377,819	
	· Geotextile cushion layer	$65,183	$35,851	$92,282	$50,755	$207,328	
	· Geosynthetic clay liner	$385,350	$211,943	$498,265	$274,046	$464,025	
	· Leachate collection drainage layer	$753,802	$414,591	$1,064,604	$585,532	$1,237,861	
	· Geotextile separator layer	$43,068	$23,687	$60,973	$33,535	$65,207	
	· Geocomposite drainage leachate collection	$199,387	$109,663	$237,420	$130,581	$197,871	
	· Protective soil layer	$418,057	$229,931	$532,744	$293,009	$532,046	
	· Leachate collection window	$236,374	$130,006	$235,427	$129,485	$269,088	
	· Liner trench/penetration boxes	$479,910	$263,950	$498,572	$274,215	$488,860	

Table I-3. Summary of EMDF Conceptual Design Cost Estimate (Continued)

Element Number	WBS Element	EBCV Site Option		WBCV Site Option		Dual Site Option	Hybrid Disposal
		6 Cell Cost (FY 2012 Dollars)	**5 Cell Cost (FY 2012 Dollars)**	**6 Cell Cost (FY 2012 Dollars)**	**5 Cell Cost (FY 2012 Dollars)**	**Sites 6b and 7a (FY 2012 Dollars)**	**Site 6b (FY 2012 Dollars)**
	Phase III Construction	***$10,215,457***	***$5,618,501***	***$4,659,847***	***$2,562,916***	***$10,322,038***	
	· Side slope riprap armour (3:1 side slopes)	$0	$0	$0	$0	$708,843	
	· Side slope riprap buttress	$6,091,335	$3,350,234	$0	$0	$5,448,034	
	· Perimeter road/ditch construction	$325,740	$179,157	$445,634	$245,099	$340,045	
	· Upgradient ditch/french drain	$224,696	$123,583	$482,047	$265,126	$444,382	
	· Sediment basin construction	$0	$0	$0	$0	$57,514	
	· Security fencing/lighting	$305,923	$168,258	$328,369	$180,603	$347,790	
	· Drainage and erosion controls	$618,795	$340,337	$618,795	$340,337	$327,967	
	· Leachate piping	$381,044	$209,574	$517,079	$284,393	$455,025	
	· Power to alarm controls	$66,004	$36,302	$66,004	$36,302	$66,004	
	· Engineering & Testing	$2,201,919	$1,211,055	$2,201,919	$1,211,055	$2,126,434	
10	**EMDF Engineering Final Cap**	**$2,046,565**	**$2,046,565**	**$2,046,565**	**$2,046,565**	**$4,093,130**	**$2,046,565**
	Engineering	**$2,046,565**	**$2,046,565**	**$2,046,565**	**$2,046,565**	**$4,093,130**	**$2,046,565**
	Requests for proposals/review/award	*$346,610*	*$346,610*	*$346,610*	*$346,610*	*$693,220*	*$346,610*
	DOE Order, CERCLA compliance; design addendum	*$1,699,955*	*$1,699,955*	*$1,699,955*	*$1,699,955*	*$3,399,910*	*$1,699,955*
11	**EMDF Construction Final Cap**	**$69,219,039**	**$63,352,356**	**$67,751,080**	**$58,198,181**	**$88,170,649**	**$39,087,777**
	Project Management	**$7,072,992**	**$7,072,992**	**$7,072,992**	**$7,072,992**	**$7,936,870**	**$3,663,171**
	Construct Final Cap	**$62,146,047**	**$56,279,364**	**$60,678,088**	**$51,125,189**	**$80,233,779**	**$35,424,606**
	Construction Management and Oversight	***$6,665,242***	***$6,331,980***	***$6,665,242***	***$6,331,980***	***$10,112,782***	***$4,596,719***
	Oversight and Quality Assurance	***$6,498,415***	***$6,173,494***	***$6,498,415***	***$6,173,494***	***$10,070,009***	***$4,616,887***
	Mobilization/demobilization	***$3,271,078***	***$3,205,656***	***$3,271,078***	***$3,205,657***	***$5,871,595***	***$2,862,939***
	· Pre-mob submittals	$317,658	$317,658	$317,658	$317,658	$635,315	$317,658
	· Work packages	$136,673	$136,673	$136,673	$136,673	$273,346	$136,673
	· Personnel training	$250,608	$250,608	$250,608	$250,608	$501,216	$250,608
	· Temporary facilities	$366,416	$366,416	$366,417	$366,417	$732,834	$366,417
	· Support equipment and services	$1,245,471	$1,245,471	$1,245,471	$1,245,471	$2,490,941	$1,245,471
	· Site restoration/erosion control	$802,342	$802,342	$802,342	$802,342	$934,123	$394,203
	· Mobilization/demobilization	$151,910	$151,910	$151,910	$151,910	$303,820	$151,910
	Final Cap Construction	***$45,711,311***	***$40,568,234***	***$44,243,353***	***$35,414,058***	***$54,179,393***	***$23,348,061***
	· Test pads	$536,491	$536,491	$536,491	$536,491	$1,072,982	$536,491
	· Compacted clay layer	$4,199,258	$3,695,347	$4,053,331	$3,188,698	$4,749,720	$2,009,354
	· Amended compacted clay layer	$9,477,385	$8,340,098	$9,303,923	$7,319,263	$10,865,321	$4,596,364
	· Geomembrane liner	$1,189,287	$1,046,573	$1,166,136	$917,383	$1,362,716	$576,454
	· Geotextile cushion layer	$756,820	$666,001	$742,087	$583,789	$867,183	$366,834
	· Lateral drainage layer	$3,493,778	$3,074,525	$3,420,409	$2,690,787	$3,853,104	$1,695,387
	· Biointrusion layer	$6,951,997	$6,117,758	$6,811,918	$5,358,839	$7,968,577	$3,372,370
	· Geotextile separator layer	$500,042	$440,037	$490,307	$385,718	$572,960	$242,373
	· Granular filter layer	$3,380,403	$2,974,755	$3,305,624	$2,600,487	$4,070,247	$1,641,885
	· Erosion control layer	$12,910,005	$11,360,804	$12,097,282	$9,516,759	$14,164,893	$5,994,704
	· Engineering & Testing	$2,315,845	$2,315,845	$2,315,845	$2,315,845	$4,631,690	$2,315,845

Table I-3. Summary of EMDF Conceptual Design Cost Estimate (Continued)

Element Number	WBS Element	EBCV Site Option		WBCV Site Option		Dual Site Option	Hybrid Disposal
		6 Cell Cost (FY 2012 Dollars)	5 Cell Cost (FY 2012 Dollars)	6 Cell Cost (FY 2012 Dollars)	5 Cell Cost (FY 2012 Dollars)	Sites 6b and 7a (FY 2012 Dollars)	Site 6b (FY 2012 Dollars)
12	**Support Facilities Demolition**	**$3,680,000**	**$3,680,000**	**$3,680,000**	**$3,680,000**	**$3,680,000**	**$3,680,000**
	Water Treatment System Demolition	**$3,680,000**	**$3,680,000**	**$3,680,000**	**$3,680,000**	**$3,680,000**	**$3,680,000**
	SUBTOTAL ON-SITE DISPOSAL FACILITY (FY 2012 Dollars)	**$638,041,093**	**$613,373,017**	**$652,665,221**	**$625,360,532**	**$760,232,876**	**$363,260,476**
	CONTINGENCY (22% on all but Base & Security Operations and completed work scope; Base and Security Operations 5%; Water treatment – capital and operations – contingency already in cost;no contingency on Perpetual Care Fee)	$77,901,416	$72,474,440	$81,732,352	$75,725,320	$100,790,134	$43,112,212
	TOTAL with Contingency (FY 2012 Dollars)	**$715,942,509**	**$685,847,457**	**$734,397,573**	**$701,085,853**	**$861,023,011**	**$406,372,688**
	Purple indicates Capital portions of scope and cost.						
	Orange indicates Operations portions of scope and cost.						

[a] The RI/FS development and Perpetual Care Fee do not carry the Contractor 15% G&A and Fee.

3.2.1.2 Wage Rates

Labor crafts that are expected to perform the tasks have been identified and appropriate wage rates applied. Labor rates used in the estimate are based on construction labor agreement rates for the Oak Ridge area. Fixed-price construction labor rates were based on average crew sizes with necessary foremen, general foremen, etc. All fringe benefits, payroll taxes, and worker's compensation insurance were included.

3.2.1.3 Material, Equipment, and Production

The material, equipment, and production rates were generated using national averages obtained from nationally recognized cost references such as R. S. Means. The estimators used their experience to modify national average production rates for remedial action work. Special equipment and special facilities costs were obtained from vendors or from similar projects. Vendor quotes are used in the estimate for certain activities, which are not commonly found in cost references. These vendor quotes could change based on final engineering.

3.2.1.4 Indirect Markups

Indirect markups for construction have been applied according to DOE guidelines. Indirect markups for fixed price construction used in the estimates cover expenses incurred by the subcontractor such as overhead (e.g., home office support, G&A expenses) profit, bond, and markup on subcontractors utilized for various specialty construction services. A compounded rate of 28% has been applied to both material and labor to account for these activities.

A prime contractor to DOE is assumed to oversee all work elements, including design, operations, and construction. A 15% overhead rate to cover G&A expenses and fee is assumed on all elements.

3.2.1.5 Contingency and Risk

For the on-site cost estimates a 22% contingency was applied to all elements except operations: 22% is the sum of 7% scope contingency and 15% bid contingency. EPA recommends a 5–10% scope contingency for clay caps, 5–10% scope contingency for surface grading/diking, and 10–20% scope contingency for synthetic caps. A 7% scope contingency was selected based on the fact that needed design considerations have been readily available from the existing EMWMF design. A mid-range bid contingency of 15% (EPA recommends 10–20%) was applied, to account for changing conditions (e.g. material pricing and weather disruptions). Therefore, a 22% contingency is calculated and applied to all construction and design elements, pre-construction elements, and operations that have not previously been performed at EMWMF (e.g., the water treatment operations). Contingency on base operations (includes base operations and security) was held to 5% since DOE currently operates an existing and very similar landfill, and those costs are very well known. No contingency was added on completed work scope (e.g., preparation of the RI/FS and Phase I Characterization). No contingency is added to the Perpetual Care Fee.

Risks identified for the on-site alternative were identified along with cost implications and probability of occurrence. Contingency was assumed based on these risks:

Risk	Cost Implications	Probability of Occurrence
• Material and/or labor cost increases during construction or operation	Moderate cost	Moderate
• Waste not meeting facility WAC and requiring off-site disposal	Moderate cost	Unlikely
• Compliance issues/operational issues requiring corrective actions	Low cost	Unlikely
• Increased long-term S&M costs	Moderate cost	Moderate
• Disposal site shutdown during operations	High cost	Unlikely
• Post-closure, extreme maintenance issues	High cost	Unlikely

3.2.2 Descriptions of Estimate Activities and Assumptions

3.2.2.1 Pre-construction Activities and Design (Elements 1 and 4 in Table I-3)

Early actions to support remedial design include activities under site characterization such as construction of new ground water monitoring wells and surface water weirs, upgrading existing down-gradient ground water monitoring wells (if required), ground water monitoring, hydrogeological and geotechnical investigations, and wetland delineation activities. Topography and threatened and endangered species surveys are completed. (Note that some of these activities have been completed and are summarized in this RI/FS. Others such as the topographic survey have not been completed as of this writing. WBCV was assumed to have approximately a Phase I characterization level amount of information available, as is true for EBCV.) These early actions would be completed prior to design and issuance of the draft Remedial Design Report (RDR)/ Remedial Action Work Plan (RAWP). Characterization is completed in two Phases.

Included in pre-construction activities are the efforts to produce and review CERCLA documents (e.g., this RI/FS, a Proposed Plan, Record of Decision, and Remedial Design Work Plan). Compliance with DOE orders (e.g., DOE O 435.1 and 413.3B) are assumed to be completed under pre-construction and engineering activities.

Remedial design for the On-site Disposal Alternative includes development of a RDR/RAWP (required by CERCLA) and Title I and Title II design engineering. Title I and Title II design activities include preparation of design drawings, specifications, reports, calculations, etc., required to construct and operate the new disposal facility and support facilities. In addition, remedial design includes preparation of design documents for site development activities. Procurement activities include development, issuance of request for proposals, review, and award of contracts for the different phases of facility design and construction.

For Phase I construction only, operational readiness and startup is part of the pre-construction activities.

Assumptions include (note that some of these activities have been completed as of the writing of this document, others are planned/assumed):

- EBCV Site Option:
  - Two phases of characterization: Phase I (mostly complete; hydrology monitoring is ongoing), and Phase II to be completed.
  - Phase I Sampling and Analysis Plan development and request for proposal are completed.
  - Phase I characterization: Five ground water well pairs, one deep and one shallow, are installed. Three flume locations will be monitored.
  - Phase I access roads are built.
  - Continued hydrological monitoring in the five Phase I well pairs for one year.
  - Limited geotechnical data summaries in Phase I characterization.
  - No contingency applied to completed scope of Phase I characterization.
- WBCV and Sites 7a/6b:
  - Some Phase I characterization is assumed. Assigned a value of Phase I for EBCV.
- All Site Options:
  - Extensive Phase II characterization, including the Data Quality Objectives, development of a Sampling and Analysis Plan, and Quality Assurance Plan.
  - Phase II characterization to include: One deep well, six intermediate wells, six shallow wells, one flume.
  - Phase II includes sampling and characterization to develop background constituent levels; a total of 1,777 samples are collected and laboratory analyses included.
  - Phase II includes a topographical survey.
  - Phase II includes geotechnical borings and analyses.
  - Phase I and II reporting included.
  - Oversight of field work included.
- Completion of the RI/FS and other required CERCLA documentation (proposed plan and record of decision) is part of pre-construction.
- No contingency is applied to the RI/FS development; no contractor G&A and fee is applied to the RI/FS preparation.
- Compliance with DOE O 435.1 is in pre-construction, and required for each site separately.
- Compliance with DOE O 413.3B (Critical Decision [CD]-0, 1, and 2/3A, CD-4A and completion report at completion of Phase I construction]. Includes all document development and reviews. Pre-construction includes this effort for Phase I only, for CD-2/3A and CD-4A. CD-0 and CD-1 are all inclusive of the whole landfill (all six cells).
- Engineering design procurement activities for a contractor to complete a full design are included.
- Engineering design: preparation of design drawings, design specifications, design calculations, final WAC, final WAC Attainment Plan, and the RDR/RAWP; development of operating plans, regulatory review, and project management for the landfill and for the water treatment system.

3.2.2.2 Site Development and Phase I, II, and III Construction (Elements 5, 6, 7, 8, and 9 in Table I-3)

Site development activities described in Section 6.2.2.3 of the RI/FS would be performed as a separate early phase of construction prior to construction of Phase I (Cells 1 and 2). Site development activities would include constructing access roads to the landfill site; preparing additional parking, laydown, spoil, and staging areas; creating/expanding wetlands as required; extending utilities to the landfill site; relocating the Y-12 229 Security Boundary and installing new guard stations; clearing and grubbing, and installing initial sediment and erosion controls for site development activities; upgrading and installing new weigh scales; and setting up construction trailers. Purchase and installation of a pre-fabricated bridge for the access road is included. A new Northern Tributary (NT)-3 culvert purchase and installation is included.

Elements of the EBCV estimate and pertinent assumptions, which were modified as necessary to develop estimates for WBCV and Sites 7a and 6b based on material quantities for those sites [numbers however are not indicated here in the text – only those for EBCV are given. See the end of these bullets for a table of values for WBCV and Sites 7a/6b], for site development include:

- Mobilization/demobilization of subcontractor with appropriate work packages and lift plan.
- Mobilization and rental of construction equipment.
- Wetlands/stream replacement: construct 2.5 acres of replacement wetlands and 1,607 linear feet (LF) of replacement streams at the East Bear Creek Valley Site to mitigate impact on any wetlands and streams that would be disturbed during early actions, construction, operation, or closure of EMDF. Develop Wetlands Design Report and drawing of wetlands boundary and data collection points. Assume a cost of $100,000 per acre for wetland development per EPA guidance. Assume a cost of $200/LF for an estimated 1,607 LF of impacted stream.
- Clearing, grubbing of 13 acres, topsoil removal (10 acres), excavating, off-site borrow, and grading for site development activities.
- Installation of sediment controls include installation of silt fence, erosion control matting, and construct sediment basins 1 (5,516 yd^3) and 2 (1,867 yd^3). Silt fence will be installed along down-gradient slopes of NT-3 stream.
- Construction of access roads and laydown areas includes constructing a laydown and parking area south of the Haul Road and a gravel access road and staging area north of the Haul Road. Both areas are assumed to need minimal grading due to existing site conditions, but are assumed to need culverts installed prior to placing geotextile and gravel.
- Relocation of the 229 Boundary, assumes 4,350 LF of fencing demolished and 5,842 LF of fencing installed.
- Utility installation and distribution, includes water, communications, and associated equipment installation and connection. Assume EMWMF overhead power line can be extended for use. Water line extended from Bear Creek. Communications lines extended from EMWMF.
- Project oversight and reporting (engineering, health and safety, regulatory review, field services, document control, and project management).

Construction activities for all phases would include construction of the disposal facility cells (clearing/grubbing, hydrogeologic buffer, liner system, berms, etc.). Construction of six disposal cells of the facility would be in three phases (two cells in each phase [Phases I, II, and III]). Support facilities, including construction of the landfill wastewater treatment system described in Section 6.2.2.5 of the RI/FS, are part of Phase I construction. Placement of interim covers is part of operations and not included in construction; however, the interim cover materials are noted in Table I-3.

Support facilities, to be constructed as part of Phase I only include:

- Installation of personnel facilities and parking. Includes purchase and installation of six trailers to support construction personnel. Site preparation not required (already provided at EMWMF). Installation of two septic tanks, 2,000 gallons each.
- Installation of truck scales and three guard stations. Includes preparations (concrete pads and communications).
- Landfill wastewater treatment system (estimate from IWM FFS).
- Leachate storage tanks (new) to provide for 1,500,000 gallons of storage. Assumes three new tanks at 500,000 gallons each. Includes site preparation and concrete pads installed.
- Bypass pipelines for EMWMF and EMDF to allow for direct discharge.
- In-cell macroencapsulation batch plant (from URS|CH2M Oak Ridge LLC [UCOR] provided estimate).
- Elements 6 and 8 in Table I-3 contain efforts to develop requests for proposal for update of design and construction, and review/award of the contracts. Effort to complete the design addendum, and DOE O 413.3B requirements (Critical Decision-2/3 at the start and CD-4 at completion of each phase) is included.

Phase I, II, and III construction includes:

- Elements 5, 7, and 9 in Table I-3 summarize costs for construction of Phases I, II and III.
- Material (soil layer) for contouring of previous cells (e.g., Phase II includes soil contour for Cells 1 and 2; Phase III includes soil contour for Cells 3 and 4; Capping includes soil contour for Cells 5 and 6). Placement of all interim covers (enhanced operational cover) is assumed to be part of ongoing cell operations, and therefore the material (soil layer) is not considered capital cost.
- Mobilization/demobilization of construction subcontractor includes development of pre-mobilization submittals, work packages and lift plan; personnel training, construction of temporary facilities, support equipment and services, and site restoration upon completion of construction phase.
- Preparations for construction include clearing, grubbing of area for cell placement, topsoil removal, excavating, off-site borrow, and grading for site development activities.
- Excavation and fill costs for Cells 1 and 2 assume grading, filling, and installation of underdrain system below areas of Cells 3 and 4 to control surface water in upper areas of Northern Tributary-3 watershed.
- Landfill Construction Project Management includes project manager (includes managing subcontracts); project controls; scheduling and estimating; project engineer (includes Change Order reviews and engineering design modifications); health and safety officer; field engineers (construction observation); administrative support; development of preliminary hazard analysis reports, hazard acceptance and safety assessments documents; request for proposal efforts; document production/reproduction; procurement efforts for different design phases; and development of operation and maintenance manuals and record drawings.
- Actual construction of cells includes the following, significant materials (synthetic layers) were based on vendor quotes (P2S 2015, P2S 2016) listed below:
  - Installation of sediment controls.
  - Installation of security fencing, lighting, and alarms.
  - Site restoration.
  - Engineering and testing.

- – Support equipment services.
- – Underdrain construction.
- – Rough grading for under landfill liner (includes excavation and off-site borrow costs).
- – Test pads.
- – Construction of clean fill dike.
- – Construction of liner layers.
- – Installation of liner trenches and excavation boxes.
- – Armoring side slopes.
- – Construction of perimeter road and ditch.
- – Construction of upgradient ditch and French drain.
- – Installation of leachate and leak detection piping and equipment.
- – Installation of landfill waste water manholes.

- At the conclusion of design of each Phase, As-Built drawings/specs are finalized.
- For WBCV Site, and Dual Sites 7a/6b quantities are as follows:

Material Element	WBCV Site Option	Dual Site		Units
		Site 7a	Site 6b	
Phase I:				
Site Development				
Wetland mitigation	**2.1**	**4.5**	**0.2**	acres
Clearing and Grubbing	**22**	**22**	**8**	acres
Sediment basin(s)	**1 @ 5,516 2 @ 1,867**	**1 @ 5,516 2 @ 1,867**	**1 @ 5,516 2 @ 1,867**	yd^3
Phase I Construction				
6" Topsoil Removal =	**23,877**	**16,940**	**14,520**	yd^3
Soil Cut =	**18,923**	**71,857**	**3,604**	yd^3
Bedrock Cut =	**2,103**	**7,984**	**400**	yd^3
Riprap =	**170,073**	**144,676**	**125,674**	yd^3
Structural fill =	**617,738**	**712,113**	**140,249**	yd^3
Geologic Buffer =	**218,202**	**148,435**	**132,130**	yd^3
Phase II Construction				
Clearing and Grubbing	**16**	**12**	**8**	acres
6" Topsoil Removal =	**12,584**	**12,907**	**70,987**	yd^3
Soil Cut =	**20,932**	**71,857**	**94**	yd^3
Bedrock Cut =	**2,326**	**7,984**	**10**	yd^3
Riprap =	**97,471**	**99,072**	**71,741**	yd^3
Structural fill =	**380,247**	**952,194**	**178,022**	yd^3
Geologic Buffer =	**131,811**	**16,095**	**75,714**	yd^3
Phase II Construction				
6" Topsoil Removal =	**10,083**			yd^3
Soil Cut =	**196**			yd^3
Bedrock Cut =	**22**			yd^3
Riprap =	**20,044**			yd^3
Structural fill =	**259,900**			yd^3
Geologic Buffer =	**80,200**			yd^3

3.2.2.3 Operations (Element 2 in Table I-3)

It is assumed that all operations activities would be performed by a prime contractor to DOE. Transition of most equipment from the existing EMWMF to use at EMDF is assumed. Minimal equipment purchase is included. Operations activities would consist of waste record-keeping, receipt and inspection, WAC attainment, placement of wastes into the disposal cell, decontamination of waste packaging and transport vehicles, and maintenance of the disposal facility. Facility maintenance includes providing daily cover over the emplaced waste, landfill wastewater collection and management, equipment maintenance, support facility (e.g., roads and buildings) maintenance, and record keeping. Interim capping of filled cells is included in operations scope. Interim capping, with an enhanced operational cover, is considered part of ongoing operations; materials are included in operations with the exception of the contour layer (1 ft of soil). This contour layer is included in construction of cells (see Section 3.3.2.2). Disposal facility operations costs are based on actual EMWMF operations cost data as provided by UCOR, the current EMWMF operating contractor. Annual operations costs are taken from actual costs at EMWMF, estimated at $10.5M per year.

Treatment of waste to meet the disposal-facility WAC would remain the responsibility of the waste generator and is not included in this alternative.

Collected landfill wastewater would be stored in the existing EMWMF leachate storage tanks and contact water collection basins/modular tanks as well as new storage tanks. The landfill wastewater will be sampled and characterized. It will be managed as specified in the IWM FFS. The estimate for landfill wastewater treatment operations is taken from the IWM FFS. It includes all labor and materials to operate a 60 gallon per minute facility as described in the IWM FFS. Sampling and analysis are included. The lifetime is assumed to be 22 years of active cell operations plus an additional three years until final capping of the landfill is completed for a total of 25 years of operation.

Security operations were estimated based on the volume of classified waste predicted for receipt over the 22 year active life of the facility. Assumptions include:

- **Cell Security:** Assume classified waste will be received at the start of operations. Assume ½ day per week for a security guard to be on duty at the cell when classified waste is received. This is 5 hours/week or 260 hours/year for 22 years.
- **Drive by Security Checks:** Assume one drive-by per shift each day (there are three shifts in a day). Assume each drive-by is two hours. This totals 2 hours × 3 shifts/day × 7 days/week = 42 hours/week or 2,184 hours per year for 22 years.

3.2.2.4 Post-closure Care Operations (Element 3 in Table I-3)

Leachate post-closure costs include the cost to run the leachate treatment system for ten years following final capping of the landfill. This estimate includes sampling and analysis of the leachate. The annual estimate is from the IWM FFS; however, the FFS assumes a 30-year duration while this RI/FS assumes a ten year duration, after which the leachate generation is assumed to cease.

3.2.2.5 Final Capping and Facility Closure (Elements 10 and 11 in Table I-3)

Final capping and facility closure would include final design of the cover system, placement of the final cover system and quality assurance procedures associated with cover placement, removal of support facilities, and site restoration (see Section 6.2.8 of the RI/FS).

The final cap includes placing multiple layers over all filled waste cells. All overlying cap layers will tie into the clean-fill dikes. Site restoration will include seeding and mulching cap and dikes with native grasses and maintaining this until vegetative cover is established.

The final cover system (11 ft) is described in Section 6.2.2.4.7 of the RI/FS. It consists of multiple layers, beginning with the 1 ft contour layer that is added as part of the enhanced operational cover during the phased construction of Cells 3 and 4, and 5, and 6. A 1 ft thick compacted clay layer (native or amended to achieve specifications) is the first layer of the final cap. Subsequent layers include an amended clay layer, geomembrane layer (40 mil), geotextile cushion layer, lateral drainage layer (1 ft of #57 siliceous stone), biointrusion layer (2 ft 4–12 in. diameter riprap), geotextile separator layer, and final layer is the erosion control layer (4 ft vegetated soil/rock matrix), which includes a seed mix specially designed for this application. The final cover system would tie into the top of the perimeter clean-fill dike. The drainage and overlying layers would discharge water into perimeter ditches that would carry runoff away from the landfill. Quantities given in the bullets are for the EBCV Site conceptual design. Other site facilities were adjusted as needed.

Assumptions include:

- Mobilization/demobilization of construction subcontractor includes development of pre-mobilization submittals, work packages and lift plan; personnel training, construction of temporary facilities, support equipment and services, and site restoration upon completion of construction phase.
- Two test pads, each 100 ft × 100 ft for compacted clay liner and amended compacted clay liner.
- Purchase and installation of the compacted clay liner layer (67,600 yd^3).
- Purchase and installation of the amended (bentonite) compacted clay liner layer (67,600 yd^3).
- Geomembrane (40 mil) purchase and installation (1,673,100 ft^2).
- Geotextile (16 oz/yd^2) purchase and installation (1,673,100 ft^2).
- Lateral drainage layer purchase, constructed at 1 ft thick. Assumes stone density of 1.6 ton/yd^3 and 108,160 tons. Equipment and labor to construct.
- Biointrusion layer, purchase, construct at 4 ft thick. Assumes stone density of 1.5 ton/yd^3 and 202,800 tons. Equipment and labor to construct.
- Geotextile separator layer (8 oz/yd^2) purchase and installation (1,673,100 ft^2).
- Granular filter layer (1 ft thick, consisting of 6 in. thick #57 stone siliceous layer and 6 in thick sand layer) purchase and installation, 33,800 yd^3 of each layer.
- Erosion control layer 4 ft thick, purchase and build, soil and rock mixture 1:1, 270,400 yd^3.
- Erosion control matting, 9 mil thick, to be placed over erosion control layer, 169,000 yd^2.
- All oversight and construction quality assurance and control, testing, is assumed.
- Construction management is assumed.
- Development of As-Builts.

3.2.2.6 Post-closure (Element 12 in Table I-3)

Post-closure is assumed to be funded by the Perpetual Care Fee (see Section 3.3.2.4 above). As discussed, post-closure care is assumed to be carried out for 100 years. After 10 years, it is assumed that leachate from the landfill in the leachate collection system has ceased. The demolition of the water treatment system and support systems (tanks, ponds, etc.) is completed.

3.2.3 Present Worth

Present worth cost for the cost estimates were calculated based on EPA guidance (EPA 2000) using a real discount rate of 1.5% according to published 2016 Discount rates for Office of Management and Budget (OMB) Circular No. A-94 (OMB 2016). The present worth cost is based on discounting cost of non-escalated dollars over the period of activity as determined by the project schedule. For the On-site

Disposal Alternative, the period of activity is FY 2016 through FY 2047, with long-term maintenance extending for 1,000 years post-closure.

3.2.4 Construction of Five Cells

As stated in the Introduction of this Appendix, for the On-site Disposal Alternative, the 1.95 M yd^3 as-generated waste volume results in 2.18 M yd^3 as-disposed volume (required disposal capacity) as demonstrated in Chapter 2 (see Tables 2-3 and 2-4 in Chapter 2). This is the capacity provided by five cells, whereas the conceptual design is a six-cell design for both the EBCV and WBCV Sites. The cost developed for the EMDF and given in Table I-3 is for both the conceptual design (six cells) and the planned buildout of five cells. As only five cells are currently projected to be required (per the volume estimate), and that is the volume of waste assumed for the Off-site Disposal Alternative, a five cell estimated cost for the On-site Disposal Alternative WBCV and EBCV sites is used to compare to the Off-site Disposal Alternative cost. Table I-4 summarizes the reduction in costs if Cell 6 is not constructed for the EBCV Site (similar calculations were completed for the WBCV Site). Savings are realized in both the construction costs and the final cap costs. A revised total landfill estimate is also given in the table.

Assumptions used to reduce the cost of constructing a landfill with five cells, rather than the six cell design, include:

- Cell 6 is 45% of the capacity of Cells 5 and 6 combined. Reductions in construction costs (site preparations, liner, cell) are likewise reduced by 45%. This is the case for both the EBCV and WBCV sites.
- Cell 6 is 12% of the total capacity of Cells 1–6. Final capping materials and labor are reduced by 12% for the EBCV site. Cell 6 is 21% of the total capacity of Cells 1–6 for WBCV site, therefore final capping materials and labor are reduced by 21% for the WBCV site.
- Project management, oversight, and quality assurances costs for Phase III construction will not decrease commensurate with size reduction; a 25% reduction in cost is assumed.
- Project management, oversight, and quality assurances costs for Final Cap construction will not decrease commensurate with size reduction; a 5% reduction in cost is assumed.
- No reduction in engineering costs is assumed.
- No reduction in mobilization/demobilization costs is assumed.
- No reduction in project management for final capping is assumed.

Table I-4. Summary of Cost Reductions for Landfill Construction of Five Cells versus Six Cells

WBS Element	Original Cost ($)	Revised Five Cell Estimated Cost ($)	Reduction Taken for Cell 6 ($)
EMDF Construction Phase III	**$49,751,900**	**$30,950,506**	**$18,801,394**
Project Management	**$5,327,856**	**$3,622,942**	**$1,704,914**
Engineering (design, DOE/CERCLA doc.)	**$2,102,443**	**$2,102,443**	**$0**
Construct Cells 5 and 6	**$42,321,602**	**$25,225,122**	**$17,096,480**
Construction Management	*$3,142,200*	*$2,356,650*	*$785,550*
Oversight and Quality Assurance	*$2,969,358*	*$2,227,018*	*$742,339*
Mobilization/demobilization	*$1,613,176*	*$1,613,176*	*$0*
Cell 5 & 6 Preparations	*$5,443,382*	*$2,993,860*	*$2,449,522*
Cells 5 & 6 Buffer and Liner Systems	*$18,938,029*	*$10,415,916*	*$8,522,113*
Cells 5 & 6 Construction	*$10,215,457*	*$5,618,501*	*$4,596,956*
EMDF Construction Final Cap	**$69,219,039**	**$63,352,358**	**$5,866,681**
Project Management	**$7,072,992**	**$7,072,992**	**$0**
Construct Final Cap	**$62,146,047**	**$56,279,366**	**$5,866,681**
Construction Management and Oversight	*$6,665,242*	*$6,331,980*	*$333,262*
Oversight and Quality Assurance	*$6,498,415*	*$6,173,495*	*$324,921*
Mobilization/demobilization	*$3,271,078*	*$3,205,657*	*$65,422*
Final Cap Construction	*$45,711,311*	*$40,568,234*	*$5,143,077*
SUBTOTAL (FY 2012 $)			**$24,668,075**
Contingency (22%)			**$5,426,977**
TOTAL with Contingency (FY 2012 $)			**$30,095,052**

3.3 LONG-TERM CARE AND SURVEILLANCE AND MAINTENANCE

Long-term care and S&M are calculated by several methods of accomplishment for comparison purposes. The existing EMWMF uses a perpetual care fee paid annually to the State of Tennessee to cover the cost of standard S&M and post-closure care. Another method of accomplishment is to do a straight assumption of cost incurred over the lifecycle of long-term care for the facility. A comparison of both methods is made here. The comparison is made on a present worth basis.

3.3.1 Perpetual Care Fee Method (Trust Fund)

A perpetual care fee is paid on an annual basis. The purpose of this fee/payment is to collect and invest funds upfront, so that upon closure more funds are available because of investing the money. Assuming an annual payment of $1M into some type of trust (e.g., there is no assignment of performer), for 22 years of operation (or $22M total), will earn compounded interest. At the end of operation these funds have been earning interest for that entire time period. At an estimated 3% return, the base amount ($22M, $1M annually invested) will have grown to $34,369,415 after closure (investment for 22 years + 3 years during capping). Interest alone on this amount provides an annual income of $1,031,082 in its 25th year. Annual costs for S&M are estimated in Table I-5 (FY 2012 dollars) for all sites. In present dollars (FY 2016), these costs range from about $550,000 per year to $157,000 per year. Provided investments keep up with inflation, the perpetual care fee could be expected to fund S&M of the landfill through the 100-year period following closure or far beyond, in perpetuity.

3.3.2 Summary of Long-term Maintenance (no Trust Fund)

The second method to consider the cost of long-term maintenance is to sum the years of long-term care. A summary that compares long-term S&M costs via a perpetual care fee versus straight summary of costs over the 1,000 year compliance period is given in Table I-6 for all sites. Final values are reported in Present Worth dollars (FY 2016 $).

Assumptions for all long-term maintenance include:

- Annual mowing and fertilizing (see Table I-5 for acreage mowed, for each site).
- Watering to occur only the first three years.
- Annual weed control in specific areas.
- Annual surface water drainage maintenance.
- Quarterly ground water monitoring of 12 wells per landfill. Includes sampling, analysis, and reporting. Personnel include: Two Technicians, one Supervisor, one Radcon, one Health and Safety, one Engineer.
- Quarterly records maintenance and CERCLA reporting.
- CERCLA five-year review input at $50,000 per review.
- Yearly inspections, quarterly for the first three years.
- Cap maintenance annual repair. Reseeding for first three years until vegetation is established.
- Project management of effort (15%) and contingency at 27%.
- For VR estimation, annual mowing; watering (for initial three years); and annual weed control were removed for 7 of the 40 acres. This resulted in years 1 -3 cost of $389,190 and subsequent years annual cost of $278,820 (years 4-100). Over a period of 100 years of post-closure care, this is approximately $1M.
- See Table I-5 for additional assumptions.

As demonstrated in Table I-6 results, the present worth cost for 1,000 years of long-term care is significantly less than the present worth value of the trust fund, except in the case of the Dual Site Option, where the sum of the cost for 1,000 years of post-closure care exceeds the trust fund value. The biggest expense of S&M during the long-term maintenance is the sampling and characterization costs. The present worth costs given here assume a $7M repair (approximately 10% of the cap construction costs) to the cap at two points in time, one at 50 years post-closure the other at 100 years post closure. The total estimates given throughout the document for the On-site Disposal Alternative, for each Site, and the Hybrid Disposal Alternative use the higher of the two values, Present Worth of the Perpetual Care Fee or Present Worth of the 1,000 year long-term care. Thus the Perpetual Care Fee is incorporated into the lifecycle costs of the alternatives. As indicated in the table, for the Hybrid Disposal Alternative, a $12M Perpetual Care Fee ($1M per year of operation), is nearly equivalent to the Present Worth of 1,000 years of long-term care. Additionally, the Perpetual Care Fee for the Dual Site was adjusted up to $25 M total, just over $1 M annually.

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Table I-5. Estimated Annual S&M Costs in FY 2012 dollars for All Sites

		Option 5 (EBCV Site) acreage		70		Option 14 (WBCV Site) Acreage		71	Dual Option (Site 6b) Acreage		50	Dual Option (Site 7a) Acreage		59
	Expenses to be assumed by Some Unnamed Entity (DOE or TDEC) upon completion of final closure include:	**Annual Cost**	**Additional Annual Cost for first 3 years**	**Amount**	**Unit**	**Annual Cost**	**Additional Annual Cost for first 3 years**	**Amount**	**Annual Cost**	**Additional Annual Cost for first 3 years**	**Amount**	**Annual Cost**	**Additional Annual Cost for first 3 years**	**Amount**
8.a.	Maintenance (mowing, weed eating, fertilizing, watering). Mowing will be performed 2x per year, fertilizing 1x per year and watering 2x year for 3 years. Per CostPro, $1.76/1000 sq ft mowing; $2.62/1000 sq ft fertilizing; $20.19/1000 sq ft watering. escalate from fy11 $ to fy12 $ @ 2.3%	$ 13,663	$125,959	3,049,200	sq ft	$ 13,858	$127,758	3,092,760	$9,759	$ 89,970	2,178,000	$ 11,516	$106,165	2,570,040
8.a. > 30 year	Mowing after 30 years will decrease to cap only. EBCV = 35 + 5 = 40 acre WBCV = 34 + 5 =39 acre Site 7a = 23 + 5 =28 acre Site 6b = 17 + 5 = 22 acre	$7,807		1,742,400	Sq ft	$7,612		1,698,840	$4,294		958,320	$5,465		1,219,680
8.b.	Weed control (spraying) around appurtenances (vents, wells, rip rap) and spraying for bugs (fire ants) 4x per year. Assume 2 FTEs, 8 hr/ea per event.	$ 884		$ 28	labor rate	$ 884			$ 884			$ 884		
	Surface water & underdrain exit maintenance of drainage	$ 15,000	-	-	-	$ 16,800			$5,100			$9,408		
8.c.	Groundwater monitoring													
i.	Analysis, $887 per well x # wells x 4 events per year EBCV, WBCV = 12 wells; Site 7a and 6b = 10 wells	$ 39,744				$ 39,744			$ 33,120			$ 33,120		
ii.	Sampling, 4 hr per well, includes 2 techs and 1 supervisor ; 1 radcon @ 30 hr; H&S tech @ 10 hr; supervisor engr @ 20 hr	$ 13,951		$ 36	tech	$ 13,951			$ 11,626			$ 11,626		
		$ 12,432		$ 65	supervisor	$ 12,432			$ 10,360			$ 10,360		
		$8,872		$ 74	radcon	$8,872			$7,393			$7,393		
		$2,880		$ 72	H&S tech	$2,880			$2,400			$2,400		
		$6,334		$ 79	engr rate	$6,334			$5,278			$5,278		
iii.	Analytical records maintenance, review, and reporting/filling (Assume 1 FTE 48 hr per sample event,192 hr per year; technical personnel 2 FTE per event 4 hr each, 32 hr per year)	$ 14,122		$ 74	labor rate	$ 14,122			$ 14,122			$ 14,122		
		$2,533		$ 79	engr rate	$2,533			$2,533			$2,533		
iv.	Assume annual update to SAP/QAPP, 1 FTE 24 hr per year	$1,900		$ 79	engr rate	$1,900			$1,900			$ 1,900		
v.	Shipping of samples $3400/event	$ 13,600				$ 13,600			$ 13,600			$ 13,600		

Table I-5. Estimated Annual S&M Costs in FY 2012 Dollars for All Sites (Continued)

		Option 5 (EBCV Site) acreage 70				Option 14 (WBCV Site) Acreage 71			Dual Option (Site 6b) Acreage 50			Dual Option (Site 7a) Acreage 59		
	Expenses to be assumed by Some Unnamed Entity (DOE or TDEC) upon completion of final closure include:	**Annual Cost**	**Additional Annual Cost for first 3 years**	**Amount**	**Unit**	**Annual Cost**	**Additional Annual Cost for first 3 years**	**Amount**	**Annual Cost**	**Additional Annual Cost for first 3 years**	**Amount**	**Annual Cost**	**Additional Annual Cost for first 3 years**	**Amount**
8.d.	Post-closure inspections (non-security related, these are physical inspections of pumps, pipes, automatic monitoring) 6x per year, 4 hr ea event, 2 FTE; assume $5K in maintenance costs per year	$8,108		$ 65		$8,108			$8,108			$8,108		
8.e.	Engineer inspections quarterly per year first 3 years; 1x per year thereafter. 8 hr/event	$ 633	$1,900	$ 79	tech rate	$ 633	$1,900		$ 633	$1,900		$ 633	$1,900	
8.f.	Cap repair													
i.	Fill in low spots of cap with soil/gravel mix and reseed as necessary	$ 10,000				$ 10,000			$8,000			$6,000		
ii.	Repair eroded areas; areas that will not grow vegetative cover will be controlled with rip rap; assume $2/sq ft	$ 60,984		30,492	sq ft	$ 61,855		30,928	$ 43,560		21,780	$ 51,401		25,700
iii.	Combine tilling with reseeding in first three years, for 1/4 the acreage	---	$ 15,745	3,049,200	sq ft		$ 15,970	3,092,760		$ 11,246	2,178,000		$ 13,271	2,570,040
10	Management of Post Closure Care (assume 15%)	$ 33,846	$ 21,541			$ 34,276	$ 21,844		$ 26,756	$ 15,468		$ 27,972	$ 18,200	
TOTAL	**FY 2012 DOLLARS**	**$259,484**	**$165,144**			**$262,781**	**$167,472**		**$205,132**	**$118,584**		**$214,453**	**$139,536**	

	Option 5			Option 14			Site 6b			Site 7a		
FY 2012 dollars	$424,628	Years 1-3	Sampling decreases; mowing decreases	$430,253	Years 1-3	Sampling decreases; mowing decreases	$323,716	Years 1-3	Sampling decreases; mowing decreases	$358,359	Years 1-3	Sampling decreases; mowing decreases
	$259,484	Years 4 to 30		$262,781	Years 4 to 30		$205,132	Years 4 to 30		$218,823	Years 4 to 30	
	$166,354	Years > 31		$169,260	Years > 31		$122,918	Years > 31		$136,024	Years > 31	
	$7,000,000	Cap Maintenance 2x, once 50 years after closure. Once 100 years after closure.		$7,000,000	Cap Maintenance 2x, once 50 years after closure. Once 100 years after closure.		$7,000,000	Cap Maintenance 2x, once 50 years after closure. Once 100 years after closure.		$7,000,000	Cap Maintenance 2x, once 50 years after closure. Once 100 years after closure.	

	Option 5		Option 14		Site 6b		Site 7a	
FY 2016 dollars	$ 541,462	Years 1-3 w/22% conting.	$ 548,634	Years 1-3 w/22% conting.	$ 412,785	Years 1-3 w/22% conting.	$ 456,960	Years 1-3 w/22% conting.
	$ 330,880	Years 4 to 30 w/22% conting.	$ 335,083	Years 4 to 30 w/22% conting.	$ 261,573	Years 4 to 30 w/22% conting.	$ 279,031	Years 4 to 30 w/22% conting.
	$ 212,125	Years > 31 w/22% conting.	$ 215,830	Years > 31 w/22% conting.	$ 156,738	Years > 31 w/22% conting.	$ 173,450	Years > 31 w/22% conting.

Table I-6. Comparison of Present Worth Cost for Long-term Care versus Present Worth Value of a Perpetual Care Fee

Annual Estimated Cost	Proposed Sites in BCV			
	EBCV	WBCV	Dual Site	
			Site 6b (Hybrid Site also)	Site 7b
Annual S&M cost, FY2016 dollars				
Years 1 – 3	$ 541,462	$ 548,634	$ 412,785	$ 456,960
Years 4 – 30	$ 330,880	$ 335,083	$ 261,573	$ 279,031
Years 31 – 1,000	$ 212,125	$ 215,830	$ 156,738	$ 173,450
Cap Maintenance, $7 M at 50 years and 100 years	$ 14,000,000	$ 14,000,000	$ 14,000,000	$ 14,000,000
Total Cost, Present Worth (FY16 dollars) 1,000 years	$14,602,986	$14,771,678	$11,955,915	$12,718,490
			$ 24,674,404 (both Sites 6b/7a)	
Present Worth Value of Perpetual Care Fee (Trust Fund) FY 2016 dollars				
Present Worth Value of Perpetual Care Fee (Trust Fund)	$18,900,137	$18,900,137	$18,900,137 (12 years, for Hybrid, $11,071,118)	

4. OFF-SITE DISPOSAL ALTERNATIVE COST ESTIMATE

This section provides the key assumptions for the Off-site Disposal Alternative cost estimate, the basis for the estimate, and the summary results.

4.1 COST ESTIMATE CONDITIONS AND ASSUMPTIONS

A cost estimate was assembled for the Off-site Disposal Alternative based on the as-generated waste volume estimate discussed in Chapter 2 and Appendix A of the RI/FS. This section provides the conditions and assumptions for the estimate. Table I-7 summarizes those volumes as they are used in the off-site estimate. Note that an assumption is made that mixed waste soil is treated by generators to meet Land Disposal Restrictions prior to disposal, and therefore is considered only LLW or LLW/TSCA for purposes of disposal.

The cost estimate for the Off-site Disposal Alternative includes truck-to-rail transfer, long-distance transportation of the waste to the off-site disposal facilities, and disposal fees. Costs excluded from the estimate are those common to both disposal alternatives (see Section 2 of this Appendix).

Figures I-3 and I-4 show the off-site disposal activities and responsible entities for waste shipments to NNSS, Energy*Solutions,* and/or WCS.

Table I-7. As-generated Waste Volume Estimate (FY 2022 – FY 2043) for Off-site Disposal Alternative

Off-site Disposal Facility	Waste Type	Volume Including 25% Contingency (yd^3)
Option 1: NNSS (Non-Classified)	LLW and LLW/TSCA Debris	1,151,440
Option 2: Energy*Solutions*	LLW and LLW/TSCA Soil	607,468
	SUBTOTAL	**1,758,908**
NNSS (Classified)	LLW Debris	35,612
	LLW/RCRA (mixed) Debris[1]	4,621
	SUBTOTAL	**40,233**
Energy*Solutions* or WCS	LLW/RCRA (mercury) Debris[2]	149,418
	SUBTOTAL	**149,418**
	TOTAL	**1,948,559**

[1]This waste volume assumed to be treated by generator prior to disposal, and thus meets land disposal restrictions.

[2]This waste may or may not be treated at the disposal facility. Regardless of how/where it is treated, the cost for treatment is not included in the Off-site Disposal Alternative estimate.

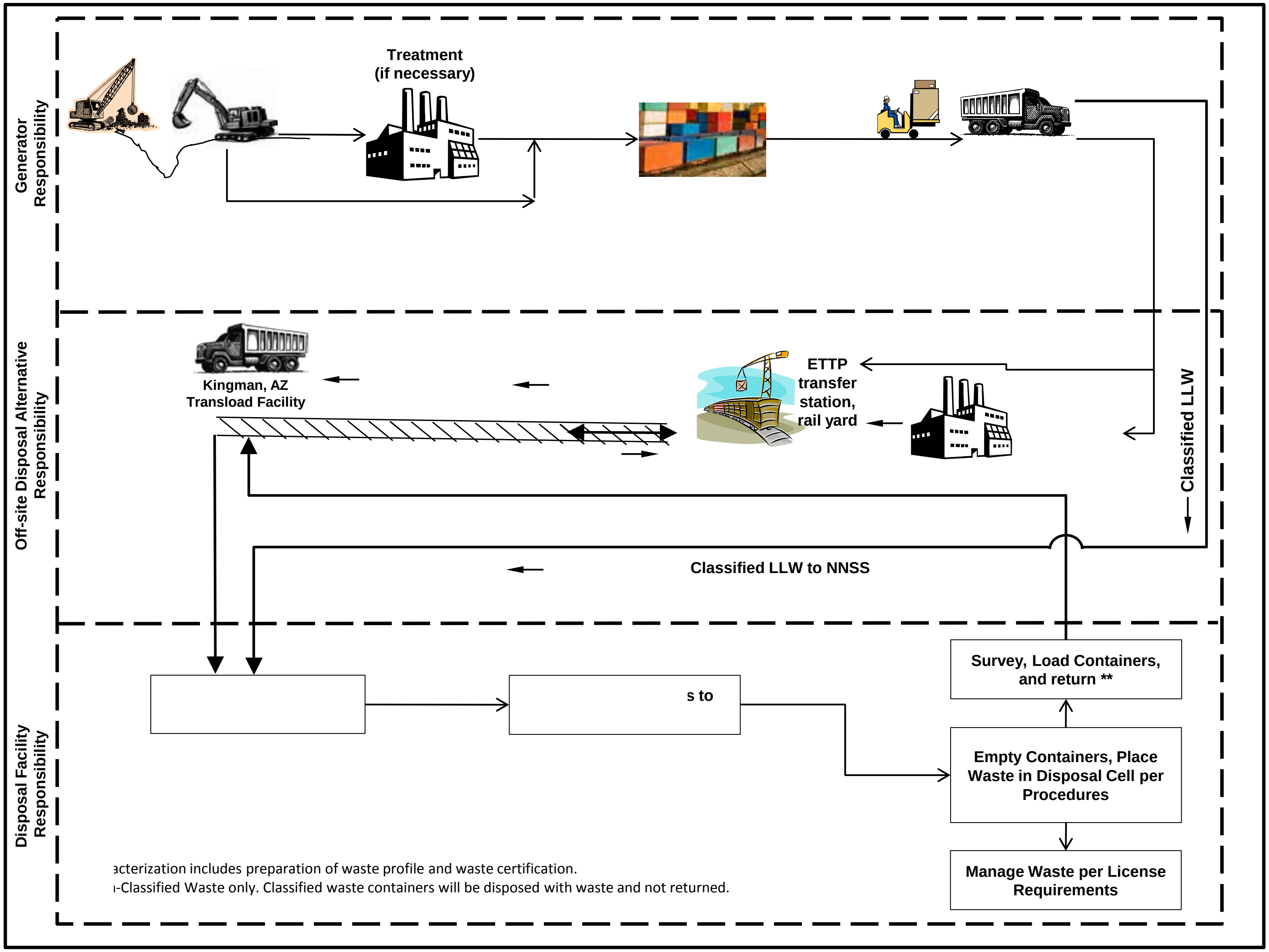

Figure I-6. Schematic of Responsibilities for Waste Shipments to NNSS for Off-site Disposal Alternative

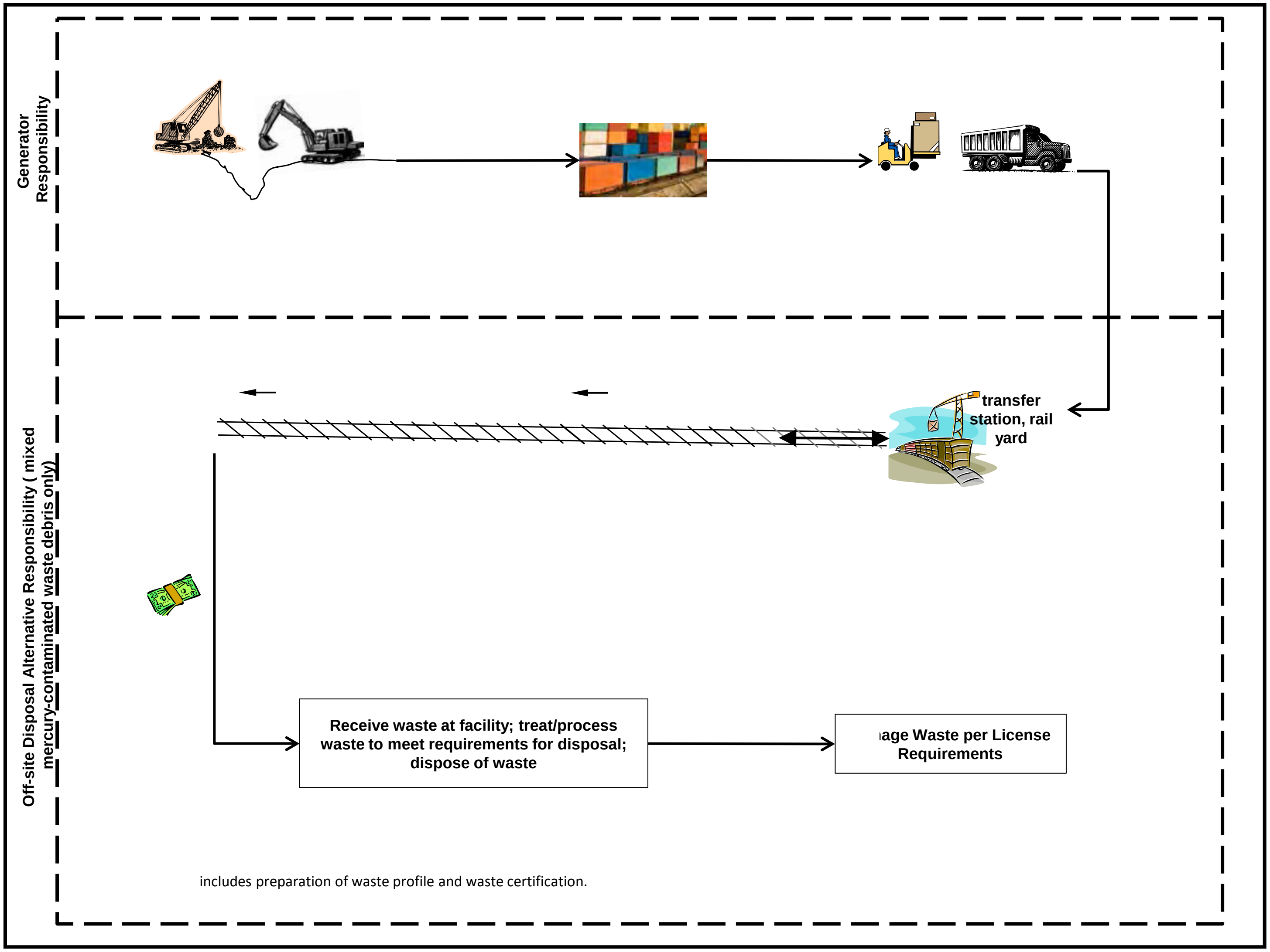

Figure I-7. Schematic of Responsibilities for Waste Shipments of Mercury-contaminated Waste to Energy*Solutions* or WCS in Off-site Disposal Alternative

This alternative provides for the transportation of future candidate waste streams off the ORR to approved disposal facilities and placement of the wastes in those facilities. For purposes of the cost estimate, two options are examined: non-classified LLW and LLW/TSCA waste would be shipped to either NNSS in Nye County, Nevada, or Energy*Solutions* in Clive, Utah. Any classified LLW or LLW/TSCA waste would be shipped for disposal at NNSS. Classified mixed waste would be treated by the generator to meet the NNSS WAC prior to shipment to NNSS. Any mixed (LLW/RCRA) waste requiring treatment (e.g., the mercury-contaminated debris) is assumed to go to either Energy*Solutions* or WCS in Andrews, Texas, where it may undergo treatment to meet land disposal restrictions and be disposed (the cost of this treatment is not included in the estimate. That cost is assumed to be paid by the waste generator/demolition contractor and not within the scope of this RI/FS). Waste generator costs for treatment of waste to meet the facility WAC are not included in the Off-site Disposal Alternative estimate. All non-classified waste would be shipped by rail to Energy*Solutions* or NNSS. For transport to NNSS, rail to a transloading station in Kingman, Arizona, would be followed by truck transport to NNSS. All classified waste shipments to NNSS would be by truck transport. Thus, two options are considered:

Option 1 (Major Destination NNSS):

- All classified waste disposed by NNSS
- All mixed waste treated and disposed by Energy*Solutions* and/or WCS (no additional cost for treatment included; waste generator scope would include this cost)
- All LLW and LLW/TSCA disposed by NNSS

Option 2 (Major Destination Energy*Solutions*):

- All classified waste disposed by NNSS
- All mixed waste treated and disposed by Energy*Solutions* and/or WCS (no additional cost for treatment included; waste generator scope would include this cost)
- All LLW and LLW/TSCA disposed by Energy*Solutions*

The key assumptions for the Off-site Disposal Alternative cost estimates for both options are as follows:

- All classified LLW would be disposed at the NNSS facility in Nye County, Nevada.
- Classified mixed waste would be treated by generators to meet NNSS WAC, and transported after treatment by truck to NNSS for disposal.
- Classified waste would travel in intermodals to NNSS. Those intermodals would be disposed with the waste.
- The NNSS WAC allows for the use of returnable intermodal containers used for LLW and LLW/TSCA (non-classified).
- All LLW/RCRA (mixed) waste may be treated and would be disposed at the Energy*Solutions* facility in Clive, Utah, or WCS in Andrews, Texas. Costs for treatment are not included. Destination is assumed to be Energy*Solutions* facility.
- All non-classified waste shipped to NNSS would be transported in lined intermodal containers from the individual remedial sites to the ETTP rail siding, loaded onto railcars, and shipped by rail to Kingman, Arizona, transload facility followed by truck transport to NNSS (two intermodal containers per truckload for debris and one intermodal container per truckload for soil).
- Articulated bulk container (railcars) would be used for transportation of soil and debris to NNSS.
- Each intermodal would contain approximately 21.2 yd^3 of debris waste or 14.5 yd^3 of soil waste and each railcar will carry eight intermodal containers.
- Intermodal containers would be purchased and reused for all non-classified, non-RCRA hazardous waste shipment.

- All waste shipped to Energy*Solutions* would be collected at demolition sites in trucks and transferred to high-sided (super) gondolas at the transloading station at ETTP, and shipped (rail) to Energy*Solutions* for disposal.
- High-sided gondolas (super gondolas) have a weight limit of 100 tons.
- Intermodal containers would be purchased for all classified waste shipments (non-returnable containers).
- All intermodal/sealand containers would include a plastic liner for each shipment.
- Intermodal/sealand container design life is 10 years. Containers are purchased then disposed when they reach 10 years.
- Macroencapsulation is the assumed waste treatment for LLW/RCRA (mixed) waste disposed at Energy*Solutions* or WCS; however, no cost is assumed for that treatment.
- Waste treatment/disposal fees for Energy*Solutions* or WCS are based on the actual volume shipped in the container and not on the total container volume.
- Per a National Nuclear Security Administration memorandum (NNSA 2008), a disposal access fee rate of $14.51 per ft^3 is applied for NNSS disposal.
- No capital improvements would be required at ETTP to handle loaded intermodal containers. (All labor and necessary equipment costs for handling at ETTP are included in the rail shipment cost estimate.)
- Energy*Solutions* Indefinite Delivery Indefinite Quantity (IDIQ) contract fees for LLW debris and soil disposal were used, for year one (FY 2012). Disposal fees were discounted by 15% when yearly shipments exceeded the 50,000 yd^3 per year cap, per the IDIQ.
- VR is applied to the Off-site Disposal Alternative, Option 1 (all LLW and LLW/TSCA disposed at NNSS). Per Appendix B, this includes construction and operation of a size reduction facility. Corresponding net avoided cost of Option 1 off-site disposal costs (total) in FY 2012 dollars is $80,501,000.
- For the Off-site estimate, the scope contingency was estimated at 12%, toward the higher value recommended by EPA (off-site disposal 5-15% contingency range) since the scope (e.g., disposal cost per volume of waste) used in the estimate is not adjusted for surcharges that are likely to be leveled (e.g., those for fuel, over-sized equipment disposal, water content of soils). A mid-value bid contingency of 15% is applied due to the significant risk inherent in an alternative that might be affected by external uncontrollable influences such as travel across state lines, potential for modified off-site availability, and the unusually long timeframe in which waste is expected to be generated. Therefore, a total 27% contingency is applied to the off-site alternative.
- Project Management by a Management and Operating Contractor, to oversee and coordinate the off-site packaging, shipment and disposal is assumed at 2.5% of the off-site transport and disposal costs.
- Present Worth calculations assume a 1.5% real discount rate.
- Escalation calculations assume a 4.52% escalation rate for the whole period 2012 to 2016 (CPI 2016), and a 2.3% escalation rate thereafter.

4.2 FINANCIAL BASIS OF ESTIMATE

The key components of the Off-site Disposal Alternative cost estimate are those costs associated with packaging, transportation, and treatment/disposal. Costs calculated for the Off-site Disposal Alternative estimates are situation-specific rates based on privatized cost estimates, and include an allowance for involvement of an integrating contractor. Table I-8 shows the costs used for transportation and disposal.

The transportation and treatment/disposal costs are based on assumed contractual parameters and may not represent individual shipments. The estimate includes purchase cost for intermodal containers for waste shipments to NNSS and sealand containers for waste shipments to Energy*Solutions*. Intermodal/sealand containers used for LLW would be reused as many times as possible during an assumed design life of 10 years. Intermodal containers for classified waste are considered single use. Disposal costs for Energy*Solutions* are based on Indefinite Delivery/Indefinite Quantity rates in the current contract with DOE (Energy*Solutions* 2012). All containers are assumed to require liners, which are purchased for each shipment.

Rail transportation, which is approximately 11% less expensive than truck transport, is assumed for all shipments (with the exception of classified waste shipments to NNSS). It is likely that a combination of rail and truck transport would be used.

Table I-8. Transportation and Treatment/Disposal Costs for Off-site Disposal Alternative

Transportation Costs*		
Rail from ETTP Railyard to Kingman, Arizona	$ 25,440	Per ABC railcar (8 intermodals per railcar)
Rail from ETTP Railyard to Clive, Utah	$ 18,500	Per Gondola (3 sealands per gondola)
Truck transport from Kingman, Arizona to NNSS	$1,000	Per truckload for soil waste (1 intermodal per truckload)
	$ 2,000	Per truckload for debris waste (2 intermodals per truckload)
Rail loading/unloading for truck transport and return of empty containers (Kingman, Arizona)	$ 370	Per intermodal
Container purchase (classified waste shipments)	$ 6,300	Per intermodal
Container purchase (sealands)	$ 8,804	Per sealand
Container liner purchase	$ 545	Per intermodal/sealand, per trip
Truck transport to NNSS for classified waste	$ 15,887	Per truckload (2 intermodals per truckload for classified debris waste)
Treatment/Disposal Costs*		
Energy*Solutions* Disposal Fee for bulk LLW debris	$ 533.96	Per yd^3 of debris
Energy*Solutions* Disposal Fee for bulk LLW soil	$ 198.35	Per yd^3 of soil
Surcharge for sealands by railcar	$ 16.63	Per Gondola/railcar
NNSS disposal access fee rate	$ 391.77	Per yd^3

**All rates are in 2012 dollars*

4.3 CONTINGENCY AND RISK

For the Off-site estimate, the scope contingency was estimated at 12%, toward the higher value recommended by EPA (off-site disposal 5–15% contingency range) since the scope (e.g., disposal cost per volume of waste) used in the estimate is not adjusted for surcharges that are likely to be leveled (e.g., those for fuel, over-sized equipment disposal, water content of soils).

A mid-value bid contingency of 15% is applied due to the significant risk inherent in an alternative that might be affected by external uncontrollable influences such as travel across state lines, potential for modified off-site availability, and the unusually long timeframe in which waste is expected to be generated. Therefore, a total 27% contingency is applied to the off-site alternative.

Risks, implications to cost, and probability of occurrence associated with off-site disposal include:

Risk	Cost Implications	Probability of Occurrence
• Delay of ORR Cleanup corresponding to Program annual appropriations that do not increase commensurate with increased annual disposal cost (off-site versus on-site)	Very high cost	Likely
• Disposal of greater than Class A waste at NNSS in the Option 2 Off-site Disposal Alternative	Low to moderate cost	Very likely
• Public road travel from demolition site to rail transloading station located at ETTP	High cost	Very likely
• Fuel, debris size/weight, soil water content surcharges	Low to high cost	Very likely
• Mercury-contaminated debris that does not exhibit the hazardous characteristic must be disposed of as mixed waste, regardless	Moderate to high cost	Moderate
• Shutdown of off-site facilities due to violations	Very high cost	Unlikely
• Unavailability of facilities due to state equity issues	Very high cost	Unlikely
• Multi-state travel; equity issues	Moderate to very high cost	Moderate
• Long-term DOE liability at an off-site location	Moderate to very high cost	Unlikely

Estimates for the two off-site disposal options are given in Tables I-9 and I-10.

4.4 PRESENT WORTH

The present worth calculation approach for the Off-site Disposal Alternative using a real discount rate of 1.5% is the same used for the On-site Disposal Alternative estimate as described in Section 4.2.7 of this Appendix. Present worth is given in FY 2016 dollars.

Table I-9. Off-site Disposal Alternative Estimated Cost, Option 1 Disposal at NNSS

Element	Volume (yd^3)	Cost (FY 2012 dollars) Destination: NNSS
Classified Waste – Debris	32,186	
With 25% uncertainty	40,233	
Packaging (intermodals and liners)		$ 12,990,231
Transportation		$ 30,149,861
Disposal Fee		$ 15,761,969
Subtotal		**$ 58,902,061**
LLW or LLW/TSCA – Debris	1,040,686	
With 25% uncertainty	1,300,858	
Packaging (intermodals and liners)		$ 46,272,081
Transportation (ABC rail cars/truck)		$329,238,000
Disposal Fee		$ 509,636,987
Subtotal		**$885,147,067**
LLW or LLW/TSCA – Soil	485,974	
With 25% uncertainty	607,468	
Packaging (intermodals and liners)		$ 26,827,064
Transportation (ABC rail cars/truck)		$ 190,881,600
Disposal Fee		$ 237,987,742
Subtotal		**$ 455,696,406**
Project Management and Oversight		$36,043,638
SUBTOTAL (FY 2012 $) • All waste to NNSS	**$ 1,435,789,173**	
Subtract the net cost avoided by implementing VR for Option 1 only (see Appendix B)	**– $ 80,501,000**	
Revised SUBTOTAL (FY 2012 $)	**$ 1,355,288,173**	
CONTINGENCY (12% Scope, 15% Bid) 27%	**$ 365,927,807**	
TOTAL with CONTINGENCY (FY 2012 $)	**$ 1,721,215,979**	
TOTAL with CONTINGENCY (FY 2016 $)	**$ 1,799,014,941**	
ESCALATED COST with CONTINGENCY (FY 2022 – FY 2043)	**$ 2,802,305,959**	
PRESENT WORTH with CONTINGENCY (FY 2016)	**$ 1,494,358,468**	

[1] WCS destination only for mixed, mercury-contaminated debris.

Table I-10. Off-site Disposal Alternative Estimated Cost, Option 2 Disposal at Energy*Solutions*

Element	Volume (yd^3)	Cost (FY 2012 dollars)	
		Destination: NNSS	**Destination: Energy*Solutions***
Classified Waste – Debris	32,186		NA
With 25% uncertainty	40,233		
Packaging (intermodals and liners)		$ 12,990,231	
Transportation		$ 30,149,861	
Disposal Fee		$ 15,761,969	
Subtotal		**$ 58,902,061**	
LLW or LLW/TSCA – Debris	1,040,686		
With 25% uncertainty	1,300,858		
Transportation (Gondola)			$ 211,061,485
Disposal Fee			$ 662,724,303
Subtotal			**$873,785,788**
LLW or LLW/TSCA – Soil	485,974		
With 25% uncertainty	607,468		
Transportation (Gondola)			$ 140,720,300
Disposal Fee			$ 77,078,584
Subtotal			**$217,798,884**
Project Management and Oversight		$ 29,812,168	
SUBTOTAL (FY 2012) • Classified debris to NNSS for disposal • All remaining waste to Energy*Solutions*	**$ 1,180,298,901**		
CONTINGENCY (12% Scope, 15% Bid) 27%	**$ 318,680,703**		
TOTAL with CONTINGENCY (FY 2012 $)	**$ 1,498,979,605**		
TOTAL with CONTINGENCY (FY 2016 $)	**$1,566,733,483**		
ESCALATED COST with CONTINGENCY (FY 2022 – FY 2043)	**$ 2,273,455,268**		
PRESENT WORTH with CONTINGENCY (FY 2016)	**$ 1,315,127,421**		

5. HYBRID DISPOSAL ALTERNATIVE COST ESTIMATE

This section provides the key assumptions for the Hybrid Disposal Alternative cost estimate, the basis for the estimate, and the summary results. For this alternative, because it is a combination of on-site and off-site disposal, much of the information given previously for on- and off-site disposal applies. Only those assumptions and bases that differ from the information given in Chapters 3 and 4 are given here.

5.1 COST ESTIMATE CONDITIONS AND ASSUMPTIONS

For the hybrid scenario, Site 6b was selected for the location of the EMDF. Table I-3 contains the detailed cost estimate for the hybrid on-site portion. The summary on-site cost and off-site portion are contained in Table I-11. Key assumptions that are modified from the on-site estimate include:

- Assume EMWMF capacity is filled in FY 2024. EMDF would have an operational lifespan of approximately 12 years from FY 2022 through FY 2034 and waste would be generated during the 12 years of operation. This schedule assumes approximately two years of operational overlap of the two facilities. Waste disposed past FY 2034 would be disposed off-site entirely.
- During operation of the EMDF (on-site facility) waste would also be disposed of off-site (debris only) at a rate of 10% of the generated debris.
- Activities for CERCLA waste disposal began in FY 2012, and will complete in FY 2044 in the current schedule; this is a total life-cycle of 33 years.
- The total capacity of EMDF would be approximately 0.85M yd^3. The disposal facility would be constructed in two phases. Each phase would include the construction of two or three disposal cells; the entire facility would include five cells.
- Site development activities would be performed to prepare the site and provide/modify support facilities and utilities prior to landfill construction. Some support facilities would be shared with the existing EMWMF.
- The first phase of landfill construction would include the construction of two waste disposal cells (Cells 1 and 2) and the associated structural features necessary for operation of Cells 1, 2 and future disposal cells. Construction of the first phase would be implemented so that the EMDF is ready to receive waste for approximately two years prior to reaching capacity at EMWMF.
- Phase II construction would include the construction of two waste disposal cells (Cells 3, 4 and 5) and the soil contour layer for interim capping of Cells 1 and 2. This construction would occur simultaneously with the operation of the disposal cells.
- The EMDF would be closed with a final cap that would be placed at the conclusion of operation of Cell 5 including an interim cap (soil contour layer).
- The new disposal facility would be a stand-alone facility. Complete self-supporting infrastructure (e.g., access roads, utilities, disposal cells, leachate collection, treatment facilities, staging, truck scales, etc.) would be constructed or shared with EMWMF (see Section 6.2.2.5 of the RI/FS).
- A VR facility would be built adjacent to the cells. Operation of the facility would occur alongside the operation of the disposal facility, for the same duration. Details of the VR facility are contained in Appendix B. Costs given in Appendix B are modified here to reflect the reduced operating period (from 22 years in Appendix B to 12 years for the Hybrid). The cost of VR for a lifecycle of 12 years is estimated to be: $29,354,512. (see Table B-13 in Appendix B).
- Off-site disposal occurs via the Off-site Disposal Alternative Option 2 (Major Destination Energy*Solutions*):
  - All classified waste disposed by NNSS

- All mixed waste treated and disposed by Energy*Solutions* and/or WCS (no additional cost for treatment included; waste generator scope would include this cost)
- All LLW and LLW/TSCA disposed by Energy*Solutions*

- Off-site disposal will not have a concerted effort for disposal until the on-site facility is closed. Then a transloading facility at ETTP will be dedicated to the loading of rail cars for disposal.

Table I-11. Hybrid Disposal Alternative Estimated Cost

Off-site Portion Estimated Cost			
Element	**Volume (yd^3)**	**Cost (FY 2012 dollars)**	
		Destination: NNSS	**Destination: Energy*Solutions* or WCS[1]**
Classified Waste – Debris	15,335		NA
With 25% uncertainty	19,169		
Packaging (intermodals and liners)		$ 6,189,157	
Transportation		$ 14,364,812	
Disposal Fee		$ 7,509,743	
Subtotal		**$ 28,063,712**	
LLW or LLW/TSCA – Debris	566,831		
With 25% uncertainty	708,539		
Transportation (Gondola)			$ 115,022,725
Disposal Fee			$ 356,946,419
Subtotal			**$ 471,969,144**
LLW or LLW/TSCA – Soil	408,409		
With 25% uncertainty	510,511		
Transportation (Gondola)			$ 118,189,880
Disposal Fee			$ 76,581,442
Subtotal			**$ 194,771,322**
Project Management and Oversight	$ 17,277,785		
SUBTOTAL (FY 2012 $)	**$712,081,963**		
CONTINGENCY (12% Scope, 15% Bid) 27%	**$192,262,130**		
TOTAL with CONTINGENCY (FY 2012 $)	**$904,344,093**		
TOTAL with CONTINGENCY (FY 2016 $)	**$945,220,447**		
ESCALATED COST with CONTINGENCY (FY22 – FY43)	**$1,479,402,170**		
PRESENT WORTH with CONTINGENCY (FY 2016)	**$797,659,250**		
On-site Portion Estimated Cost			
SUBTOTAL (FY12 $)	**$363,260,476**		
CONTINGENCY (22% with Base/Security Ops 5%)	**$43,112,212**		
TOTAL with CONTINGENCY	**$406,372,688**		
TOTAL with CONTINGENCY (FY16 $)	**$424,425,518**		
LONG-TERM CARE	**$537,475,569**		
PRESENT WORTH with CONTINGENCY (FY 2016)	**$346,519,855**		
TOTAL HYBRID ALTERNATIVE ESTIMATED COST			
SUBTOTAL (FY12 $)	**$1,075,342,439**		
CONTINGENCY (22% with Base/Security Ops 5%)	**$235,374,342**		
TOTAL with CONTINGENCY	**$1,310,716,781**		
TOTAL with CONTINGENCY (FY16 $)	**$1,369,645,965**		
PRESENT WORTH with CONTINGENCY (FY 2016)	**$2,016,877,739**		

6. REFERENCES

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CERCLA D3 RI/FS COMMENT AND RESPONSE SUMMARY

Comments by: **Environmental Protection Agency Region 4**
Comments Received: August 6, 2015
Title of Document: Remedial Investigation/Feasibility Study for Comprehensive Environmental Response, Compensation, and Liability Act Oak Ridge Reservation Waste Disposal Oak Ridge, Tennessee
Revision No.: D3 [to be managed as a D1]
Document No: DOE/OR/01-2535&D3
Date: March 31, 2015

Comment #	Comment	DOE Response
EPA.G.001	The revised Remedial Investigation/Feasibility Study (RI/FS) eliminates all radioactive low level waste (LLW) relevant and appropriate requirements (RARs) under Nuclear Regulatory State Equivalent Standards and "to be considered" (TBC) requirements under DOE Order 435.1. Many of these substantive requirements were included in the Record of Decision (ROD) for the existing CERCLA landfill (i.e., EMWMF) and in early drafts of this RI/FS. A large portion of the planned waste to be placed in this landfill is LLW. The following statements from DOE's Order 435.1-1 Implementation Guide (DOE G 435.1-1, 7/9/99), pages I-60 through I-64 and I-113 through I-114, appear to be in direct conflict with DOE ORR's action to eliminate LLW requirements from this draft of the RI/FS: a. *"…radioactive waste disposal facilities under the CERCLA process are to meet the substantive requirements of DOE O 435.1."* b. *"The CERCLA process is to be used to comply with the requirements of DOE M 435.1-1 for environmental restoration actions"* c. *"The substantive requirements of DOE M 435.1-1 should be directly incorporated into the CERCLA process to the extent practical and consistent with site-specific technical and regulatory issues"* d. *"The Deputy Assistant Secretary may assign the LFRG the task of reviewing the information submitted by the Field Element Manager."* e. *"The disposal authorization statement does not impact the decision in the CERCLA Record of Decision on whether to build a facility because this decision is made through the CERCLA process. The disposal authorization statement specifies the limits and conditions on design, construction, operation, and closure of the radioactive waste disposal facility. The disposal authorization statement could be included as part of the Record of Decision."* f. *For environmental restoration activities, if the CERCLA Record of Decision is to serve as the disposal authorization statement, it must include the same information as stated above, or the disposal authorization statement can be issued separately."* g. *Regarding the distinction between substantive and administrative requirements, DOE follows the guidance provided in the rulemaking published for the National Contingency Plan (NCP)… …substantive requirements are those that set environmental protection requirements, criteria, or limitations…"* h. *"…substantive requirements of DOE M 435.1-1 are included as information "to be*	Agreement has been reached on including ARARs for NRC-based TDEC rules regulating LLW as 'relevant and appropriate' and DOE Order (Manual) references as to be considered (TBC) guidance in the revised RI/FS. DOE is following the CERCLA process in the RI/FS document. That process ensures protection of the public and environment within the cancer risk range of 10^{-4} to 10^{-6} and hazard index of 1 (see Remedial Action Objectives). Preliminary waste acceptance criteria are determined based on meeting the CERCLA risk range and HI=1 for the compliance period. The compliance period is determined based on DOE orders. CERCLA does not specify a time frame for compliance, but rather requires a review every 5 years to ensure protectiveness is being maintained. DOE fully agrees with, and intends to abide by, the 5 year review process. The compliance period (per DOE orders) is used as an indicative time frame based on DOE's requirements and direction regarding land disposal of LLW, and because uncertainties associated with timeframes exceeding 1,000 years (in terms of geologic modeling, projections on land usage and the state of society in general) are so significant as to make projections past that time frame ambiguous, such that using them as a basis for decision making is imprudent, and advised against in DOE Order 435.1. Having said that, DOE recognizes that this remedy is dealing with contaminants that last well beyond 1,000 years and can pose concerns in terms of protection of human health and the environment, so with that in mind, the RI/FS has carried out hydrogeologic/fate-transport modeling well in excess of 1,000 years and based on the significant increase in uncertainty of the results of that modeling, proposes meeting the least restrictive cancer risk range (10^{-4}) and an adjusted HI of 3, to set preWAC limits for contaminants posing a concern past the 1,000 year compliance period. DOE Order protectiveness of human health is based on dose, not risk. However, in meeting the acceptable risk range through the CERCLA process, which is more restrictive than the dose limits set forth by DOE Orders (and NRC-based TDEC requirements), the dose requirements of DOE (and TDEC) are necessarily met for the contaminants of potential concern identified.

	considered" (TBC) rather than specific ARARs because DOE Orders are not promulgated under the Administrative Procedures Act." Describe how DOE ORR is implementing each of these specific internal DOE requirements in a. through h. above and how these matters are coordinated with CERCLA process to constrain the level of contamination placed in the landfill, including a specific discussion of the RI/FS Appendix H, the subsequent Record of Decision and a final waste acceptance criteria.	DOE Order requirements direct that an intruder analysis be performed. NRC-based TDEC requirements also address intruder analyses. Because it is a requirement of the DOE Order, and this is a DOE facility, the analysis will be completed, and the results will inform final WAC limits, if those identified limits based on the intruder analyses are more restrictive, or place additional restrictions, above and beyond those determined in the RI/FS preliminary WAC determinations. In this way, a final WAC is determined and will be documented in a primary document, the WAC Attainment (Compliance) Plan required by the ORR FFA for this remedy. Regarding the Record of Decision (ROD), fulfillment of the DOE Order requirements (e.g., performance assessment-PA, preliminary Disposal Authorization Statement (DAS)) is planned to precede the approval of the ROD, and the results of the PA and accompanying preliminary DAS will be provided to the regulators, therefore informing the triparties of DOE approval for LLW disposal prior to triparty approval of the remedy in a ROD.
EPA.G.002	*"DOE Order 435.1-1 Implementation Guide, p. IV-187 includes a discussion of the "All-Pathways Performance Objective. This discussion states: "Depending on the particular source of concern, DOE EPA, and the NRC have typically established limits of 10 to 25 percent (10 mrem)… … although higher or low fractions may be appropriate."* Although CERCLA is a risk-based, not dose-based, program, the Implementation Guide alludes to situations in which DOE's dose-based requirements can be adjusted to meet more stringent standards. This may include showing protectiveness consistent with the CERCLA risk ranges. This discussion on radiation protection appears to support use of the CERCLA risk range as a means to reach consensus on cleanup criteria among DOE, NRC and EPA standards. Explain why the 10% fraction (approximating the upper bound of the CERCLA risk range) described above in DOE's guidance, or lower fractions of 1% and 0.1% (equating approximately with the middle and lower bound of the risk range) would be inappropriate to develop and evaluate alternatives that would satisfy both CERCLA risk-based and DOE Order dose-based thresholds in the FS.	The quote indicated here is preceded by the following statement: "Consistent with established radiation protection practices articulated by the National Council on Radiation Protection (NCRP) and the International Council on Radiation Protection (ICRP), the projected dose attributable to any single source, practice, or activity should be some fraction less than the applicable overall dose limit." The statement following the quoted text reads, "The DOE performance objectives for low-level waste disposal are established with the goal of assuring that the single practice of low-level waste disposal will not consume more than 25 percent of the overall objective for protection, which is the primary dose limit of 100 mrem (1 mSv) in a year to members of the public." In other words, the DOE performance objective for LLW disposal establishes a fractional goal (25%) of the overall dose limit [overall dose limit = 100 mrem/yr]. This fractional goal is 25 mrem/yr. The 10% fraction [or 10 mrem/yr] is the lower end of the range given in the quote, which states "Depending on the particular source of concern, DOE, EPA, and the NRC have typically established limits of 10 to 25 percent (10 mrem [.10 mSv] to 25 mrem [.25 mSv]) of the primary dose limit for protection of the public (100 mrem [1 mSv]/year) to any particular source, although higher or lower fractions may be appropriate." The 10% fraction is included in this text as the fraction adopted by EPA. Because the statements made here refer to "any particular source", they are encompassing multiple, various source(s), not just disposal of LLW, so therefore an allowance is made for higher or lower fractions [nonspecific, just as the statement "any particular source" is very nonspecific]. However, when talking specifically about LLW disposal this guide implements a goal/performance objective of "25% of the overall total dose allowable" [that 25% being 25 mrem/yr]. Additionally, the DOE guide and manual include the "as low as reasonably

		achievable" or ALARA principal, and thus require a demonstration that releases are maintained ALARA. In fulfilling this requirement, doses should be demonstrated to be below the 25 mrem/yr, in which case a "lower fraction" would be an accurate statement and reasonable expectation, and a 10% or 10 mrem/yr goal is appropriate and conservative. However, DOE does not see that going from a 25% fraction to a 1%, much less a 0.1% fraction, is necessary or justified for attaining this performance objective [location not withstanding]. Additionally, because this dose-based discussion is taken from the DOE 435.1 requirements, this dose goal is applied in the Performance Assessment modeling, which uses a source term, or waste profile, in the disposal cell. It is representative of the waste disposed in the facility as a whole, and is not representative of determining limits for each contaminant, which is the focus of the FS. The FS modeling focus is determining limits based solely on mobility (other limits such as transuranic waste limits were not yet presented for the disposal facility in the FS), and as a CERCLA action those limits are dictated by the NCP risk range, which EPA has indicted (OSWER 9200.4-18) corresponds to about 10 mrem/yr at the upper end of the risk range (e.g. 10^{-4}). Regardless, the limits in the FS were determined based on meeting the risk range, not meeting a specified dose. While the exact correspondence between dose and risk is dependent on the specific radionuclide and exposure pathways of interest, the FS analysis is based on an upper risk constraint of 10^{-4}, which EPA's guidance indicates would correlate to approximately 10 mrem/year; where lower risk constraints (e.g., 10^{-5} or 10^{-6}) are considered in the FS analysis, the corresponding estimates of dose would be proportionately lower. The use of the CERCLA risk range in calculating preliminary waste acceptance criteria in the RI/FS is fully described in comment EPA.G.001 above.
EPA.G.003	The Point of Compliance (POC) in "a" below and the Point of Exposure (POE) in "b" through "d" below should be established as follows: a. At the downgradient limits of the waste in the disposal facility for protection of the groundwater resource (i.e., SDWA ARAR MCLs for chemicals and radionuclides [See attached table "Derived Concentration (pCi/l) of Beta and Photon Emitters in Drinking Water"]); b. At the location where discharges to surface water require protection of the surface water resource (i.e., CWA AWQCs) and ecological receptors (i.e., Bear Creek and its tributaries); c. At the downgradient limits of the waste in the disposal facility for protection of the future reasonable maximum exposed individual at a risk of 10^{-4} and an HI of 1; and, d. At the downgradient location where the future reasonable maximum exposed individual is exposed to landfill releases and any other source releases at a risk of 10^{-6} and an HI of 1.	a. DOE agrees, the POC for this facility is based on the requirements under RCRA 40 CFR 264.95(a) "the point of compliance is a vertical surface located at the hydraulically downgradient limit of the waste management area that extends down into the uppermost aquifer underlying the regulated units." However, note that the CFR text says the "limit of the waste management area", which is described in 40 CFR 264.95(b)(1) as "The waste management area includes horizontal space taken up by any liner, dike, or other barrier designed to contain waste in a regulated unit." Not, as the comment says "limits of the waste". DOE also agrees that the POC is used to show protection of groundwater by meeting MCLs. DOE adds that backgrounds must be taken into account as well in determining compliance with this ARAR as is indicated in the RCRA requirements. DOE also adds that monitoring at this POC is an actual physical methodology (involving groundwater well placement for actual sampling), and is not determined by modeling analyses. Physical monitoring at the RCRA POC will follow the RCRA Subpart F requirements. Indications of releases from the facility (per compliance monitoring in Subpart F) at this POC will be followed up as necessary by corrective actions that will be completed within the FFA guidelines. b. DOE agrees with the statement here that CWA AWQC must be met at a

		POE in surface water (in Bear Creek and its tributaries) to show protection of surface water resource and ecological receptors. DOE adds that determining compliance with this requirement (which is given as an RAO) is met through modeling analyses for the compliance period (1000 years post-closure), at a surface water POE in Bear Creek. Estimation of contaminant concentrations in the tributaries is provided in modeling sensitivity analyses. c. DOE does not agree with statement "c" that indicates the limits of waste should be used as the POE for determining protection of the MEI. This comment statement "c" would place the MEI closer to the waste (at the edge of the waste) than the monitoring POC described in "a" above. Surface water and groundwater POE assumed for developing PreWAC and for demonstrating compliance with MCLs (for groundwater) and AWQCs (for surface water) are described in comment response EPA.G.5. d. Consideration of risk to human health and water resources resulting from multiple Bear Creek Valley contaminant sources, within the 1000 year post-closure compliance period, will be provided in a Composite Analysis performed to meet the requirements of DOE Order 435.1. The results of the CA will be provided to EPA and TDEC once the DOE review of the CA has been completed.
EPA.G.004	Appendix H, Sections 2.4 and 2.5 describe the location for which the risk range must be met. Describe how the risk range is used in the evaluation. CERCLA uses the lower bound of the risk range (10^{-6}) for establishing the preliminary remedial goals (PRGs) for cleanup as the point of departure for evaluating alternatives. Alternatives may also consider adjusting PRGs to hi^{gh}er levels up to the upper bound of the risk range (10^{-4}). Clarify how this CERCLA principle is used in the document. During scoping meetings for this document it was discussed that fate and transport models used to calculate limits on waste concentrations would use the risk range at varying distances from the landfill with the upper bound of the risk range (10^{-4}) being used at the closest distance of 100 meters based on DOE Order 435.1. This location that is consistent with DOE Order 435.1 may be a reasonable point of exposure for the 10^{-4} upper bound of the risk range, given the uncertainty in the fate and transport models in this complex hydrogeologic setting. However, as discussed in other comments, the location of the point of exposure adjacent to Bear Creek is a concern because it assumes greater mixing of contaminated groundwater with karst flow in the zone of Bear Creek. Also, at further distances, potential future releases from the EMWMF and other sources should be accounted for in establishing limits on waste concentrations, consistent with DOE Order 435.1 guidance for a composite analysis. For these reasons, as discussed during scoping meetings, setting the point of exposure the furthest distance from the landfill at Bear Creek may be a reasonable location for the most conservative approach to setting limits on waste concentrations that may appropriately account for greater uncertainty in fate and transport models due to the greater distance and use the lower bound of the CERCLA risk range (10^{-6}). A point of exposure in between these two locations that is not likely to be impacted by other potential source releases may be appropriate for establishing limits on waste concentrations based on the mid-point of the CERCLA risk range (10^{-5}). Model runs that consider these risk-based exposure scenarios at varying locations for the point of exposure may provide the best approach to managing the uncertainty in release scenarios for establishing limits on waste concentrations.	DOE agrees to use a graded approach to demonstrate attainment of the risk range. The graded approach will be based on the time frame and the location of the analysis. At time frames within the 1000 year compliance period (per DOE O 435.1), DOE will meet an ELCR=10^{-5} risk for calculating a preliminary WAC. The 10^{-5} ELCR (or HI=1) will be met assuming a well water intake POE located 100 m from the waste management area boundary at the point of maximum plume concentration, and assuming a surface water POE in Bear Creek downstream of the NT3 confluence. (Refer to Figure H-3 for illustration of these POE locations) DOE notes that adopting the 10^{-5} ELCR for the 100 m groundwater POC is more conservative than the 10^{-4} risk criterion referenced in this EPA comment. The preWAC determined for isotopes within the 1000 year compliance period (based on the 10^{-5} ELCR) limit the groundwater concentration of those isotopes to a fraction of the MCLs for those isotopes (H-3 and Cl-36). A 10^{-5} ELCR is used rather than the most conservative departure point of 10^{-6} for several reasons listed here, not in order of priority. For one, it is consistent with other goals set throughout the DOE complex for CERCLA disposal facilities. Additionally, the limits on waste to remain in-place in this remedy are determined by modeling, using necessarily conservative assumptions and involve predictions of future conditions and future waste, thus uncertainty is a significant factor (compared to cleanup remedies that are based on actual sampling/ characterization) further justifying a modification to the ELCR goal. Implementation of stricter risk goals would put more burden on characterization of waste being disposed in an on-site facility that, for some isotopes, would border on detection limits, and when compounded over the lifetime of the facility and large projected volumes of waste would significantly increase these expenditures. The natural background concentrations of some radionuclides already exceed a 10^{-6} risk, which limits implementation of target risks lower than a 10^{-5} risk for those isotopes. And in conclusion, a target risk of 10^{-5} has been deemed protective by EPA as it is within the acceptable risk range.

		For COPCs that peak after the 1000 year compliance period, PreWAC development is based on the same ground water point of exposure at 100 m from the waste, at the point of maximum plume concentration (minimum dilution). This revised well location does not present a concern with karst flow. Given the uncertainties for this distant future time frame, the carcinogenic risk goal will be set to the upper bound of the risk range (10^{-4} ELCR) and the toxicity-based risk goal will be adjusted to HI=3 for purposes of analytical PreWAC development. These POE and risk level assumptions for exposures beyond 1000 years post-closure are justified for use in developing PreWAC, given that detailed characterization of future waste streams is not possible; increasing uncertainties associated with modeling of these extended time frames; and that (following final WAC development) an inherently conservative approach to WAC compliance will be adopted. Examples of such an approach might be a mass-weighted sum-of-fractions, a radioactivity-based limit on contaminants for the landfill as a whole, or other similar approach. This approach, to be agreed on by the Triparties and documented in a Primary FFA document (the WAC Attainment (Compliance) Plan), will control the final inventory in the landfill, and thus the cumulative risk posed by the in-place waste upon closure. Model sensitivity evaluations in the revised RIFS (Appendix H, Section 4.5.3) consider PATHRAE sensitivity to surface water –related assumptions (stream flow rate and distance to the surface water POE). In terms of interactions with other sources, the Composite Analysis performed under DOE O 435.1 will investigate combined source interactions.
EPA.G.005	DOE Order 435.1guidance requires an evaluation for the protection of water resources. CERCLA and RCRA require protection of water resources at a POC (See General Comment 3) that is established at the down-gradient limit of the waste. This location is not the same as the POE for the maximum exposed individual for purposes of the risk evaluation, as described in General Comment 4. In Appendix H, describe how the pre-WAC will ensure protection of the water resource at the CERCLA/RCRA POC that uses the 4mrem based MCL standards for protection of groundwater resources for radionuclide contamination, and the protection of surface water resources from releases into NT-3.	As stated above in the response to General Comment 3(a), the POC per the CERCLA/RCRA ARAR is the monitoring well locations (per 40 CFR 264 subpart f) at the down-gradient limits of the waste management area. Additionally as pointed out in the response to 3(a) above, the location(s) of the groundwater monitoring wells are not used in modeling but are part of the facility's physical monitoring program. These GW wells will be monitored per triparty agreed-on methods (ARARs from Subpart F, 40 CFR 264). Thus modeling and the PreWAC determined in modeling analyses will not use the POC location to predict future compliance with ARARs. DOE plans to continue monitoring at the POCs as required under CERCLA/RCRA subpart F, with all that entails (e.g., detection monitoring, compliance monitoring, and corrective actions if indicated that will be performed per FFA guidelines) for the compliance period. Refer to RIFS revisions to Chapter x.x and Appendix H section 2.5. As indicated in EPA General Comment 3 (b-d), water resource protection is ensured during the 1000 year compliance period through development of PreWAC by modeling contaminant concentrations at Points of Exposure (POEs). These POEs are established for surface water use and groundwater use in a residential farmer MEI scenario to demonstrate RAO goals are met for protection of human health and water resources. For COPCs predicted to peak within the 1000 year compliance period, water

		resource protection is demonstrated by developing PreWAC that ensure meeting established MCLs (or 4 mrem/yr equivalent for radionuclides) at the groundwater POE and that also meet established AWQC (for hazardous chemicals) at the surface water POE for the compliance period. Model sensitivity evaluations in the revised RIFS (Appendix H, Section 4.5.3) consider PATHRAE sensitivity to surface water –related assumptions (stream flow rate and distance to the surface water POE). As explained above, RCRA Subpart F monitoring requirements will be carried out, per the ARARs (to include detection monitoring, compliance monitoring if indicated, and corrective actions if deemed necessary by the triparties, to be accomplished per FFA guidelines).
EPA.G.006	Appendix H, Section 3 establishes models for fate and transport and exposure. DOE should also consider building into the suite of models the PRG calculator models developed by Oak Ridge National Lab for EPA Headquarters.	The PRG calculator is a screening tool used to identify cleanup levels at a particular location to be met in a particular media to attain a specific risk value for a specified receptor for all applicable exposure pathways. It does not allow the incorporation of transient groundwater flow or site geologies (various K values), recharge rates, etc that are site-specific information incorporated in the RI/FS model. The PRG would be considered a preparation/screening step prior to more detailed modeling such as is completed in the RI/FS. In other words, the modeling completed in the RI/FS is much more site-specific and incorporates transient flow behaviors not accounted for by the PRG calculator – which can be used as a tool to estimate a broad expectation of preliminary remediation goals, if more sophisticated modeling were not available. The slope factors used in the RI/FS modeling are those used in the PRG calculators. As a check on the conservatism of the modeling assumptions used to develop PreWAC, model predictions of ground water concentrations were compared to groundwater concentrations calculated using the EPA Radionuclide PRG Calculator and the EPA RSL Calculator. All radionuclide and non-radionuclide groundwater concentrations determined from the EMDF fate and transport models are below those calculated using the EPA Calculators. This indicates conservatism in the modeled groundwater concentrations when compared to groundwater values from the calculators.

EPA.G.007	The onsite disposal alternative screens out all locations considered except for Option 5. This single retained onsite location includes site conditions that would require a waiver and implementability challenges similar to the existing EMWMF Landfill that was built over NT-4 for which performance issues have arisen due to a shallow water table along the axis of NT-4. Additional alternatives should be retained for the detailed analysis that will address the following concerns: a. Retain an alternative(s) that will not require a TSCA Waiver of the requirement established in 40 CFR 761.75(b)(3) - *"There shall be no hydraulic connection between the site and standing or flowing surface water;"* b. If a TSCA Waiver related to the hydraulic connection between the site and standing or flowing surface water is needed at all other locations considered in Appendix D, an alternative for detailed analysis which minimizes this shallow water table connection (i.e., not located on an NT to Bear Creek) to the site and the scope of the variance required under 40 CFR 761.75(c)(4); and, c. The EMWMF Landfill encountered unexpected high water table locations due to its construction over NT-4. Unplanned actions were taken to mitigate high water table conditions. Furthermore, since the action to construct the underdrain, high water table conditions remain a concern. Given the uncertainty of the effectiveness of this underdrain design over the long-term, an additional alternative(s) that would not require an underdrain should be included in the detailed analysis.	The revision to the RI/FS will consider three options for on-site disposal in Bear Creek Valley. All three options will be included in the detailed alternative analysis. [Options include: East Bear Creek Valley Site; West Bear Creek Valley Site; and a Dual Site Option that includes one location directly west of EMWMF and another location 1 ½ mi further west]. a. All three options will require a TSCA waiver of the requirement at 40 CFR 761.75(b)(3). There is likely no site on the ORR that would not require a waiver to this requirement while also meeting other site requirements such as no karst, suitable topography, capacity, among others. b. DOE agrees; a dual location option that contains two sites (e.g., one which considers 2-landfill footprints) has been incorporated that both minimize the hydraulic connection. A third option at West Bear Creek Valley is also included that also minimizes the hydraulic connection. c. All three options considered include underdrain features (see a. above) and DOE believes that it is best management practice to provide these engineered features based on the shallow groundwater present on the ORR in Bear Creek Valley, which has been identified as the best general location for waste disposal on the ORR.
EPA.G.008	Appendices B (Waste Volume Reduction) and C (On-site Treatment and Disposal Options for Mercury-Contaminated Wastes) describe and evaluate potential options for managing CERCLA waste both on and off-site. Appendix B screens out all waste volume reduction treatment actions from the on-site alternative. Conversely, Appendix C screens out all options for treatment except in-cell treatment. The appendices should be used to identify the most viable treatment options and establish alternatives for the detailed analysis that evaluates use of treatment, consistent with the preference for treatment, and not using treatment in the different alternatives for the detailed analysis. This will enable a comparison, against the nine criteria for consideration of whether or not to deploy treatment, and in the Case of Appendix C, whether to deploy treatment at the point of generation or in the landfill.	Appendix B, Volume Reduction, screens out ONLY mechanical means for VR at a facility located either at the disposal site or Y-12/ORNL (e.g., VR at a programmatic level – this does not preclude VR by mechanical means occurring at the generator/demolition site). Other VR actions (waste sequencing, recycle, and segregation) are retained and considered part of the On-site Alternative, but as discussed in the document those VR methods are completed by the generator and not at the disposal facility itself. Assumptions are made in the document that those VR methods are employed. Changes have been made to the Appendix B VR to evaluate the implementation (versus do not implement) of VR mechanical size reduction for on-site and off-site alternatives based on seven of the CERCLA criteria. This evaluation demonstrates that use of mechanical VR at the disposal facility is not preferable to disposal without mechanical size reduction. Likewise, it demonstrates that use of mechanical VR for off-site disposal is recommended. See new Section 5.4.4 in Appendix B. Additionally, a new Hybrid Alternative that evaluates the use of a smaller disposal facility on-site in combination with off-site disposal, will retain VR by mechanical means. This alternative will be included in the detailed analysis. Mercury-debris treatment by ICM has been included in Appendix C for information only. None of the alternatives include ICM as a process option. See the revised discussion in Section 5.1.4. Costs for treatment of Hg-debris have been removed from all alternatives.

EPA.G.009	A primary basis for screening out site locations was due to the projected waste volume and the results in an area of the landfill footprint that would cross NTs. These assumptions are questioned due to the significant uncertainty in the waste volume forecast (i.e., + 25% contingency) and the lack of commitment to volume reduction. DOE should consider a smaller footprint with a recognition that the footprint may require expansion and alternatives where the expansion may not be a continuous footprint.	A new Hybrid Alternative that evaluates the use of a smaller disposal facility on-site in combination with off-site disposal, will retain VR by mechanical means. This alternative will be included in the detailed analysis. Additionally, a table has been added to Chapter 2 to review and justify the volume uncertainty assumptions. A section describing the Hybrid Alternative (Section 6.4) has been added to the RI/FS revised document. This section reviews the "cutoff" where on-site disposal becomes less costly (per unit volume) than off-site disposal, which supports the selection of the small landfill site to be used in the Hybrid Alternative.
EPA.G.010	The implementability of the mercury in-cell treatment option requires further detail in describing how this activity can be conducted that adequately addresses: a. The risk of transportation spills of untreated mercury during shipment to the landfill; b. The risk of generating landfill leachate and contact water that contains excessive mercury concentrations that may be generated after placement but prior to subsequent LDR treatment; c. The benefits of small scale treatment batches to address concerns in b above; and, d. The ability to verify macroencapsulation performance objectives are being met in the vaults.	Revisions to the D4/D2 RI/FS do not include ICM as part of an alternative. Appendix C discusses Hg-contaminated debris treatment and a path for regulatory approval/acceptance as a potential future option. With respect to item d, the relevant regulatory technology performance standard is "*the encapsulating material must completely encapsulate debris and be resistant to degradation by the debris and its contaminants and materials into which it may come into contact after placement (leachate, other waste, microbes*)" (40 CFR 268.45, Table 1) The specific performance objectives for treatment by macroencapsulation, and methods to verify that the objectives have been met, will depend on the specific techniques and materials utilized..
EPA.G.011	Include a more thorough discussion in Section 6, Section 7 and Appendix G on the TSCA *"Technical Requirements"* ARARs and provide factual information on how the landfill on-site locations meet, or waive, the siting ARARs in 40 CFR 761.75(b), including site soils (40 CFR 761.75(b)(1)); site hydraulic conditions (40 CFR 761.75(b)(3)); site proximity to the floodplain (40CFR 761.75(b)(4)); and, site topography (40 CFR 761.75(b)(5).	Agree. Technical justification for a waiver to 40 CFR 761.75(b)(5) for site EBCV was added to Appendix G. Technical justification for a waiver to parts of 40 CFR 761.75(b)(3) were added to Appendix G. See Chapter 4. Soil requirements under TSCA are addressed in Section 7.2.2.2.3. Floodplain proximity is also addressed in Section 7.2.2.2.3.
EPA.G.012	Include a more thorough discussion in Section 6, Section 7 and Appendix G on the TSCA "Technical Requirements" ARARs for leachate collection and handling (40 CFR 761.75(b)(7)) and landfill operations (40 CFR 761.75(b)(8)). The RI/FS needs to provide assurances that these action-specific ARARs are being met.	Agree. Section 6.2.2.4.3 describes the leachate collection system and indicates that it will meet TSCA 761.75(b)(7). Section 6.2.5 discusses Operations. Text was added that says "*Operations are guided by ARARs contained in Appendix G, Table G-7. Operational Plans and Procedures will be developed for the EMDF that address these ARARs. As is done for EMWMF, a cross walk would be developed that indicated which operational plan or procedure addressed each ARAR.*" Operations such as are addressed under 40 CFR 761.75(b)(8) would be addressed accordingly in procedures developed at a later time. Sections 7.2.3 and 7.2.4 in Appendix G (ARARs) address meeting these ARARs as well.

EPA.G.013	The third remedial action objective (RAO) presented in Section 4 lacks sufficient detail. For example, Section 4.1.2.1 (Development and Screening of Alternatives) of the Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (EPA/540/G-89/004), (OSWER Directive 9355.3-01), dated October 1988 (RI/FS Guidance) states that RAOs should specify the contaminants and media of interest, exposure pathways, and preliminary remediation goals that permit a range of treatment and containment alternatives to be developed. However, the third RAO presented in Section 4, which discusses ecological exposure, does not specify the contaminants of concern (COCs), media of interest, exposure pathways or preliminary remediation goals that permit a range of treatment and containment alternatives to be developed. Modify the RAO to specify the objective of meeting CWA AWQCs at the point of exposure (See General Comment 3) and where AWQCs are not available ecological or human health based levels of protection. Consider using the EPA Headquarters PRG calculator developed by ORNL for this effort. Revise the RI/FS to provide more clearly-defined RAO related to ecological risk that specifies the COCs, media of interest, and exposure pathways.	Because this is not a remediation project, there are no specific COCs; rather there are potential COCs. These COPCs are discussed in the document, in Chapter 2, and again in text of Chapter 4 immediately preceding the RAOs themselves (along with the reference to see Chapter 2). Previous RAOs 2 and 3 have been combined into a single RAO. The revised RAO notes that CWA AWQC are goals to be met in surface water to demonstrate protectiveness of water resources and ecological sources. Discussion following the ROA states that CWA AWQC are demonstrated to be obtained in Bear Creek surface water, and additionally, risk-based radioactive contaminant limits have been identified and met in Bear Creek surface water. Thus RAOs one and two now read: 1. Prevent exposure of human receptors to CERCLA waste (or contaminants released from the waste into the environment) that exceeds a human health risk of 10^{-4} to 10^{-6} Excess Lifetime Cancer Risk (ELCR) or Hazard Index (HI) of 1.[1] 2. Prevent adverse impacts to water resources or unacceptable exposure to ecological receptors from CERCLA waste contaminants through meeting chemical-, location- and action-specific ARARs, including RCRA waste disposal and management requirements, Clean Water Act (CWA) Ambient Water Quality Criteria (AWQC) for surface water in Bear Creek, and Safe Drinking Water Act (SDWA) MCLs in waters that are a current or potential source of drinking water. [1] Non-carcinogenic contaminant exposure is modeled to determine PreWAC limits based on an HI equal or less than 1.0 for the compliance period, up to 1,000 years. With increased uncertainty in modeling results past 1,000 years, the target HI is increased to 3.0 beyond the compliance period. Likewise, the target ELCR is set at the high end of the risk range, 10^{-4}, for the post-compliance time period for carcinogenic contaminant fate and transport modeling.
EPA.G.014	Table 5-1 identifies process options that are eliminated; however, the specific criteria (i.e., effectiveness, implementability or cost) are not identified which justify the elimination of these process options. For example, the Tumulus facility is eliminated; however, the reasoning for eliminating this process option is not clear. For clarity, revise Table 5-1 to clearly indicate the reasoning for eliminating process options.	In the case of elimination of a process option, a reason for the elimination was added to the table (e.g., for a tumulus: eliminated due to high cost (in excess of $4000/yd3, escalated to 2015 dollars) Ref. Van Hoesen 1991 was added to the table).
EPA.G.015	Section 5.4.2 in Appendix B, Waste Volume Reduction, states, "Cost effectiveness is determined by comparing the cost of size-reduction processing (capital cost and operating cost) with the cost savings realized through the reduction in fill requirements and reduced landfill size for several waste material types and processing methods." However, by only evaluating cost savings, neither Appendix B, nor the RI/FS as a whole, takes into account additional benefits of Volume Reduction (VR). For example, by using VR, the siting location for the On-Site Alternative, could be effected due to a smaller footprint, which in turn could affect the overall protection of human health and the environment. As such, it appears more appropriate to consider VR in the context of being part of an On-Site Alternative that includes a smaller footprint, which would be evaluated against CERCLA's nine criteria. Revise the RI/FS to propose VR as part of a unique on-site alternative, or provide a basis for only evaluating VR in the narrow context presented in Appendix B.	Appendix B, VR, evaluates VR by mechanical size reduction for the on-site and off-site alternatives against seven of the nine CERCLA criteria. The analysis compares the use of mechanical size reduction versus not using mechanical size reduction, and concludes that mechanical size reduction is not recommended for on-site disposal, while it is recommended for off-site disposal. By completing this analysis in the Appendix, it simplifies the analysis of CERCLA waste disposal alternatives in the main document. See the new Section 5.4.4 in Appendix B. Additionally, the Hybrid Alternative will consider VR as an option employed in that alternative due to the very limited on-site disposal capacity this alternative offers.
EPA.G.016	Section 4, Treatment Options for Mercury Contaminated Y-12 Debris, in Appendix C states,	Mercury in-cell macroencapsulation (ICM) is not part of an alternative in the

[1] Non-carcinogenic contaminant exposure is modeled to determine PreWAC limits based on an HI equal or less than 1.0 for the compliance period, up to 1,000 years. With increased uncertainty in modeling results past 1,000 years, the target HI is increased to 3.0 beyond the compliance period. Likewise, the target ELCR is set at the high end of the risk range, 10^{-4}, for the post-compliance time period for carcinogenic contaminant fate and transport modeling.

	"This section evaluates three general options for on-site macroencapsulation in terms of treatment effectiveness, technical and regulatory feasibility, and cost. This approach is similar to the technology screening process described in RI/FS Section 5.1.2, and encompasses the five balancing criteria used to analyze the general waste disposition alternatives in RI/FS Section 7." However, it is not clear why in-cell mercury macroencapsulation is not presented as a unique on-site alternative, with another separate alternative which would include generator/demolition site encapsulation; both of which would be evaluated against CERCLA's nine criteria. It is noted that Section 5.2.5, Treatment of Mercury-contaminated Debris, of the RI/FS indicates that Appendix C evaluates only the cost effectiveness and risk involved with performing the macroencapsulation operation at the disposal facility versus at the demolition/project site. Revise the RI/FS to propose in-cell mercury encapsulation as a unique on-site alternative, or provide a basis for only evaluating mercury disposal as part of Appendix C	revised D4 RI/FS. The treatment of mercury-contaminated debris is discussed in Appendix C, as a potential option for consideration, It is assumed, for the purposes of cost estimates of all alternatives, that the treatment of the mercury-debris is part of the demolition contractor's (Project generating the waste) scope, and therefore outside of the alternatives' scope. Appendix C discusses the cost differentials in managing the mercury-contaminated debris by various means, including off-site treatment and disposal.
EPA.G.017	Table 6-2, Summary of EMWMF Lessons Learned, states, "Underdrains can be successfully utilized in managing existing ground water at sites, but should be appropriately designed in advance of landfill operations. The materials of the various components of the underdrain system and backfill should be carefully selected to ensure drain longevity. Underdrains can provide a backup LDRS and should be part of the ground water monitoring plan for the facility." However, the performance issues with the underdrain at EMWMF are not discussed (e.g., intrusion of groundwater into the geobuffer, even with an underdrain in place) and the potential liability for long term protectiveness of human health and the environment of constructing a highly permeability unit that funnels directly to surface water resulting in potential very short time of travel of contaminant release, as the bottom most engineering feature of a landfill is not addressed. Further, the comparison of the underdrain to a backup LDRS, does not appear appropriate as the LDRS has an underlying geomembrane which greatly reduces permeability and has a storage system associated with it, both critical components. Revise the RI/FS to provide a more detailed analysis of the underdrain and its appropriateness as an engineered landfill feature, including references to other similar designs.	DOE agrees. More text was developed to include a better description of how the underdrain performs, how it will remain protective, and support its functioning, through references. Discussion on improvement of the EMWMF design was included. See relevant Sections in Chapter 6 and Chapter 7. The revised D4/D2 RI/FS includes a GW model simulation of partial clogging to address sensitivity of water table elevation to underdrain performance and corresponding impacts to EMDF performance/protectiveness. Refer to Appendix H, Section 4.5.1. A new section has been added to Appendix E (Section 2.9) addressing the effects of landfill construction on the water table that include 1) underdrain effects; 2) umbrella, diversion, and upslope recharge effects; 3) post-construction simulations of the water table decline; and 4) variations of these effects on the water table and ground water underflow among the proposed sites.
EPA.G.018	The RI/FS presents the On-Site Alternative in the Executive Summary (Page ES-8) as the preferred remedy for waste disposal; however, presentation and documentation of a recommended remedy is inappropriate at this time as this is performed during the Proposed Plan stage. As specified in the National Contingency Plan (NCP) and RI/FS Guidance, the FS documents the development and analysis of alternatives only. In addition, modifying criteria (i.e., State and community acceptance) have not yet been met. Revise the RI/FS to remove all language which discusses the On-Site Alternative as the recommended remedy	Agree, all language indicating a selected alternative has been removed.
EPA.G.019	Appendix D, Section 2, Preliminary Screening, under the first bullet describing the siting criteria, indicates that a minimum landfill footprint area is 60-70 acres; however, this limitation appears to screen out a possible option of multiple, non-contiguous landfills which might otherwise be viable and potentially more suitable. For example, smaller landfills may require fewer ARAR waivers (i.e., Tennessee Department of Environment & Conservation [TDEC] requirements) and may also enhance implementability and long term protection uncertainty if not constructed over an NT surface water feature. Given the ARAR waiver concerns and the siting issues identified by TDEC at the location of Option 5, it appears that the RI/FS should evaluate the scenario of multiple, non-contiguous landfills as remedial alternative.	The RI/FS evaluates two additional options in the on-site alternative. One looks at a two footprint option (two non-contiguous footprints) and the second is a West Bear Creek Valley (WBCV) footprint option. The D3 East Bear Creek Valley Option footprint is also included in the revision of the document. These three options are considered as separate "on-site alternatives" in the detailed analysis.

EPA.G.020	Appendix D, Table D-2, Preliminary Screening of Candidate Sites, eliminates several sites based on a lack of suitable area; however, this evaluation is based on projected waste volumes that are uncertain, overinflated, and without consideration of volume reduction (VR) treatment. Similarly, Table D-4, Secondary Screening of Candidates Sites, also eliminates sites based on disposal capacity. Revise Appendix B, Appendix D Section 6 and Section 7, consistent with General Comment 8, to support the addition of an alternative(s) with VR treatment that consider more reasonable estimates of the waste generation forecasts (i.e., do not assume the 25% + uncertainty) and consider varying proportions of on and off-site disposal.	Revised RI/FS will consider a total of three possible options, including one option that encompasses two landfill footprints. An additional Hybrid Alternative will include a single, small footprint along with VR, and off-site disposal. It is not appropriate to judge alternatives on different volume bases, so a single volume basis is used throughout the analysis. An addition to the document is a table (Table 2-5) of volume uncertainties justifying the assumption for 25% uncertainty in the document. Waste volume projections along with uncertainty are aimed at bounding the volume of waste expected to be generated during the next 30 years of cleanup on the ORR that will be amenable to on-site disposal. The assumed uncertainty takes into account factors such as inability to use ALL soil waste as fill material (the assumption in the RI/FS for sequencing is that nearly all of soil waste is used as fill.) However, this may not be feasible in all situations, for example, the current "Excess Facilities" scenario in which OREM may receive some significant funding to demolish facilities, but the funding cannot be used to remediate soils. Additionally, future volumes of waste that are currently known to require off-site disposal are NOT included in this estimate, or in the RI/FS. Those volumes are relatively small, and because they would go off-site regardless of the selected alternative, they have not been included in the analysis (it would be adding "x" to both sides). Uncertainty is also aimed at capturing volumes that are not currently in the OREM baseline of projects. This includes cleanup that currently has no decision document. Each of these projects has an assumed path forward, but if the remedy selection/decision process at some future time recommends a remedy that includes generation of significantly larger volume of waste than was originally assumed (e.g., BCBG) there may still be a path to dispose of that waste under an on-site scenario.
EPA.G.021	Appendix D, Section 3.1, Proximity to the Public, does not address the nearby Scarboro Community. Revise the RI/FS in appropriate locations (e.g., Section 7.1.9, 7.2.2.8, Appendix D, and Appendix E [1.2.2]) to address any potential Scarboro Community environmental justice concerns and efforts to implement community relations consistent with 40 CFR 300.430(c)(2), including consideration of environmental justice concerns (See http://www.epa.gov/oswer/ej/index.html). In this revision to the RI/FS and any update to the supporting Public Involvement Plan, describe DOE ORR's efforts to enhance community engagement for this evaluation of waste disposal alternatives to best engage interested members of the public (e.g., local officials, community residents, public interest groups, or other interested or affected parties), in addition to those opportunities for public engagement through the support of the Oak Ridge Site Specific Advisory Board (See EPA's letter of July 24, 2015 for further discussion on this matter).	Agree. Revisions will be made as suggested. In particular, Appendix E, Section 2.4.2 Demographics, has been expanded to describe more than a decade of regular monitoring of ambient air and other environmental media (surface water, etc.) during ongoing operations at the EMWMF. Results have indicated no significant negative impacts to human health or the environment, including landfill workers at and adjacent to the site and the nearest citizens of Oak Ridge and the Scarboro community quite distant from the site. DOE is currently updating their Public Involvement Plan as is routinely accomplished. This update, due May 30, 2016 to the regulators as a D1 version, will document completed and planned efforts to engage the community on the alternatives presented in this RI/FS. The ORSSAB is participating in the review of that document. This information has been added to the RI/FS.
EPA.G.022	Several locations within the RI/FS, including Appendix E, Section 2.3.3.2.1, Shallow Aquifer Zone, describe artesian conditions at the site at groundwater monitoring well GW-968/-969; however, the RI/FS does not discuss if these artesian conditions will affect the effectiveness or implementability of the proposed On-Site Alternative. For example, it is not clear if these conditions will affect: the conceptual site model, the surface water hydrology of the site; the ability of the underdrain to capture and prevent groundwater intrusion into the liner system; the effectiveness of the geologic buffer with this potential artesian condition; and, the effectiveness of a groundwater monitoring system. In addition, as groundwater intrusion into the geologic	These issues were addressed on p. 73 and p. 124-125 of the EMDF Phase I Characterization Report - Attachment A to Appendix E. Page 73 describes the following: "*As noted in Section 4.1.7.2, artesian ground water conditions were encountered at GW-968(I) overflowing the top of casing early in the Phase I field program. These were followed later with casing overflow conditions in the adjacent shallow well, GW-969(S). Table 1 includes the pre-Phase I ground surface elevations estimated for these well locations. No springs, seeps, or evidence of continuous or intermittent surface water flow had been identified*

	buffer has been an issue at EMWMF, potential artesian conditions at EMDF appear to be a critical issue. While it is noted that the RI/FS implies that the artesian conditions are the result of the well pad being excavated, it appears additional information on the potential issues associated with these artesian conditions should be evaluated. Revise the RI/FS to present additional information on the effects of potential artesian conditions at the site on the evaluation of the On-Site Alternative and address how shallow water table conditions affect the alternatives effectiveness and implementability.	*within the ravine area of this well cluster during previous field reconnaissance work at the EMDF site (including detailed wetland surveys involving GPS delineation of wetland areas). However, the water level monitoring data from GW-968(I)/GW-969(S) well pair suggests that shallow ground water at this location prior to the Phase I effort may have been near the ground surface during the annual wet season. While the Phase I results suggest that the seasonally high water table surface may be relatively shallow near the base of similar ravines at the EMDF site, it is important to note that the current landfill design places the base of the geologic buffer at elevations on the order of 20–30 ft or more above these areas. Each of these ravines would be backfilled with engineered fill prior to placement of the more elevated geologic buffer and overlying liner system. The distance between the waste and the original ground surface at these ravine locations would therefore be on the order of 50 ft or more at locations such as GW-968(I)/GW-969(S).”* These conditions are accurately illustrated in Plate 3 of the Phase I Report which shows the high wet season water level in GW-969(S) to be ~30 ft below the base of the geobuffer, and the model predicted water table to be ~60 ft below the base of the geobuffer. Additional information regarding artesian conditions and casing extensions was provided on p. 16 of the Phase I Report, and Table 1 of the report shows that an estimated 4.7ft and 7.2ft of the original natural topsoil materials were removed at the locations of GW-969(S) and GW-968(I), respectively. The artesian conditions there are clearly the result of site grading that lowered the original ground surface, well construction itself that creates a conduit down into the saturated zone, and ground water convergence at the base of the ravine accompanied by relatively higher hydraulic heads that are attributable to recharge from upslope areas along the south face of Pine Ridge. Most of the base level grade for the landfill (i.e. – at the base of the 10 ft thick geobuffer) would require structural fill to build up the landfill base prior to construction of the geobuffer layer. The effects on recharge and the water table during and after landfill construction are described on p. 124-125 of the Phase I Report to specifically address the issues raised by the EPA. The artesian conditions seen in the GW-968/969 cluster or elsewhere along the base of similar ravines below Pine Ridge should not alter the effectiveness or implementability of the disposal facility. Nor are these conditions at all inconsistent with the site conceptual model, the surface water hydrology of the site (including the nature of and locations of springs and seeps and natural wetland areas). As illustrated in Plates 1 and 3 of the Phase I Report and summarized on p. 124-125, the base levels of the underdrain network would establish a new lower base level for the water table that along with capping and surface water diversions to significantly reduce infiltration and recharge would lower the current water table by several feet below the EMDF footprint during and after construction. Please see the text on P. 124-125 for additional details. Artesian conditions are only of concern where cut grades for the landfill intersect with the saturated zone at and below the water table. The base level grade in the conceptual design has been laid out so that the base of the geobuffer (roughly 13 ft below the base of the waste) sits everywhere above the lowered post-

		construction water table (simulated by modeling) and the majority of the geobuffer base sits above the estimated high water table based on Winter wet season Phase I water table data. A series of 16 north-south cross sections across the EMDF site along with a cut/fill isochore map showing the areas and thicknesses of cut/fill were used to identify areas that might be initially vulnerable to the estimated water table surface during initial construction. The landfill base elevations were adjusted in places to raise elevations based on the high Phase I data from December 25, 2014. As necessary, future refinements to the base level of the landfill will also be made as part of the detailed engineering design. However, it is important to reiterate that the post construction water table surface will naturally decline to elevations well below the wet season high levels and below the dry season low elevations once the underdrain network is placed and the footprint area is covered cutting infiltration and recharge to the water table to a fraction of pre-construction conditions. Use of naturally occurring high water table conditions as a benchmark for setting the base of the landfill is a very conservative approach that enhances the likelihood that the geobuffer and waste will remain well above the saturated zone during the post closure period. A new section has been added to Appendix E (Section 2.9) to more explicitly address these issues and the significant lowering of the water table that is expected to follow construction and capping.
EPA.G.023	Appendix B, Section 2.3.1.3 Cavities, states that the proposed EMDF site overlies lower Conasauga units that apparently are not susceptible to conduit development. According to Moore (1988), cavities in the Conasauga Group have been reported only in the Maryville Limestone, Nolichucky Shale, and Maynardville Limestone. While this assertion may have merit, the results of the tracer dye tests presented in Section 2.3.3.2, Results of tracer tests, of Appendix E, provide substantial insight into water movement as well as contaminant transport processes. First arrival velocities from as low as 6 ft/day to as high as 1,314 ft/day have been observed in tests conducted in the ground water zone of Conasauga Group units. As such, it is not clearly understood if the results of tracer dye test suggest other more dominant preferential flow paths may exists due to the presence of stratigraphic and structural controls (e.g., bedding planes, fractures, micro and meso-scale structures) that have more influence and dominance on valley head distribution and flow paths than the karst dissolution cavities and conduits. Revise the RI/FS to address this issue.	Note this comment should refer to Appendix E (not B). The velocity ranges noted by EPA quoted from this section do not distinguish between those in karst conduits of the Maynardville versus those in the dominantly clastic and fractured rocks of all the other geologic formations within the Conasauga Group. These sections will be revised to clarify this important distinction between predominant fracture flow in the clastic formations across and immediately south of the EMDF footprint versus the carbonate karst conduit flow of the Maynardville that begins approximately 1300 ft south of the southern EMDF waste limit near the contact between the Nolichucky Shale and the Maynardville Limestone. In addition, the sections will be revised to emphasize and clarify the key finding from tracer tests that peak arrival times lag behind first arrival times by orders of magnitude, apparently associated with matrix diffusion that dramatically attenuates the migration of tracer concentrations over time. The new Section 2.13.5 – Tracer Tests – in Appendix E has been reorganized and greatly expanded to address tracer tests in predominantly clastic rocks and tests in the carbonate karst rocks of the Maynardville Limestone and Copper Ridge Dolomite. The section includes much more detail and several figures to clearly demonstrate the differences among the tests. A final subsection summarizes key findings.
EPA.G.024	In Section 2.2.4, Seismicity, the text states although there are a number of inactive faults passing the Oak Ridge Reservation (ORR), although there are no known or suspected seismically capable faults. The text further states as defined in 10 CFR 100, Appendix A, a seismically capable fault is one that has had movement at or near the ground surface at least once within the past 35,000 years, or recurrent movement within the past 500,000 years. The citation 10 CFR 100, Appendix A refers to the Nuclear Regulatory Commission (NRC) regulation regarding Seismic and Geologic Siting Criteria for Nuclear Power Plants. However, the regulation NRC 10 CFR 100, Appendix A is not listed in Table G-3. Action–specific ARARS and TBC Guidance (Siting Requirements) for CERCLA Waste Disposal Alternative.	The nearest mapped fault to the EMDF site (the White Oak Mountain Thrust Fault) is on the northwest side of Pine Ridge. This fault is greater than 200 feet from the edge of the disposal cell (see Figures E.8 and E.9) and there is no evidence that this fault has had displacement in Holocene time. Information available at this time indicates that the EMDF can comply with the seismic considerations in 40 CFR 264.18(a)(1) which is identified as an ARAR for EMDF. The RDR will demonstrate compliance with this ARAR after a seismic evaluation is completed. In addition, there was such an evaluation conducted for EMWMF which showed that this ARAR was met.

	Rather, Table G-3 lists 40 CFR 264.18(a)(1) as the applicable regulation regarding siting of a RCRA hazardous waste landfill. The applicable regulation 40 CFR 264.18(a)(1) requires a new facility where treatment, storage, or disposal of hazardous waste will be conducted must not be located within 200 feet of a fault which has had displacement in Holocene time. A fault is defined in 40 CFR 264.18(a)(2)(i) as a fracture along with rocks on one side have been displace with respect to those on the other side. Displacement is defined as the relative movement of any two sides of a fault, measured in any direction [40 CFR 264.18(a)(2)(ii)]. The Holocene period includes the past 11,000 years [40 CFR 264.18(a)(2)(iii)]. As stated, Oak Ridge lies within the East Tennessee Seismic Zone (ETSZ), a seismically active zone where the mechanism and frequency of occurrence of earthquakes in the ETSZ are not well understood. As such, based on the information presented in this section, it remains uncertain whether the EMDF has demonstrated compliance with the RCRA seismic standard. Revise the RI/FS to address this issue.	The definition from and reference to 10 CFR 100, Appendix A has been removed from this section of the main text.
EPA.G.025	The underlying assumption for the ground water modeling for the EMDF is that the subsurface can be treated as an equivalent porous medium (EPM); however, some experts have concluded that the EPM approach is not applicable for fractured rock. For example, Chapman and Parker (2011)[2] state that the EPM approach is inadequate for simulating contaminant transport in fractured porous rock (e.g., sandstone). Evaluation of modeling methods at several sites with fractured sedimentary rock indicates that contaminant fate and transport cannot be adequately assessed using an EPM approach; and, an approach based on a discrete fracture network (DFN) is necessary (Parker, Cherry, and Chapman, 2012)[3] with use of DFN software modules like Fractran, which can be run with MODFLOW. However, the groundwater model (MODFLOW/MODPATH) utilized to support Preliminary Waste Acceptance Criteria (PreWAC) development assumed an EPM and did not utilize a fracture-specific model. Since fractured sedimentary rock rarely has a sufficiently uniform fracture system, groundwater flow can be quite rapid along interconnected fractures or follow a lengthy tortuous path. As such, a detailed evaluation of the fracture network and use of a DFN software module is essential to accurately predict contaminant transport. The model should therefore be rerun using a DFN software module like FRACTRANS. If this is not done, the groundwater flow and transport model should not be used to predict contaminant arrival times after the EMDF is constructed. Regardless of the modeling employed, a sufficient monitoring well network should be installed so that contaminant release and migration can be monitored empirically.	Some key issues are associated with application of DFN approach described by Parker, Cherry, Chapman 2012 to the EMDF project. 1) The DNF approach relies on detailed characterization followed with modeling. The approach requires accurate characterization of the fracture network using rock cores, liners for sealing boreholes and transmissivity measurements, high res temperature profiling to ID active fractures, borehole geophysics, straddle packer hydraulic testing, high res multilevel monitoring for hydraulic head (and GW sampling), data storage/management. Characterization results are used to develop a detailed and reliable DFN site conceptual model that is used in conjunction with static/dynamic modeling and model calibration and simulations. 2) The modeling part of the DFN approach cannot be applied until detailed site characterization data are obtained and evaluated and incorporated into a detailed 3D site conceptual model that would form the foundation for subsequent modeling. This comment, stating that the current EPM model should be rerun with a DFN module ignores the contradictory fact that the DFN relies on first characterizing the DFN at a site. Application of a DFN model is not feasible at this time, in the RI/FS, which will (a) propose three sites (b) will not provide the detailed characterization data required to accurately complete/calibrate a DFN model for one site let alone three sites. 3) Parker notes that existing 3D fracture models are inadequate and that EPM 3D models must be used in conjunction with 2D fracture models

[2] Chapman, Steven W. and Beth L. Parker. 2011. Use of Numerical Models to Examine Contaminant Mass Distribution and Attenuation in Fractured Sedimentary Rock, Proceedings GeoHydro2011, Quebec City, Canada, August 29-31, 2011.

[3] Parker, B.L., Cherry, J.A., and Chapman, S.W. (2012). Discrete fracture network approach for studying contamination in fractured rock. AQUAmundi: Journal of Water Science, 60, 101-116. DOI:10.4409/Am-052-12-0046. Please note that this paper indicates that based on more than 15 years of field research, an EPM should not be used to model contaminant transport in fractured bedrock, contrary to the statements from Groundwater (Freeze and Cherry, 1979); i.e., hydrogeology has moved beyond the information presented in this noteworthy and historic text.

		such as FRACTRANS. 4) The DFN approach has been applied to waste sites with existing ground water plumes that have involved characterization at and downgradient of the contaminant source – the EMDF situation is working in reverse – attempting to simulate future sources that cannot be characterized and future release scenarios to hypothetical receptors, so there are no existing sources or plumes to characterize or to calibrate simulations against. The site can be characterized and modeled using the DFN approach but the limitations of both should be defined first. Furthermore, most landfill pre-design characterization efforts do not involve characterization along presumed downgradient flowpaths, only characterization at and near the footprint area. By definition, the DFN approach involves complete characterization along downgradient contaminant flow paths. 5) The DFN approach toward much better characterization of fractured sedimentary rocks is appropriate and applicable to the EMDF (see details in the Parker et al article). However, inherent to this characterization are the assumptions that the site conceptual model is updated based on DFN characterization results and the modeling is adapted to incorporate the detailed findings of the DFN characterization. In addition, the detailed characterization of the local DFN could be used to provide a much better design for the release detection monitoring system (i.e. – monitoring wells and underdrain outfall locations) for the EMDF that would ultimately be placed primarily along the downgradient perimeter of the landfill (with one or more upgradient wells). Site hydrogeological conceptual models for the ORR and BCV suggest that the saturated zone within highly fractured and weathered saprolite and uppermost bedrock where the bulk of ground water flux occurs may be appropriately simulated by EPM modeling. The EMDF groundwater modeling framework represents the bedrock fracture patterns as large vertical variations in hydraulic conductivity (K decreasing with depth) and strong horizontal anisotropy in conductivity (Ky=10Kx) to simulate the preferential strike-parallel (y-direction) groundwater flow observed in Bear Creek Valley. The fate and transport models (MT3D and PATHRAE) use the modeled groundwater flow fields and velocities to predict peak contaminant concentrations and peak times, rather than first arrival times for contaminants, which can be dominated by rapid flow along a small number of fractures.
EPA.G.026	Appendix H does not include sufficient information about model parameters and setup to facilitate an evaluation of the groundwater flow and transport model. If the MODFLOW/MODPATH/ MT3D modeling approach is pursued, Appendix H should be expanded to provide setup information for each of the model layers. For example, the recharge distribution is provided only for the upper layer and hydraulic conductivity is provided only for Layer 1. Revise Appendix H to present all of the model input parameters for each layer, including figures as necessary.	Appendix H section 4.2 has been revised to provide additional information on the development, calibration and validation of the Upper Bear Creek groundwater flow model. Table H-3 gives all the K values for each layer and hydrogeologic formation, as well as other groundwater model inputs. These pieces of information fully identify the inputs to the ground water flow models. Note that recharge only applies to the uppermost (surface) model layer (Layer #1).
EPA.G.027	The discussion of flow model calibration is insufficient. For example, the following deficiencies were noted, but are not limited to: a. There is no discussion of calibration statistics; b. There are no figures depicting actual and simulated groundwater elevation contours for	A more thorough discussion of the development, calibration, and validation of the groundwater flow model has been incorporated into Appendix H, Section 4.2, including a discussion of sensitivity analyses that were performed for the UBCV model prior to its use for this RI/FS. In addition, the text describing model

	the various layers; There is no figure depicting residual head differences between actual and modeled groundwater elevations (e.g., where different colors are used to distinguish between positive and negative head differences and the residual head difference is posted); c. The details (e.g., parameters evaluated) and results of the sensitivity analysis are not presented; d. Total and effective porosity should be varied in the sensitivity analysis, but other parameters should be tested as well; e. The text should include a detailed discussion explaining the model calibration and sensitivity analysis and findings; and, Validation of the flow model is not discussed, so it is unclear if the model was validated.	calibration for the current effort (Section 4.2.1.4) and sensitivity evaluations performed to evaluate key assumptions (Section 4.5.1) has been revised.
EPA.G.028	The impact of using effective porosities that are a small fraction of the total porosity (i.e., see Appendix E, Section 2.3.1.1, where the effective porosity of soil and weathered bedrock is stated to be about 0.2%, compared to a matrix porosity of 30-50%) can result in underestimating the mass of contaminants in the transport model. If the total and effective porosity are similar, the error of using one or the other is not that great (compared to the wrong hydraulic gradient). But when the effective porosity is only a small fraction of the total porosity, then the mass balance is incorrect. Leonard F. Konikow[4] (2011) stated: "Although the assumption that porosity is spatially constant may be quite reasonable and induce very little error even when it varies spatially, it tends to mask another issue of concern about porosity that is generally overlooked or ignored. Specifically, the porosity term on the left side … [of the classic advection dispersion equation] reflects the mass storage of solute within a volume of aquifer, and hence reflects the total (or bulk) porosity. The right side of … [of the classic advection dispersion equation], however, reflects a porosity that is effective for the fluxes of water and solute-more a measure of mean cross-sectional area at the pore scale and interconnectedness of pores-and which will have a value less than that of the total porosity. If a single value representative of the effective porosity is used, then the solute storage capacity (and mass stored) would be underestimated; if a single value representative of the total porosity is used, then the average seepage velocity would be underestimated." Revise Appendix H to consider this issue and include a mass balance for the transport model.	Appendix H Table H-5 summarizes the assumed values for key parameters in the models used for the RI/FS risk assessment and analytical PWAC development. Section 4.5 has been added to address sensitivity of the groundwater and fate and transport models to the aquifer porosities selected. For the revised PATHRAE model runs, an aquifer porosity of 4% is assumed and an average linear groundwater velocity (21.3 m/yr) is derived from a MODPATH sensitivity run assuming 4% porosity in model layers 1-3. The contaminant mass balance represented mathematically in the MT3D and PATHRAE models assumes a single aquifer porosity value (for each layer in the groundwater model domain) and does not account for the porosity-related uncertainty raised in this comment. The accuracy (relative to field observations) of a predicted contaminant dilution field (MT3D) or groundwater discharge concentration (PATHRAE) could be related to this uncertainty and the choice of porosity values, but because the RIFS modeling effort is a forecast of future conditions, it is not possible to evaluate the choice of porosity values based on model accuracy. Rather, it is the conservatism of assumptions with respect to risk estimation that is important. Supplemental modeling to evaluate limitations in the PATHRAE approximation of radionuclide transport processes (saturated zone dispersion and equilibrium sorption only) suggest that the PATHRAE predicted concentrations are conservative compared to results based on representing primary and secondary porosity and mass transfer via matrix diffusion explicitly. Refer to Appendix H, section 4.5.for additional detail.
EPA.G.029	The approach for modeling contaminant transport needs to be evaluated. Specifically, the groundwater model does not account for rapid contaminant transport in fractured rock. Chapman and Parker state that "bulk average linear groundwater velocities in fractures [are] generally high (1 to >10 m/day [greater than meters/day])" (Chapman and Parker, 2011). Tracer tests in wells screened in fractured bedrock have resulted in estimated groundwater velocities ranging from 0.75 to 650 feet per day (i.e., Appendix E, Section 2.3.2.2). This tracer test data indicates that rapid flow in fractures is occurring. The implications for contaminant transport in fractures at these velocities are significant and may invalidate the predictions in Figure H-19 (MT3D Model-Predicted Groundwater Well concentrations (Relative to Leachate) with Time), as this figure indicates that contaminants will not reach the hypothetical receptor for more than 1000 years. However, at 650 feet per day, contaminants released from the	The RIFS modeling effort is focused on modeling peak contaminant concentrations and peak times, rather than first arrival times. A modeling approach simply focused on accurately predicting rapid contaminant transport via fractures is not appropriate for estimating the magnitude and timing of peak risk/dose to receptors. While tracer tests conducted at sites on the ORR (WBCV LLWDDD site and BG4 at ORNL) in fractured rocks similar to those underlying the EMDF have demonstrated relatively early first arrival times, they have also demonstrated a much slower moving center of mass, apparently limited by transverse dispersion and matrix diffusion effects. Peak tracer concentrations are significantly delayed relative to the first arrival of tracers. Evaluation of PATHRAE model limitations relative to a modeling approach incorporating

[4] Leonard F. Konikow, 2011. The Secret to Successful Solute-Transport Modeling, Ground Water, Vol. 49, No. 2, March-April 2011, pp. 144-159.

	landfill would reach the hypothetical receptor well (460 meters from the EMDF) in a little more than 2.32 days. Further, if flow rates like those observed during the tracer tests occur, there would not be sufficient time for chemical compounds to decay as assumed in Section 4.4.1 on page H-54. Revise the text to discuss this issue and the implications for the transport and PATHRAE models. In addition, run the PATHRAE model for chemical compounds	vadose zone dispersion, realistic aquifer fracture parameters and matrix diffusion effects suggest that the PATHRAE assumptions yield conservative (higher) peak concentrations for radionuclides. This evaluation is presented in the D4 revision, Appendix H, section 4.5.4 MT3D model output is not utilized to predict the timing of peak contaminant concentrations. The contaminant fate and transport modeling approach utilizes the one-dimensional PATHRAE model to estimate the magnitude and timing of peak flux of groundwater contaminants to surface water at a given distance from the waste facility. MT3D model output is used primarily to simulate the three-dimensional pattern of dilution by clean groundwater for estimating drinking water well concentrations at a given location within the simulated contaminant plume. MT3D relative concentration predictions for groundwater are used in conjunction with peak surface water concentrations predicted by PATHRAE to derive a predicted contaminant concentration in the receptor drinking water well. Refer to Appendix H Section 4.3.3 for additional detail. PATHRAE is run for an extensive set of hazardous chemical compounds. See Appendix H, Attachment B, Table 2. Also see extensive revisions to Tracer Test Section 2.13.5 in Appendix E noted above in response to EPA G.023. The tracer tests in predominantly clastic rocks such as those at and adjacent to the proposed EMDF sites, indicate that ground water tracer flow rates based on time to reach peak concentration lag significantly behind first arrival times. See new Section 2.13.5 for other key findings from tracer tests relevant to fate and transport modeling.
EPA.G.030	If the MT3D transport model is utilized, a sensitivity analysis is necessary. Conduct a sensitivity analysis for the transport model and revise the text to discuss in detail the parameters varied and the results of the sensitivity analysis	MT3D is utilized only to predict a relative groundwater dilution field for the modeled EMDF site configuration and hydrogeologic setting. Sensitivity of the groundwater flow models (including MT3D) to parameter assumptions is presented in the revision of Appendix H in section 4.5.1..
EPA.G.031	The Executive Summary states on page ES-4 that the analytic Waste Acceptance Criteria (WAC) of the proposed new disposal facility would ensure the risk to future receptors would not exceed and Excess Lifetime Cancer Risk (ELCR) of 10E-05 or a Hazard Index (HI) of 1 in the first 1,000 years. However, the RAOs included in Section 4.0, Remedial Action Objectives, for the EDMF state that risk will be maintained within the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) acceptable risk range of an ELCR of 10E-04 to 10E-6, and a HI of 1 to 3. Additionally, generally when a HI of 1 is maintained, the ELCR is 10E-06 is also maintained (as opposed to 10E-05). Revise the RI/FS to provide clarifying statements about how it was determined that an ELCR of 10E-05 or a HI of 1 for the EMDF will be achieved through the analytic preWAC, or revise the Executive Summary to be consistent with Section 4.0 of the RI/FS.	The executive summary was revised to be consistent with Section 4.0 of the RI/FS and the RAOs as written in the executive summary, which states that risk will be maintained within the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) acceptable risk range of an ELCR of 10E-04 to 10E-6, and a HI of 1.
EPA.G.032	Section 4, Remedial Action Objectives, of the RI/FS states that the first objective for evaluating remedial alternatives is to prevent direct or indirect exposure of a human receptor to a future-generated CERCLA waste that exceeds an ELCR of 10E-04 – 10E-06 or HI of 1 to 3. Section 2.3, Hypothetical Receptor, of Appendix H states that the maximally exposed individual (MEI) was selected to be the hypothetical resident farmer. The text does not state whether a child of the resident farmer was considered. Provide a response about whether a child resident scenario was evaluated in this RI/FS	Slope factors and DCS values account for multiple receptor age/size for radiological/carcinogenic exposure. For analysis of toxicity effects of hazardous chemicals, the RIFS revision assumes a child receptor in determining the modeled HI value and the associated analytical PreWAC. See revisions to Appendix H Section 4.4.3.2
EPA.G.033	The remedial action alternatives listed in Table 5-1, Technology Descriptions, Screening,	The disposal site in Barnwell, SC is open to only 3 states, and TN is not one of

	Evaluations, and Selection of Representative Process Options of the RI/FS includes a list of the off-site facilities that were considered as possible options for disposal of the ORR waste streams. This list includes the Chem Nuclear commercial low-level waste (LLW) and mixed LLW disposal facility in Barnwell, South Carolina. However, Chem Nuclear is not listed in Section 5.1.3.1, Existing LLW and Mixed-Waste Facilities, and is not included in the evaluation of these potential off-site facilities provided in Section 5.2.3.2, Existing LLW and Mixed-Waste Facilities. Revise Table 5-1, and Sections 5.1.3.1 and 5.2.3.2 to provide consistent information about the off-site disposal facilities that were evaluated through the remedial action alternative selection process.	them (in addition it has very limited capacity). It was eliminated from consideration in Table 5-1 for these reasons. Sections 5.1.3.1 and 5.2.3.2 were revised to reflect this situation for the Barnwell facility and note that it was eliminated for these reasons.
EPA.G.034	Appendix H, Section 4.4, Pathrae Modeling and Risk/Dose Analysis, states that the PreWAC for the proposed EMDF was developed based on the combined effects of contaminated ground water ingestion and contaminated surface water use for a hypothetical resident farmer. The source of surface water is assumed to come from Bear Creek; however, Appendix H does not discuss the possibility of ground water discharge to any other surface water location surrounding the EMDF. As such, it is unclear if other ponds, seeps or small streams may occur in the area surrounding the EMDF which would provide a more concentrated source of surface water contamination that would be accessed by livestock or the residents than the significantly attenuated/diluted Bear Creek source of contaminants. Revise the RI/FS to address whether there are other locations of surface water near the EMDF that may be impacted from contaminated groundwater which could present a more concentrated source of contamination other than Bear Creek.	Based on historical flow monitoring, tributaries NT-2 and NT-3 do not flow year round and would not be likely to provide an adequate drinking water supply or a dependable source of irrigation water for crops. It is possible that livestock could periodically access more concentrated surface water contaminants from these sources. However, the resident farmer exposure scenario analysis suggests that drinking water ingestion, rather than ingestion of contaminated food, accounts for greater than 90% of the calculated risk or dose for all but a small proportion of COPCs. Evaluation of the sensitivity of peak surface water concentrations to assumed flow rate in the receiving stream is included in Appendix H Section 4.5.3
EPA.G.035	The Appendix H, Section 4.4.1, Site-specific PATHRAE Model Development, states on page H-54 that the initial concentration of a single contaminant in the landfill was set at 1 Curie (Ci) per meter cubed (m^3) for radioactive species, and 1 kilogram (kg)/m^3) for hazardous species. However, the text does not describe how the assumed concentration for a single radionuclide was determined to be appropriate and conservative. For example, the text does not reference a document or present a discussion in the RI/FS that addresses the expected concentrations of contaminants in the waste and how this information was used to derive the 1 Ci/m^3 concentration used in the modeling. Revise Appendix H, Section 4.4.1 to state how the 1 Ci/m^3 quantity was selected for modeling, and how this compares to the estimate of the most concentrated amount of any one radionuclide projected to be in the EDMF.	The assumption of 1 Ci/m3 (for radiological COCs) or 1 kg/m3 (for hazardous COCs) is simply a basis for beginning the model calculations. Any number may be assumed, as it serves only as a basis for starting calculations. From this basis, a surface water and ground water concentration is determined using the model. This then allows a ratio to be made ([basis, concentration in cell] to [resultant concentration in SW/GW from model]). Since the ARARs and CERCLA risk range stated in the RAO dictate the acceptable concentrations in SW/GW, those concentrations are used to back-calculate what maximum concentration is thus acceptable in the waste, or in other words the preliminary WAC. The assumed basis is a higher concentration than that of any contaminant expected to be in the waste, but if it were not (e.g., it was lower concentration than any contaminant concentration expected to be in the waste), it would not matter as it is used only to calculate a ratio.
EPA.G.036	Appendix H, Section 4.4.2.5, Summary of PATHRAE Assumptions, states that one of the assumptions made for the PATHRAE code execution included assuming a near neutral pH condition exists in the waste zone based on the EMWMF data. However, in the scenario where waste is being released, an assumption of near neutral pH conditions in the surrounding soil, does not appear realistic or conservative. Revise the RI/FS to address this concern.	Assumptions about the geochemical environment (including pH, redox potential, and other factors) in which contaminant leaching, sorption, and transport take place are implicit in the selection of a partition coefficient (K_d) for each COPC considered in the PATHRAE fate and transport model. Included in the presentation of model sensitivity evaluations is an analysis of sensitivity to uncertainty in partition coefficients. Refer to Appendix H section 4.5.3
EPA.G.037	Appendix H, Section 5.3, Discussion of PreWAC Results, states in the second paragraph that the uncertainty/sensitivity analyses appropriately compel modeling of long-lived isotopes out to peak concentrations. The text further states, "[I]n this case, the model is run for much longer periods of time, with an increased time step." However, the text does not reference the	Results were presented for modeling past 1,000 years in the D3 RI/FS. In the D4 revision, model output including peaks predicted up to 1,000,000 years post closure are included in Appendix H, Attachment B. In addition, sensitivity of the number of radioisotopes predicted to peak within various time periods to

	document that contains the results of such modeling beyond the 1,000 year requirement. Revise the RI/FS to provide reference to, or incorporate the results of the uncertainty analyses for modeling radionuclides after the 1,000 year compliance period.	PATHRAE parameter assumptions is included in Appendix H section 4.5.3.
EPA.G.038	The second paragraph of Appendix H, Section 5.3, Discussion of PreWAC Results, appears to indicate that the sensitivity analyses conducted for radioisotopes included evaluating the effects of radioisotope decay and half-life, decay plus leaching versus decay only, and partition coefficients (as demonstrated in Figures H-21 – H-25) in determining peak concentrations for assessing dose and risk at the selected location of the resident farmer. However, Appendix H does not state whether sensitivity analysis included varying other model inputs such as geochemical effects (i.e. interaction of radioisotopes with soils or other constituents), hydrological (i.e., type of bedrock, groundwater transit rates) or environmental factors (i.e., rainfall totals) to determine whether these types of model inputs were more apt to affect the outcome of peak concentrations of radionuclides or chemical contaminants. Revise the RI/FS to state if sensitivity analyses for modeling peak concentrations of radionuclides and/or chemical constituents was conducted for any modeling inputs other than those discussed in Section 5.3, or if this type of detailed sensitivity analysis will be provided in future document submittals.	A more complete set of sensitivity analyses has been added to Appendix H in Section 4.5
EPA.G.039	The RI/FS discusses several components, or potential components of the alternatives, but does not include costs for these items in Appendix I, Cost Estimates for On-Site and Off-Site Disposal Alternatives. For example: a. Section 3.2, Evaluation of Risk for the On-Site Alternative, indicates that additional risk evaluation will be completed in the design, implementation and closure stages of the project; however, these costs are not identified in Appendix I. b. The second bullet on page 6-7 of Section 6.2.2, EMDF Conceptual Design, includes a design element of the EDMF of "early actions;" however, early action costs are not itemized in Appendix I. It is noted that Section 3.2.2.1, Pre-construction Activities and Design (Elements 1 and 4 in Table I-3), of Appendix I, provides a description of activities included as early actions (e.g., groundwater monitoring); however, these cost are not itemized in Table I-3, Summary of EMDF Conceptual Design Cost Estimate. c. Section 6.2.2.4.1, Clean-fill Dike, describes the dike to be constructed around the perimeter of the landfill; however, costs for this dike construction are not included in Appendix I. d. The landfill gas collection and venting system is described in 6.2.2.4.7, Cover Systems. While it is understood that this system is not anticipated to be incorporated into the final cover, the RI/FS should note in Section 6.2.2.4.7 that costs are not included. e. Section 6.2.2.6.3, Predicting Seasonal High Ground Water Elevations, indicates additional fill was required in the conceptual design of the landfill to raise the bottom of the landfill; however, it is not clear if these costs were incorporated into Appendix I. f. Section 6.2.2.6.4, Data Gaps and Uncertainties, states, "Future mercury-contaminated debris that is planned to be treated in, and disposed of, at the EMDF [Environmental Management Disposal Facility] using the macroencapsulation method is not currently addressed by the conceptual design. Final design considerations will include an analysis of the stresses this treatment (e.g., construction of concrete forms to hold debris, and subsequent macroencapsulation activities) would place on the landfill floor, above the liner." However, Appendix I indicates that macroencapsulation is included in the costs and as such this discrepancy should be addressed Revise Appendix I to include these costs or alternatively explain in the text of the RI/FS why	Most of the costs indicated in the comments are included in the RI/FS and additional text was added as indicated to explain this. a. These costs are considered part of the on-going operations of the facility. For example, with EMWMF, calculation of the sum-of-fractions (either per waste lot, or for the facility) serves to indicate the risk presented by placed waste as operations proceed. Tracking the sum-of-fractions (SOF) of the landfill throughout operation tracks the risk presented by the facility. These results are reported in PCCRs among other documents. A final status of risk based on the final inventory of the landfill (and the "final" SOF of the landfill) would be akin to a final risk assessment. Again, this is a culmination of determining a SOF for the landfill on an ongoing basis. It is not a "specific" task. Necessarily, the final landfill SOF will not exceed 1.0, and might possibly be less than 1.0, in which case the final risk posed is less than the initial developed risk in this RI/FS. b. This cost is part of Site Characterization (under element 1 in Table I-3). Now noted in that description. c. This is part of the excavation & fill cost, listed under element 5 ($18.8 M for Cells 1 & 2)..Now noted in that description. d. This section was revised with a note that costs were not included for a venting system in the cover. e. Costs for fill were revised in the D3 to incorporate these additional fill requirements. This section (6.2.2.6.3) was updated to note the costs were added. f. Macroencapsulation is no longer discussed in this section.

	these costs do not need to be included.	
EPA.G.040	The RI/FS does not assess the environmental effects of the proposed remedial alternatives in accordance with Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites (EPA 542-R-08-002), dated April 2008 (EPA Green Remediation Guidance) or Methodology for Understanding and Reducing a Project's Environmental Footprint (EPA 542-R-12-002), dated February 2012 (EPA Environmental Footprint Guidance). For example, energy consumption, greenhouse gas emissions (carbon dioxide, methane, and nitrous oxides), pollutant emissions (carbon monoxide, oxides of sulfur, oxides of nitrogen, and particulate matter), water consumption, ecological impacts/change in resource use, resource consumption, and worker safety are not used to evaluate the environmental footprint of the remedial action alternatives. Revise the RI/FS to meet the level of detail specified in the EPA Green Remediation Guidance and EPA Environmental Footprint Guidance.	See the discussion at the end of Section 6.2.2.5 that indicates very little difference would be seen between proposed sites, in terms of energy consumption, greenhouse gas emissions, etc. as demonstrated through air pollution analysis completed for sites 7b and EBCV. However, it is noted that design and construction will take into account green practices and conservation per DOE O 436.1a *Departmental Sustainability* and per Executive Order 13693 *Planning for Federal Sustainability in the Next Decade*
EPA.S.001	<u>Section 2.2.1, As-generated Waste Volume Estimate, Background, Page 2-6</u> - The second bullet in this section states, "A correction to the waste volume estimate for Building 9201-4 (Alpha-4) demolition was used;" however, the correction is not described or quantified. For clarity, revise this section to provide additional information on this correction.	Additional information was added – this volume correction was due to prior estimate using a wrong number from a report (a containerized waste volume was used rather than the as-generated waste volume). The result was a 27,000 cy decrease in the waste volume for that facility
EPA.S.002	<u>Section 2.2.2, As-disposed Waste Volume Estimate, Background, Page 2-**10**</u> - This section indicates that the estimated capacity necessary for the EMDF is 2.2 M yd^3 (including uncertainty), but that the conceptual design in the RI/FS is based on 2.5 M yd^3. While it is understood that this is conceptual design for the RI/FS stage of the project, it is not clear why the conceptual design criteria was not adjusted to 2.2 M yd^3, as this could impact siting requirements (e.g., a smaller footprint or the feasibility of using two smaller landfills in an improved setting). Also, it is not clear if a conceptually smaller landfill footprint would substantially affect the assumption in Appendix D, On-Site Disposal Alternative Site Screening, that a 60-70 acre site is required for the proposed EMDF. Revise the RI/FS to address these issues	Changes necessary to modify the conceptual design from a 2.5 M CY landfill to a 2.2 M CY landfill were considered to be too extensive and unnecessary in the D3 RI/FS, as it is only a conceptual design and the waste volumes continue to fluctuate year to year as more information becomes available. More attention will be paid to analyzing the sites in the CERCLA analysis of the revised document under consideration of the size of landfill to be built out to contain the volume of waste assumed (for example, the area committed for a site long-term). As three options will be considered in the revised document, and all three offer different conceptual volumes. Comparisons, especially cost, were made on a limited 2.2 M CY capacity build. Thus statistics regarding building all options to a limited 2.2 M CY were included to the extent possible.
EPA.S.003	<u>Section 3.2, Evaluation of Risk for the On-Site Alternative, p. 3-6</u> - This section states, "For the On-site Disposal Alternative, long-term risk evaluation is a much more involved process. Residual risk can only be estimated in the early "feasibility" stage of this remedy, as the waste is not yet in place, and the types and amounts of contaminants are not yet fully known. As the remedy is further advanced through the design and eventually implementation and closure stages, a more quantitative approach to determining/verifying risk can be applied." However, it is not clear why conservative assumptions on the type and amounts of contaminants, and modeled receptor exposures cannot be used to account for the uncertainty and an appropriate residual risk determined. By postponing the risk evaluation to the design stage and beyond, it is not clear how evaluation of the On-Site Alternative in meeting the RAOs can be completed. Revise the RI/FS to provide additional information on the risk evaluation approach.	The RI/FS deals with the limits (analytic WAC) and therefore is looking at a maximum allowable. As the landfill is filled, these limits are not exceeded, and the actual may be less. The assumptions on the types and amounts of contaminants are conservative and <u>do</u> present a bounding case (in terms of PreWAC limits). The text quoted here is essentially describing how a "cumulative risk" is calculated throughout the lifecycle of a facility [by means of a "sum of fractions" or some other method such as hard limits being set and not exceeded – the process will be defined in a future primary document – WAC Attainment (Compliance) Plan], and will result in an increase (throughout operations, from day one to closure) to a final maximum risk that in the end will represent a "real" risk as opposed to a "projected" risk. That "real" risk or final cumulative risk will by design be within the risk range. Reworded – see page 3-6.

EPA.S.004	Section 5.3, Assembly of Alternatives and Ability to Meet Remedial Action Objectives, p. 5-18 - The description of how the On-Site Alternative meets the ecological RAO is not adequate. This section states, "Through compliance with ARARs and sound design, the onsite engineered disposal cell would effectively isolate the wastes from the environment, minimizing release of contaminants, and reducing overall environmental impact. Compliance with the facility WAC would also ensure minimal ecological exposure." However, the description as stated is vague and not quantified. As the ecological RAO (i.e., prevent ecological exposure to future-generated CERCLA waste) is also vague, it appears both the RAO and details on how On-Site Alternative meets this RAO require revision. Revise this section to provide details on how the ecological RAO will be met. In addition revise the RI/FS to include a more detailed ecological RAO.	The RAO that specifies protection of ecological sources has been revised to indicate this is accomplished by meeting appropriate CWA AWQC. These limits apply to surface water, and preliminary WAC are determined that demonstrate these limits are met in Bear Creek for the compliance period. Text has been added to indicate that CWA AWQC demonstrate protection of ecological receptors; that while radiological limits are not included in the CWA AWQC, protection of human health places limits on radiological contaminants in the major water pathway to a degree that ecological receptors are protected, and the soil pathway does not present a significant ecological risk. Text in Section 5.3 has been revised accordingly.
EPA.S.005	Section 5.3, Assembly of Alternatives and Ability to Meet Remedial Action Objectives, p. 5-18 - The No Action Alternative is not included for each of the RAO bullets in this section and the accompanying description of how the alternatives meet RAOs. For completeness, include a discussion of the No Action Alternative as part of all of the RAO bullet points in this section.	Text was added to describe how the No Action Alternative will meet or not meet RAOs.
EPA.S.006	Section 5.4, Figure 5-3 - The scenarios of various proportions for on and offsite waste should be retained for development of alternatives in Section 6 and detailed analysis in Section 7. The 80% in two landfills and 60% in one landfill onsite options are viable alternatives that would entail a smaller footprint that would be more implementable as related to site location issues, especially if waste generation forecasts are more realistic as mentioned in other comments.	A new alternative (Hybrid Alternative) is incorporated fully in the RI/FS, including both Chapters 6 and 7. This section has been deleted from the revised RI/FS.
EPA.S.007	Section 6.2.1.1, p. 6-5 - More details are needed in Section 6.2.1.1 or elsewhere, as appropriate, on the proposed rerouting of NT-3. Figure 6-8 shows the rerouted western branch of NT-3. The RI/FS does not provide any explanation for why the stream needs to be rerouted. Also, regarding Figure 6-8, BOTH the overprint pattern that encircles most of the landfill and the lighter blue line that bounds the northern part of the landfill and connects with rerouted NT-3 and an upstream tributary to NT-2 need to be identified in the legend.	Agree. Changes have been made as requested, and are added in the *Section 6.2.2.4.2 Upgradient Diversion Ditch with Shallow French Drain.*
EPA.S.008	Section 6.2.2.2, p. 6-8 - The **Hydrogeological and Geotechnical Investigations** discussion in Section 6.2.2.2 of the RI/FS reads as if no hydrogeological or geotechnical investigations have been done for the area of the proposed landfill. This statement as written is incorrect, as indicated in the very next subsection of Section 6.2.2.2. However, the statement that no previous investigations have been performed is followed in the very next sentence by a statement that the investigations would evaluate areas selected for landfill support facilities, roadways, and on-site spoil/borrow areas. There needs to be some statement regarding the criticality of hydrogeological and geotechnical investigations of those areas to the overall viability of the EMDF. If such investigations are critical to selection of the EMDF they should be done, at least in a limited sense, before moving forward with the EMDF as the alternative for waste disposal.	Section 6.2.2.2 notes that no previous investigations (prior to the current Phase I investigation) have been completed in the Site 5 EMDF footprint, and then summarizes the Phase I effort. Additional investigation is planned to obtain information for the detailed engineering design. It is understood that such investigations are critical requirements, including the investigation of subsurface conditions in the areas of ancillary support facilities. The D4 revisions to the RI/FS are being expanded in Chapter 6 to address the general layout of ancillary facilities such as sediment basins and other support structures for each of the four proposed EMDF sites [Sites 14 (WBCV), 7a, 6b, and 5 (EBCV)]. The potential for karst related sinkhole formation appears to be the only significant concern related to the viability of the proposed sites in relation to support facility areas. The site drawings suggest that the areas of support facilities would not occur within the outcrop belt of the Maynardville Limestone where karst conditions exist; rather the ancillary facilities would be located along the southern perimeter areas of the sites generally within the outcrop belt of the Nolichucky Shale where karst features (particularly sinkholes) are absent. Thus the areas anticipated for landfill support facilities do not appear to be critical to the overall viability of the EMDF at the proposed sites in BCV and would not warrant early investigations. Once DOE, EPA, and TDEC have agreed on the site(s) for the EMDF, field investigations will be conducted to characterize the sites, including the areas selected for adjacent support facilities. EPA and TDEC will have the opportunity to participate in the scoping and to comment on work plans for those investigations. In support of the characterization process, D4 revisions to

		Appendix E summarize previous investigations and available data at each of the proposed sites in BCV..
EPA.S.009	Section 6.2.2.4.2, Upgradient Diversion Ditch with Shallow French Drain, p. 6-11 - This section states, "A design requirement will be to evaluate the possibility of the upgradient ditches and drains failing. This evaluation would be conducted in order to demonstrate that the landfill will remain protective of the environment in the event these features fail." However, it is not clear why this evaluation would not be performed prior to the FS to assist in evaluating the protection of human health and the environment as part of the FS process. Revise this section to include this evaluation or provide a rationale for not including it as part of the RI/FS	Agree. Changes will be made as requested in the *Section 6.2.2.4.2 Upgradient Diversion Ditch with Shallow French Drain.*
EPA.S.010	Figure 6-13, EMDF Cross-sections, Page 6-33 - This figure includes a dashed line described as "Model Predicted Post Construct Water Levels;" however, a reference to where this model data and output is available is not included. For clarity, provide a reference to these model calculations.	Agree. The figure has been revised as requested.
EPA.S.011	Section 6.2.2.6.3, p. 6-37 - The first iteration of predicting the seasonal high water table, using data from other areas, seeps, springs et cetera did not indicate areas that could be below the water table that were documented by the Phase I characterization data from groundwater monitoring in the proposed landfill area. So, this being the case, how confident is the prediction of subsurface conditions that could be encountered in the EMDF landfill area based on subsurface data from other areas where there is more well/boring coverage? Section 6.2.2.6.4 indicates that the conceptual design for the EMDF is based on data from nearby areas. There needs to be a more comprehensive summarization here or elsewhere in the RI/FS regarding the specific data and locations that were considered. Are there any data suggesting Bear Creek baseflow downstream of the confluence of NT-3 with Bear Creek substantively differs from the value would be predicted by summing measured or inferred NT-3 baseflow in the downstream NT-3 reach and Bear Creek baseflow upstream of the NT-3 confluence. The concern is any possible discharge of underflow with a significant contribution from the NT-3 watershed into Bear Creek downstream of the confluence or notable loss of water from Bear Creek into the underlying aquifer at the point where NT-3 mixes with Bear Creek. Since the EMDF disposal cells will be constructed in phases, the EMDF disposal option should build into the conceptual design the idea that should monitoring indicate a problem with maintaining groundwater levels beneath the initial landfill cell(s) at a sufficient depth below the landfill, all future cells will be redesigned as needed to avoid this problem as later landfill cells are opened.	This comment includes two main EPA concerns: 1) those related to the water table and engineering design; and 2) those related to baseflow at and near the junction of Bear Creek and NT-3. Response to Part 1 As described in Section 6.2.2.6.3, a theoretical seasonal high water table contour map was prepared for the area across the EMDF (Site 5) footprint before the Phase I investigation data were available and with absolutely no hard data within the footprint. The water table was conjectured based on data from surrounding areas with similar terrain and used to establish preliminary base level elevations for the landfill. The base level elevations were subsequently adjusted upward in places based on water level data from the five Phase I well locations in the footprint. With the availability of the Phase I data, we see no need to provide a "comprehensive summary" of data and locations outside the footprint used as the basis for the preliminary elevations. The surrounding data and theoretical water table map can be provided to EPA if desired, but with actual Site 5 water table data now in the footprint, the previous inferences are defunct. The Section will be revised to clarify the current relationships between the landfill design elevations and the seasonal high water table conditions of April 21, 2015, developed from Phase I monitoring data after the D3 RI/FS report was issued. See response to comment G. 22 above as well for additional rationale that will be provided to address and clarify changes to the water table that will occur during and after construction, capping, and closure. Corrective actions to address any performance issues encountered during operations and future phased construction of the EMDF will be implemented as required to meet performance objectives. Response to Part 2 – Bear Creek/NT-3 base flow [Note that it is unclear how this part of the comment is related to Section 6.2.2.6.3]. A weir stream flow monitoring station is located on NT-3 within about 100 ft of the confluence with Bear Creek. A weir is also located on Bear Creek at BCK-11.54 a few hundred feet downstream of the NT-3 confluence, and several monitoring stations are located along Bear Creek upstream of the NT-3 confluence. So stream flow data are available for this area but have not been evaluated to quantify the capture of NT-3 surface water into the karst network of the Maynardville Limestone in the area near the NT-3/Bear Creek confluence.

		The surface water irrigation intake receptor location is assumed to be on Bear Creek at the confluence with NT-3, and historical flow data from BCK 11.54 has been used in the risk assessment modeling to estimate average flow along Bear Creek at the assumed intake location. The intake location was chosen based on perennial and higher flows along Bear Creek relative to NT-3. Base flow data for NT-3 including its lowermost reaches is known to be near zero during dry season base flow periods, which is why Bear Creek is assumed for irrigation and not NT-3. Groundwater modeling does suggest that some contaminated groundwater could bypass the surface water exposure point on Bear Creek below the NT3 confluence. MT3D simulation predicts that some percentage of the assumed mass flux leaving the disposal facility (assuming a constant unit concentration) would ultimately discharge to the surface downstream of the Bear Creek surface water exposure point. However the PATHRAE model used for predicting the concentration of groundwater discharging to Bear Creek conservatively assumes that the entire mass flux leaving the cell discharges at the surface water point of exposure.
EPA.S.012	<u>Section 6.2.4, p. 6-40</u> - The compacted clay liner needs to conform to the specifications of 40 CFR 264.301(c)(1)(i)(B). Appendix H Table H-1 indicates the clay would meet the minimum liner specifications required by this regulation. However considering the unfavorable aspects of the proposed EMDF location (overlying existing streams, springs and seeps, for example) it is recommended that the clay liner be designed to exceed the minimum specification with respect to at least the hydraulic conductivity.	Consideration has been given to this request. The current specification [40 CFR 264.301(c)(1)] on the hydraulic conductivity (K) for this compacted clay layer is 1x10-7 cm/s. DOE understands that exceeding this specification (by reducing (lowering) hydraulic conductivity) might appear to further inhibit upwelling groundwater from impinging on the upper liner layers and waste. However, in considering the landfill design as a whole, and over long terms, one has to protect against the “bath-tub” affect in which the liner could become less permeable than the cover, causing water to accumulate in the waste. Further lowering the K in the compacted clay layer could contribute to a higher risk of bath-tubbing occurring over long periods, as the cap may become somewhat less effective in limiting infiltration, and a corresponding decrease in the functioning of the liner is less likely due to the pressure and depth provided by 50-75 ft of waste. Additionally, 40 CFR Part 264.310(a)(5) states that “At final closure of the landfill or upon closure of any cell, the owner or operator must cover the landfill or cell with a final cover designed and constructed to have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present.” A conceptual design that uses a value of 1x10-7 cm/s offers a factor of safety to offset the potential of the overburden pressure on the liner driving the permeability to a lower value over the long term. Therefore DOE considers it prudent to stay with the current specification of 1x10-7 cm/s.
EPA.S.013	<u>Section 6.2.9, p. 6-44</u> - The basis for an assumed 100-year post closure period needs to be identified and some consideration of potential costs that would be associated with a longer life-cycle duration of post-closure monitoring should be included in the RI/FS for a fair cost comparison with the offsite proposal.	A full comparison of the perpetual care fee and long-term (1,000 yr) S&M are made in Appendix I. The conclusion (based on Present Worth Analysis) is that the Perpetual Care fee offers a higher PW value. In terms of the off-site long-term care, operators of NRC licensed facilities have to show solvency for long-term care only through 100 years.
EPA.S.014	<u>Section 7.2.2.3, Long-term Effectiveness and Permanence (On-Site), Page 7-9</u> - This section indicates that the geomembrane liner design life is at least 200 years; however, this section does not include a reference to data to support this assumption. Revise this section to provide a reference to information to support this 200 year design life.	Agree The expected life is far beyond 200 years, although modeling conservatively assumes some failure begins at 200 years. Wording and references have been be added to this Section. See revisions.
EPA.S.015	<u>Section 7.2.2.3, Long-term Effectiveness and Permanence (On-Site), Page 7-9</u> - This section	The rationale written in the document for not including the inadvertent intrusion

	states, "A more detailed and quantitative assessment of inadvertent intrusion scenarios and risks will be performed per DOE requirements to be completed prior to landfill construction;" however, it is not clear why this detailed risk assessment would need to be completed at a later stage of the project and could not be completed as part of the RI/FS. Revise this section to include this evaluation or provided a rationale for not including it as part of the RI/FS.	in the RI/FS has been added to. In order to complete an intruder analysis, a closure waste profile is needed (that is, an estimated activity content of the waste contained in the closed landfill). This estimate has not been made for the RI/FS, but is made to accomplish the Performance Assessment (PA) required by DOE O 435.1. For this reason, the intruder analysis is not completed until after the PA is at least initiated. Wording has been added to the text (Section 7.2.2.3) to note that an intruder analysis will be completed under the requirements of DOE O 435.1, and results will inform the final WAC if deemed necessary.
EPA.S.016	Appendix A - The appendix only presents waste characterization data for radionuclides. Explain why characterization data is not provided for chemicals.	Added chemical data set to Appendix A. New Table A-7 has been added.
EPA.S.017	Appendix A - Are there any soil properties criteria for soils that would be brought in to supplant contaminated soils used as landfill matrix material? Is there any benefit to using imported fill material that has defined chemical/textural properties as matrix to be landfilled with debris, versus maximizing the use of contaminated soil as fill? The contaminated soil might be less favorable as a matrix based on its intrinsic properties. Since there appears to be considerable understanding of radioactive materials present in areas that presumably will contribute to the EMDF waste stream (Appendix A, Table A-5), are there some of these materials that are so highly contaminated that co-disposal with a soil of known texture and chemical properties would be a reasonable way to reduce the mobility or toxicity of that radioactive waste material?	Investigations are ongoing into additives to soils that may retard mercury mobility in the landfill matrix. Any conclusions on this possibility will be covered during detailed design. No other potential contaminant has been identified at this time that would exist in high enough concentration to warrant specific reactive additives to the fill or waste soils used as fill.
EPA.S.018	Appendix B, Section 5.4.2.3, ROM Cost for Size Reduction Facility, p. B-29 - This section indicates that for a Rough Order of Magnitude (ROM) estimate type, a 35% contingency is added to capital costs to account for unanticipated cost items and resources; however, the basis for the 35% contingency is not provided and appears to be high. Revise this section to provide a basis for this contingency and, if necessary, revise the cost estimate using a more appropriate contingency.	The contingency provided is consistent with a Class 4 estimate accuracy from DOE G 413.3-21 Cost Estimating Guide. The Class 4 accuracy range is given as -15 to -30% on the low end to +20 to 50% on the high end. The mean accuracy on the high end was chosen because it is more likely that important cost elements are underestimated in the case of DOE projects. Text was added as a footnote to the table, to explain the contingency assumed.
EPA.S.019	Appendix B, Table B-10, Total Life-cycle Costs for Size Reduction Facility, p. B-29 - This table includes $21,131,000 in operating crew costs; however, it is not clear if this is a present value costs and how the present value was calculated (e.g., discount rate). Further, as the operating costs represent roughly 50% of the overall cost in Table B-10, it appears additional details are needed to support the basis for these costs to ensure they are appropriate. Revise this table, or appropriate sections of Appendix B to provide additional line item information on the operating costs of the Size Reduction Facility.	The costs in the D3 version (table B-10) are based on 2012 dollars. Note that this operating cost ($21 M) is life-cycle (22 years of operation). Table B-9 provided a breakdown of personnel, and shows 8 FTEs are required. Table B-10 was revised to indicate that labor was needed for the 22-year life cycle and to refer to Table B-9 for personnel and responsibilities. Additionally, the costs were converted to Present Worth so the comparison is made on PW value.
EPA.S.020	Appendix B, Table B-10, Total Life-cycle Costs for Size Reduction Facility, p. B-29 - This table includes 20% for project management costs; however, the basis for the 20% level is not provided and appears to be high. Revise this section to provide a basis for the project management costs and, if necessary, revise the cost estimate using a more appropriate percentage.	This percentage is typical for DOE projects and includes management of essential functions such as safety management, engineering support, quality assurance, environmental compliance, performance assurance, project controls, document control, and administrative support. Text was added in a table footnote to provide this basis in the document.

EPA.S.021	Appendix B and Section 5.2.4 - parts of Section 5.4.2.of Appendix B should include an evaluation of other possible benefits of size reduction such as lower potential risks associated with less number of trips to haul debris, reduced usage of fuel (a potential TBC with respect to Executive Order 13693), and other possible considerations in addition to reduced footprint size and implementability.	Actually there is more handling of debris to accomplish VR and higher potential risk associated with heavy equipment operations and airborne contamination. Double-handling of debris is necessary for staging of processor feed materials; processors have substantial fuel and energy requirements; and implementation is complex due to operations, contamination control, and maintenance requirements. These points have been made in the revision to the document in the new Section 5.4.4 As pointed out in Section 5.4.4, size reduction at the demolition facility may still be advantageous, but implementation is outside the scope of this RI/FS and the remedy being considered. Implementation at the demolition site may result in some benefits such as fewer trips to the disposal facility. However, a tradeoff study would be needed to consider the advantages/disadvantages.
EPA.S.022	Appendix C, Table 5-1 - Regarding the treatment of mercury-contaminated debris (Table 5-1; Appendix C), the RI/FS should include consideration of a process option that results in encapsulation in the proximity of the disposal facility before actual land disposal. This option mostly avoids any implementability issue related to transportation of encapsulated wastes (see Table 5, Implementability column) while avoiding an ARAR issue with respect to the requirements of 40 CFR Part 268. This comment is relevant regardless of the location of an on-Site landfill.	Appendix C revisions propose obtaining a CAMU designation for in-cell or out-of cell onsite treatment facilities, rather than a waiver of the LDR for onsite disposal of mercury waste. Debris treatment and disposal options considered in Appendix C have been revised to include macroencapsulation at a location adjacent to the proposed onsite disposal cell.
EPA.S.023	Appendix E, Figure 1 - As EPA discussed in July 8 2015 meeting regarding Phase I characterization results, there are likely benefits to implementing a more robust, quantitative flow monitoring program at some or all of the locations where there is currently “observational monitoring” of flow (see Appendix E, Figure 1 for locations).	Agreed. The original objective was primarily to obtain weekly data to better characterize the seasonal variations and intermittent nature of spring and stream channel flows in the mid to upper headwater areas of the EMDF site (Site 5). The flow monitoring must support the engineering design requirements.
EPA.S.024	Appendix E, Table 2 - In a note at the bottom of the table, there is a statement about the open-hole deep wells not being developed because they were open-hole completions. Any new well should be developed to, at the very least, remove any particulate matter than might have settled in the well after the well was drilled. If these wells are left as is, and used as long-term monitoring points, the wells need to be developed, or data should be provided showing why the wells do not need to be developed (documentation of well drilling technique without addition of drilling mud; no evidence of downward grout migration from the cased interval; evidence of sufficiently clear discharge water during routine well purging).	All of the Phase I wells are located within the EMDF waste limit footprint and must ultimately be carefully plugged and abandoned prior to landfill construction. Wells installed for long-term release detection and compliance monitoring would presumably only be located outside of the perimeter of the final cover and side slope buttress areas mostly along the downgradient margins of the landfill.
EPA.S.025	Appendix E, Section 2.3.3.2.1, Shallow Aquifer Zone, p. E-44 - This section indicates that well GW-977 was dry, but does not provide information on why the well was dry, of if this condition was expected. Revise this section to provide information on why well GW-977 was dry.	The depths to the water table and auger refusal below the crest of the spur ridge at was unknown prior to drilling and installation of the GW-976(I)/GW-977(S) well pair. The drilling and installation of GW-976(I)/GW-977(S) and subsequent water level monitoring has demonstrated that the water table at this location occurs at depths from 34-43 ft below ground surface (bgs), based on hourly water level data collected between December 2014 and August 2015. Auger refusal depths, which provide an indication of the top of competent bedrock at this well pair, are 24-25 ft bgs which places the water table around 9-18 ft below the top of rock. GW-977(S) was completed with 10 ft of screen above the top of bedrock where the well has remained above the highest water table observed in GW-976(I) in late April 2015. The D4 revisions to Appendix E addresses these issues by reference to Attachments A and B (i.e. – the Phase I site characterization report and the Addendum to the Phase I Report, respectively)
EPA.S.026	Appendix E, Section 2.4.2.2 - This section states that the lower reaches of NT-2 and NT-3 may either not be gaining streams during high baseflow conditions or may be losing streams. Some detail is needed regarding why these would be losing streams in these specific areas. Is it because of hydrologic conditions associated with high baseflow and unique to the lower reaches of the streams or is it because the streams are flowing over more permeable rocks.	The USGS data on which these definitions of gaining and losing reaches are based comes from single point flow measurements made on single days in September and March of 1994, from stream channel, seep, and spring locations. The change in discharge was simply calculated between flows at adjacent locations. A variety of relatively simple flow measurement field methods were used. The results are limited in terms of accurately defining losing/gaining stretches of the NT

		tributaries that may vary spatially and temporally with rainfall events and wet/dry seasons, and that might vary in relation to changes in the nature and extent of alluvium and bedrock conditions along the valley floors. Changes in flow along given reaches may vary considerably depending on the size and total flux of ground water discharging at seeps and springs. The USGS data should be therefore viewed with caution in terms of accurately defining gaining/losing stretches along the NT tributaries, particularly the upper headwater areas such as that of the EMDF site where flow rates are very low. Please reference the USGS original reports cited in Appendix E for details. The details requested by the EPA are currently unavailable and not afforded by the limited USGS data. These clarifications are addressed in Section 2.10.2.2 of the D4 Appendix E. It should be noted that karst flow conditions have been documented within the Maynardville Limestone subcrop belt along Bear Creek approximately 1300 ft south of the EMDF. The Report on the RI of BCV (DOE 1997) includes detailed descriptions and graphics that identify the gaining /losing reaches along Bear Creek south and southwest of the EMDF where stream flow is intermittently diverted into and resurges from bedrock conduits below the stream bed. In addition, a new figure in the D4 Appendix E illustrates these reaches along Bear Creek in close proximity to candidate Site 6b.
EPA.S.027	Appendix E, Section 2.4.2.4 - The document discusses surface water contamination detected in NT-3 resulting from various sources to the east of NT-3. The proposed EMDF could conceivably be the source of contamination reaching NT-3 in the future. There should be some discussion in the RI/FS of how monitoring of NT-3 water quality will be able to distinguish potential releases from the EMDF and ongoing stream contamination from other identified potential sources.	EMWMF detection monitoring includes sampling and laboratory analysis of surface water from the downstream end of the culvert passing below the Haul Road near the southwest corner of the EMDF site (station EMWNT-03A near the southeast corner of the EMWMF – see location on Figure 7 of Attachment A to Appendix E of the current EMDF RI/FS Report). Results from this location are used to distinguish between potential releases from the EMWMF and releases from other sources impacting NT-3 further downstream. Ongoing and historical surface water monitoring occurs at a flume sample location on NT-3 ~100 ft upstream from its junction with Bear Creek (see location BC-NT3/SP on Figure 7 of Attachment A to Appendix E; identified simply as NT-3 in other ORR monitoring reports). Details of these monitoring activities are described in the annual Phased Construction Completion Reports for the EMWMF, and in the annual Remediation Effectiveness Reports for the ORR for Zone 3 in the BCV watershed. In addition, the underdrain outfall locations, along with downgradient perimeter monitoring wells, would be part of the detection monitoring program, as is currently done for the NT-4 underdrain outfall at the EMWMF. The underdrain outfalls offer advantages over strict conventional monitoring well detection as they integrate shallow ground water discharge from the overall area below the waste footprint. These issues are addressed in Section 3.5.3 in the new D4 version of Appendix E.
EPA.S.028	Appendix E, Section 2.6.2.3 - Paragraph 2 states there has been no detailed assessment of stream quality in the footprint of the EMDF. There needs to be some assessment of NT3 upstream of the area affected by the BY/BY remedial actions, in the area more or less encompassing both of the lower reaches of the two principal NT3 tributaries (i.e. just upstream of the wetlands areas which are upstream of the culvert beneath the Haul Road (see Figure 1, Appendix E) as well as within the wetlands upstream of the tributaries. An assessment needs to be made of how construction and placement of the EMDF will affect these areas with respect to both the wetlands hydrologic function and biota in the wetlands and uncovered stream segments upstream of the haul road.	The statement quoted in paragraph 2 appears to be in error and will be revised. Three field surveys have in fact been completed for the NT-3 tributary areas upstream of the Haul Road in conjunction with ecological assessments of the EMDF site including wetland identification and delineation, stream determinations, and assessments of flora and fauna. The report references are provided in Section 3 of Appendix E and include: Collins J. L. 2015; Rosensteel, B. A. 2015; and Schacher W.H. 2015. The wetland areas identified along the NT-3 tributaries north of the Haul Road would be either completely destroyed or adversely impacted by construction of the EMDF and require compensatory

		mitigation in the form of wetland restoration, creation, or enhancement as done recently in conjunction with wetlands mitigation for the UPF haul road construction along the southeast margins of the EMDF site and as done for the EMWMF footprint area. These requirements are noted in Section 6 of Appendix G under location specific ARARs/TBCs. Section 6 of Appendix G provides a complete summary of location-specific ARARs/TBCs and current findings related to the EMDF site surveys addressing: floodplains/wetlands; aquatic resources; endangered, threatened, or rare species; and cultural resources. Please reference that section for details.
EPA.S.029	Appendix E, Section 4.1.7.2 - Paragraph 2 indicates that the open-hole bedrock wells could be tested further during Phase II characterization activities and redesigned. EPA recommends that all such wells be tested and that the final monitoring zone(s) for each well should be optimized to monitor the interval(s) where leakage from the landfill is most likely to be detected.	These well locations within the EMDF footprint will ultimately require plugging and abandonment prior to construction activities at this location (if selected), as long-term detection and compliance monitoring wells will ultimately be installed along the downgradient perimeter of the site and not below the EMDF footprint (consistent with EPA regulations and guidance for operational and post-closure landfill monitoring).
EPA.S.030	Appendix E, Section 7 - Discussion is needed regarding future predictive modeling of surface-water discharge under conditions of higher precipitation than that actually observed during any monitoring conducted prior to final EMDF design. There should be an ability to predict groundwater and surface-water flows across the EMDF area and surrounding watersheds encompassing the EMDF for a minimum of a 24-hour, 25-year precipitation recurrence interval (this selected recurrence interval and time period for the determination is based on such regulatory language as is available and pertaining to RCRA (40 CFR 264.301(h)). An assessment of potential rainfall-runoff and rainfall-groundwater levels conditions should also be made for lower probability (less frequent probability of recurrence) 24-hour rainfall events, if technically possible.	The purpose of the rainfall-runoff analysis presented in Appendix E, Attachment A was to provide quality assurance screening for the Phase 1 Site Characterization surface runoff data, rather than to develop site-specific predictive runoff modeling capacity. Final design of an onsite disposal facility will include hydraulic/hydrologic engineering design for drainage, erosion control, and storm runoff management, in accordance with applicable technical regulations such as the storm duration and frequency criteria cited in this comment.
EPA.S.031	Appendix E, Section 7 - An evaluation and discussion of the suitability of the existing precipitation monitoring station Y-12(W) for evaluation of the rainfall-runoff relationship in the NT3 subwatersheds is needed.	The rainfall-runoff analysis presented in Appendix E, Attachment A suggests that using the Y-12W precipitation measurement station was satisfactory for purposes of the Phase 1 Site Characterization effort.
EPA.S.032	Appendix E, Section 7 - In further Phase 2 investigations, detailed evaluations are needed of the relationship between rainfall and hydrologic responses to precipitation (stream flow; groundwater levels) in the EMDF area. The evaluations need to be probabilistically assessed by confidence limits on water-level and stream flow response versus rainfall estimates, using a 90% confidence on the slope of any trend line. Consideration should be given to raw data transformation if there is a non-linear relationship between variables.	Final design of an onsite disposal facility will include hydraulic/hydrologic engineering design for subsurface drainage systems and stormwater controls, including data quality requirements for additional characterization if necessary. Significant alterations to the existing watershed conditions will occur during and after construction. Thus rainfall/runoff relationships under natural conditions will be quite different from conditions analyzed during design.
EPA.S.033	Appendix E, Section 7.1.2 - Appendix E Attachment A Section 7.1.2 includes some discussion either indicating or implying that some of the to-date observed rainfall-runoff relationships have measurement errors relating to design or placement of some of the NT-3 stream flow stations. Any issues with the design, maintenance or siting of the stream flow gaging stations need to be resolved so that a more accurate record of rainfall-runoff conditions is obtained	The purpose of the rainfall-runoff analysis presented in Appendix E, Attachment A, was to provide a quality assurance screening for the Phase 1 Site Characterization surface runoff data, rather than to develop site-specific predictive runoff modeling capacity. Any further hydrologic site characterization is outside the scope of the EMDF RIFS.
EPA.S.034	Appendix E, Section 7.2.3.1 - Attachment A provides an assessment of the relationship between precipitation and water levels in existing wells in the proposed EMDF area. At both GW-968 (intermediate) and GW-969 (shallow) wells, water levels are above ground surface for at least part of the monitoring period. These wells are near the upgradient/upslope margins of the proposed landfill area. Based on Appendix E Attachment A Figure 27, the intermediate monitoring depth (bedrock) has a higher head than the shallow well. The tested upper part of the bedrock at GW-968 had a relatively high hydraulic conductivity (Plate 2). One must therefore be concerned about the potential for enhanced upward movement of groundwater	The GW-968/GW-969 well cluster is situated where substantial engineered fill would be placed prior to construction of the geobuffer and overlying liner system per the conceptual design. Cut/fill contour maps based on the conceptual design indicate this area would not require any cuts to existing surface grades. Therefore, the potentiometric surface in this area would not be penetrated eliminating the potential for any artesian flow there or in similar areas across the footprint. The concerns noted by EPA will continue to be considered in the follow-on design work. See response to EPA comment G.22 above for additional details.

	from the bedrock resulting from landfill and drainage construction that disrupts the low hydraulic conductivity saprolite geologic materials near the top of rock (see Plate 1; slug test K of 7.65E-7 cm/s from GW-969). This possibility may need to be considered further in landfill design.	
EPA.S.035	<u>Appendix E, Attachment A, Figure 25, text on page E-26</u> - This and other portions of the RI/FS infer that bedrock structural features associated with the greatest degree of hydraulic conductivity may be present along and near the valley floors, rather than in hilltop or hill slope topographic settings. Phase I investigations in the EMDF area have focused all groundwater monitoring investigations at locations away from the valley floors. EPA is concerned that the existing Phase I data do not account for the most significant hydraulic conductivities applicable to the various bedrock units. This absence of data from any valley floor locations has some unknown effect on groundwater modeling and needs to be accounted for in modeling, needs to be addressed in targeted data collection during Phase II investigations and needs to be factored into the landfill and drainage design.	The scope of future more detailed characterization will be determined through the data quality objectives (DQO) process and subsequent work plans, where sampling and data needs, requirements, and end data uses and data users are prescribed and concurrence is reached among the stakeholders.
EPA.S.036	<u>Appendix G, p. G-6</u> - DOE ORR has requested two waivers listed under 1 and 2: a. EPA does not believe that the CERCLA waiver (listed as 1) of the TSCA requirement specified is necessary or appropriate (See Specific Comment 38.a below). b. The basis that DOE ORR provided for a CERCLA waiver (listed as 2) from the ARAR prohibiting placement of untreated waste in a land disposal unit is inappropriate (See Specific Comment 38.b below).	a. A TSCA waiver will be requested as opposed to the CERCLA waiver, as requested by EPA in Comment S.38. DOE agrees with this approach, and has added text to justify a TSCA waiver. b. In-cell macroencapsulation (and any appropriate regulatory path to that treatment) has been confined to a discussion in Appendix C and is no longer part of an alternative.
EPA.S.037	<u>Appendix G, Section 3, ps. G-7 through G-9</u> - While DOE ORR's description in this section of DOE Orders vis a vis NRC regulations may be accurate in the sense of distinguishing between DOE operations and the operations of commercially licensed nuclear facilities, DOE ORR's analysis and assertion that these distinctions apply to CERCLA and remediation under CERCLA is inappropriate, and this section should be removed. In conflict with DOE ORR analysis, there is nothing in the EPA *CERCLA Compliance with Other Laws Manual* that would suggest that the state NRC rule as promulgated requirement could not be considered relevant and appropriate or that any non-promulgated Federal or State advisories or guidance, such as DOE Orders, would be exempt from consideration as a TBC. Please note that EPA does not agree with DOE ORR's interpretation of its rule and advises DOE ORR that nothing in the NCP preamble would preclude the TDEC rule from being considered a relevant and appropriate requirement. Whether the rules may be relevant and appropriate is determined by looking at the rule itself. To the degree that TDEC regulations assist in designing a safe radiological waste disposal unit, they can be identified as relevant and appropriate requirements. TBCs are used in determining the level of cleanup or how to achieve protectiveness for CERCLA response actions if no ARARs address a particular situation or if existing ARARs do not ensure protectiveness. So, where an NRC regulation is identified as both relevant and appropriate for determining the level of cleanup or how to achieve protectiveness, use of the DOE Order may not be useful or necessary. While not all parts of DOE Orders are necessarily TBCs, parts of guidance or advisories that help determine protectiveness of a remedy, those parts can be identified as a TBC. Please include portions of the DOE Orders (see the specific comment on the ARARs table) for those parts of DOE Order 435.1 and 458.1 that should be included as TBCs. Alternatively, clarify why DOE ORR has used DOE Orders (and NRC rules) in other RODs	State NRC-based requirements and DOE O/M requirements have been added to the revised RI/FS.

	and why this position has changed.	
EPA.S.038	Appendix G, p. G-9 - This section describes two requested ARAR waivers: a. EPA does not believe that the CERCLA waiver of the TSCA requirement specified is necessary or appropriate. TSCA itself provides the basis of a waiver at 40 CFR § 761.75(c)(4), which states that the EPA Administrator may waive one or more requirements in 40 CFR §761.75(b) when evidence is submitted to the Administrator that "operation of the landfill will not present an unreasonable risk of injury to health or the environment from PCBs" when those requirements are not met. Since the text here attempts to demonstrate "equivalent protectiveness," please revise this to demonstrate that the landfill will not present an unreasonable risk of injury to health or the environment from release of TSCA substances (e.g., PCBs). b. The basis that DOE ORR provided for a CERCLA waiver from the ARAR prohibiting placement of untreated waste in a land disposal unit is inappropriate. DOE ORR asserts that the "interim" nature of the action justifies the waiver. This remedial action is not an "interim" action as described in *A Guide to Preparing Superfund Proposed Plans, Records of Decision and Other Remedy Selection Decision Documents*, EPA OSWER 9200.1-23P, July 1999. As noted in 40 CFR 264.552(a)(4), placement of CAMU eligible waste into or within a CAMU does not constitute land disposal of hazardous wastes. EPA notes that the Paducah Gaseous Diffusion Plant is considering an option of designating a portion of the waste disposal unit as a corrective action management unit (CAMU) under regulations at 40 CFR §264.552 and recommends further discussion and development of this as part of an Alternative during resolution of EPA comments.	Agree, a TSCA waiver will be requested as opposed to the CERCLA waiver, as requested by EPA in this comment. DOE agrees with this approach, and has added text to justify a TSCA waiver. A corrective action management unit (CAMU) designation per regulations at 40 CFR §264.552 will be suggested as the regulatory path toward in-cell macroencapsulation in Appendix C. The alternatives considered do not incorporate in-cell macroencapsulation. The scope of the RI/FS assumes that costs for mercury-contaminated waste (soil and debris) are covered under project scope. For the on-site disposal alternatives, it is assumed the waste is received compliant with LDRs. For the off-site alternative, it is assumed the cost only covers transportation of debris; additional transportation cost for D009 debris and/or treatment of D009 debris is covered under the project scope.
EPA.S.039	Appendix G, Section 7.4, p. G-15 - Remove "At the request of TDEC and EPA" from the second paragraph, first sentence. It was a consensus decision, and not clear who first requested this path forward.	Agree. Completed.
EPA.S.040	Appendix G ARAR Tables - Remove the fifth column and utilize the format for ARARs tables as shown in EPA guidance, *CERCLA Compliance with Other Laws Manual*. To the degree there are notes that refine or clarify the requirements, those descriptions should be inserted beneath the specific requirement and preceded by the word *"Note:"*.	Agree. Completed.
EPA.S.041	Appendix G, Table G-3, p. G-30 - EPA does not believe that the CERCLA waiver of the TSCA requirement specified is necessary (See comment S38.a above). In addition, revise this citation by dividing the "Requirements" into two rows, which will place in one row the requirements that will be met (i.e., "The site shall have monitoring wells and leachate collection."), and those (i.e., the remaining requirements noted in this row) for which a TSCA waiver under 40 CFR §761.75(c) is being requested.	Agree. Changes have been made as indicated in the comment.
EPA.S.042	Appendix G, Table G-6, p. G-43 - In the first row, the "Tailoring of Requirement" column indicates that a waiver is being requested (See comment 38.b above).	See response to S.38 (b) above; in-cell macroencapsulation is not part of an alternative in the revised RI/FS.
EPA.S.043	Appendix G, Table G-6, ps. G-42 and -43 - Clarify whether this reference in the "Tailoring of Requirement" column to IWM FFS is intended to be a "tailoring" of the requirement, or if it is merely a reference to the FFS.	It is merely a reference to the FFS; this statement (and others like it) will be removed.
EPA.S.044	Appendix G, Table G-7, p. G-44 - See comment 38.b regarding the third row - "Macroencapsulation Treatment Standard" Action Characteristic.	This has been removed.
EPA.S.045	Appendix G, Table G-7, p. G-48 - In the second row, clarify the note "Combined" in the "Tailoring of Requirement" column.	Wording was removed, this was a remnant from beginning with EMWMF ARARs.
EPA.S.046	Appendix G, Table G-7, p. G-48 - In the bottom row, please clarify whether the comment beginning with "Free liquid" in the "Tailoring of Requirement" column indicates tailoring of the requirement. It appears that this text is superfluous and could be deleted.	Agree, removed text.
EPA.S.047	Appendix G, Table G-7, ps. G-49 and -50 - Clarify whether the reference in the "Tailoring of	It is merely a reference to the FFS; this statement (and others like it) will be

	Requirement" column to IWM FFS is intended to be a "tailoring" of the requirement, or if it is merely a reference to the FFS.	removed.
EPA.S.048	Appendix G, Table G-7, ps. G-56 and -57 - Remove the row associated with citation 40 CFR 264.90(f)(2). The Administrator has not been requested and is not considering developing alternative requirements for groundwater monitoring. Further, this flexibility is available only when (f)(1)(and (f)(2) have been demonstrated. If the flexibility of (f)(1) is later demonstrated, it can be addressed at that time.	Subpart F requirements as entered in the PGDP ARARs table will be used, with appropriate text edited. If PGDP final ARARs for Subpart F are not available at time of submittal, the most recent version of PGDP Subpart F will be included.
EPA.S.049	Appendix G, Table G-7, p. G-57 - In the last row, last column, revise this text by deleting "an alternative to" and replace with "a refinement of."	Subpart F, see comment EPA.S.48.
EPA.S.050	Appendix G, Table G-7, p. G-58 - In the first row, last column, add, "no less protective, and is intended to be" before "more."	Subpart F, see comment EPA.S.48.
EPA.S.051	Appendix G, Table G-7, p. G-59 - In the first row, please strike the second sentence in the "Tailoring of Requirements" column. While the location of the EMDF within the "brownfield region" of Bear Creek Valley may or may not be a relevant factor in re-evaluating the point of compliance, this rather hypothetical statement tends to indicate agreement where there is none that this location status may impact the point of compliance.	Subpart F, see comment EPA.S.48.
EPA.S.052	Appendix G, Table G-7, p. G-64 - In the second row, last column, replace, "is replaced with" with "will be refined by." Change the reference in the note to §264.93.	Subpart F, see comment EPA.S.48.
EPA.S.053	Appendix G, Table G-7, p. G-65 - In the first row, last column, please delete the last sentence, and replace with "A ROD modification or other documentation consistent with EPA ROD Guidance and the FFA will be prepared."	Subpart F, see comment EPA.S.48.
EPA.S.054	Appendix G, Table G-7, p. G-66 - In the second row, last column, please change "substituted for" with "developed from."D3	Subpart F, see comment EPA.S.48.
EPA.S.055	Appendix G Tables - Include the following citations as TBCs, in appropriate sections of the tables. The table below is not presented in the same column order as in the RI/FS, so some re-arrangement will be necessary in order to include. *[NOTE: SEE LIST IN EPA LETTER. LIST OF DOE O/M REFERENCES]*	Agreement has been reached in inclusion of DOE O/M citations.
EPA.S.056	Appendix H, Section 4.1.1, Site-specific HELP Model Development, ps. H-24 and H-25, Section 4.1.2, HELP Model Assumptions, p. H-25 and H-26 - The basis for the assumption that the underdrain system will function sufficiently well as designed to divert upwelling groundwater and the functional lifespan of this system are unclear. If this assumption is overly optimistic or the underdrain system fails to function after a period of time, groundwater infiltration will occur from beneath the liner system, which was not considered in the HELP model. To be conservative, failure of the underdrain system should be considered. Revise the HELP model to consider failure of the underdrain system.	The implications of failure of the underdrain system and reduction in the thickness of the unsaturated zone for EMDF performance are considered in sensitivity evaluations of the groundwater model suite (MODFLOW/MODPATH/MT3D) and the PATHRAE model. These evaluations are described in Appendix H Section 4.5
EPA.S.057	Appendix H - There are numerous issues with the groundwater modeling documented in this appendix that include the following: a. As noted in Specific Comment 35, there is a lack of site-specific hydraulic data for areas of most probable facture concentration in the valley floor hydrogeologic settings that would be below or downgradient of the proposed EMDF landfill. b. There is an arbitrary, speculative design of the assumed water-supply well used by the hypothetical receptor. A worst-case scenario should be applied for this receptor (well open hole or screened in shallower or deeper saturated materials (whichever is more conservative); accounting for a potentially smaller length of open hole or well screen (a potentially lower available drawdown from the well). c. The selected exposure point for risk evaluation may be too far from the landfill margin (probably placing the well completion in the karstic Maynardville Limestone, with both the potential for substantive dilution of any plume from the landfill release and the potential for additional contribution to risk from other groundwater contaminant sources	a) See response to comment EPA.G.35 above b) For the revised groundwater well locations in the D4 RI/FS (refer to Appendix H, Figure H-3), sensitivity of the simulated contaminant concentration in drinking water to the choice of well screen interval has been evaluated in Appendix H Section 4.5.1 c) The revised locations assumed for the drinking water well are within the Dismal Gap/Maryville formation. d) See responses to comments EPA.G.3 and EPA.G.5 above e) In the revised RI/FS, for risk assessment and development of PreWAC within the 1000 year compliance period, the groundwater well is assumed to be located at a distance of 100 m from the waste facility

	in Bear Creek Valley). Additive risk from other potential contamination in the bedrock is not addressed in the analysis, but if the receptor well is in areas where other contaminant sources may contribute to overall risk from groundwater exposure, it must be considered. d. There is an absence of consideration of groundwater ARARs in the analysis, which would need to be met at the downgradient margin of the landfill, independent of any potential consideration of risk from exposure to landfill-contaminated groundwater or surface water. e. There is a logical disconnect between DOE maintaining long-term control on potential exposure to groundwater in the Zone 3 designated industrial use area and DOE being unable to prevent the landfill cap from deteriorating over time. While failure of the underling multicomponent liner is possible and is less likely to be countered with corrective actions, if there is a presumptive maintenance of DOE authority (or some sort of authority) over land usage in the Zone 3 area over the course of the period evaluated in the modeling, then there is presumptively some ability of that authority to counteract landfill cover failure as well. If the landfill cover is projected to fail (even as an improbable, worst-case scenario), then an inability of any authority to maintain land-use controls should also be assumed. The fact that the hypothetical well is placed inside the Zone 3 area appears to be acknowledgement that maintenance of land-use controls in the area is not a given for the long term. Under this future scenario, there is no logical basis for not assuming the hypothetical well is located closer to the landfill than the modeling now assumes. f. There is no documentation for the source(s) of the recharge values applied to the groundwater flow model. g. Some of the hydraulic conductivity values presented in Table H-3 (model layers 1-3; Pumpkin Valley shale; Rogersville shale; Rutledge limestone) are inconsistent with field-reported hydraulic conductivity values from site-specific Phase I slug tests. Tabulated values are at least an order of magnitude higher than field-measured values. h. Section 4.2.1.4 of Appendix H, paragraph 2 states that new groundwater monitoring wells installed during Phase I characterization have been used in UBCV model calibration and well head values were in generally agreement with the model-predicted values. There is no indication of what those values are (modeled heads versus observed heads), nor what observed water levels (water levels from a specific date; average water levels for a specific time period) were used in the calibration. The calibration needs to be fully documented in the RI/FS. Comment 29k provides further discussion regarding the model calibration. i. There is no indication of the conductance values assigned to drain boundary cells. The information needs to be included in the RI/FS. j. Drainage features (underdrains) will be added as a part of the EMDF design are included in the modeling. There is a potential for substantive modifications to the design of these features depending on the results of Phase 2 investigations of the EMDF area. The modeling needs to incorporate a sensitivity analysis to account for potential modifications to the underdrain design, long-term degradation or clogging of the underdrain, and finally no underdrain. k. For groundwater calibration, there should be acceptable calibration statistics demonstrating reasonable agreement between observed and model-predicted heads and no obvious consistent bias in model results (consistent over or under-prediction of observed water levels). The predicted versus observed water levels specific to the Phase 1 wells need to be graphically presented. Calibration statistics need to be presented in the RI/FS. l. It is unclear from Section 4.2.1.4 paragraph 3 what the water balance represents. The text	boundary. f) See response to comment EPA.G.26 above g) The four Phase 1 Site Characterization hydraulic conductivity values noted by EPA appear to be relatively low. See Appendix E, Attachment A, page 82 and Section 2.13.2.4 in the D4 Appendix E for more detailed discussions. The K values assumed in the UBCV groundwater model (Table H-4) are consistent with a much larger set of field estimates performed on the Oak Ridge Reservation. Use of these K values is conservative, relative to using the four lower K values suggested by the limited Phase 1 Site Characterization results. h) UBCV groundwater model calibration with respect to Phase 1 Site Characterization observations of water table elevation has been described in Appendix H Section 4.2.1.4 i) Model results are relatively insensitive to assumed conductance values for the drain cells used to represent the engineered underdrain system. j) See response to comment EPA.S.56 above k) See responses to comment EPA.G.26 and EPA.G.27 above l) Revisions to Appendix H Section 4.2.1.4 clarify the discussion of model mass-balance accuracy/consistency and the comparison of model-predicted groundwater discharge to measured surface water flows. m) A more complete set of sensitivity analyses has been added to Appendix H, Section 4.5 .

	refers to the "model predicted ground water discharge above the Bear Creek/NT-3 junction." Whatever this value represents, it is being compared to the "…average flow rate at the junction location…" which is identified in Section 2.4.3.1 of Appendix E as the average daily flow at Bear Creek Kilometer 11.54, just downstream of the confluence of NT-3 with Bear Creek." The complete water balance needs to be included in the RI/FS, fully documenting each element of inflow and outflow. m. The third paragraph of Section 4.2.1.4 refers to sensitivity analyses. The sensitivity analyses need to be fully documented in the document.	
EPA.S.058	<u>Appendix H, Section 4.2.1.1, UBCV Model Domain and Discretization, p. H-31</u> - The text does not discuss whether model layers 4 through 11 correspond to specific lithologic units in the EMDF. Further, it is unclear if there are sufficient monitoring wells screened in each layer to validate the model. Revise the text to discuss how model layers correspond to lithologic units, and specify the number of monitoring wells screened in each layer. If there are insufficient wells in each layer to validate the model, explain why model validation is unnecessary.	The final two paragraphs of Appendix H Section 4.2.1.3 describe how litihologic units are represented in terms of the assignment of hydraulic conductivity values to particular model layers and model cells. Figure H-11 illustrates this representation of the hydrogeologic structure in cross-section. The text describing the development, calibration, and validation of the groundwater flow model has been revised in the D4 RI/FS.
EPA.S.059	<u>Appendix H, Table H-3, UBCV Groundwater Model Parameter Summary (Future Conditions), p. H-39 and H-40</u> - Since the hydraulic conductivity values are the same for each unit in Layers 4-8, it is unclear why separate layers are necessary as it appears that the same result would be obtained if a single layer was used. Revise the text to explain why separate layers are necessary for Layers 4-8, including whether there are any parameters that vary between these layers.	The layers are necessary to provide detail/granularity/accuracy to the model. See, for example, figure H-18, in which the 150 ft thick layer #9 provides much less detail than the overlying (much thinner) eight model layers. More vertical model layers (even with same K values) can provide more detailed GW head distribution in vertical intervals (with localized upgradient/downgradient flow) and provide refinement.
EPA.S.060	<u>Appendix H, On-Site Disposal Facility Preliminary Waste Acceptance Criteria, Section 4.2.1.4, Model Calibration, Page H-41</u> - The text states that the "water balance shows that essentially all water has been mathematically accounted for," but a table with the water balance details for each model layer is not included. Revise Appendix H to include a table that provides the water balance details for each model layer.	Revisions to Appendix H Section 4.2.1.4 clarify the discussion of model mass-balance accuracy/consistency. Summary model water balance statistics for the entire model domain are sufficient to describe overall model performance. Water balance statics for all model layers were examined and confirmed to be satisfactory.
EPA.S.061	<u>Appendix H, Section 4.3.2, p. H-48</u> - The receptor well pumping rate of 240 gallons per day is an arbitrary value, although reasonable, given the presumed number of groundwater users. Somewhat higher and lower pumping rates should be considered, to determine if there is any reasonable usage scenario where a larger relative contaminant concentration could be observed at a receptor.	The revised location of the groundwater withdrawal wells assumed for purposes of risk assessment and PreWAC development coincides with the axis of maximum modeled concentration within the contaminant plume. Higher pump rates would result in lower contaminant concentrations in the drinking water, since additional, relatively dilute water from the adjacent aquifer would be drawn into the well. Lower pump rates could result in somewhat higher concentrations, but conservative assumptions made throughout the PreWAC derivation
EPA.S.062	<u>Appendix H, Section 4.3.3, p. H-48</u> - Referring to the groundwater contaminant transport modeling, the last sentence in the first paragraph states most of the shallow plume discharges into surface water features. Has this mass been quantified for steady state conditions, assigned contaminant-specific concentrations for critical surface water locations, and the concentrations compared to any AWQC criteria that would be applicable to Bear Creek or NT3? Reviewing Table H-5 and Section 4.4.3, it appears that all of the presumptively contaminated water leaking out of the landfill is mixed with the assumed surface water flow at the hypothetical surface water receptor location to reach an assumed surface water concentration. If this is the case, the simplified process ignores several actual or potential factors in the leachate to surface water contamination mass transport process, including: (a) mixing of leachate with groundwater; (b) partial discharge of leachate contaminated groundwater into the surface water at the presumed receptor location and partial discharge of the contaminated groundwater into other surface water locations downstream of the presumed receptor location (underflow contaminant transport), and (c) potential presence of additional upstream sources of	(a) The groundwater model suite (MODFLOW, MODPATH, and MT3D) simulates mixing of leachate with groundwater. Model outputs include the three-dimensional pattern of relative (to leachate) concentrations in groundwater, and simulated contaminant mass fluxes to surface streams, assuming a unit leach rate from the disposal cell footprint. Appendix H revisions note that 94% of the total MT3D simulated contaminant flux discharges to surface water above the assumed surface water POE in Bear Creek. (b) For risk assessment and PreWAC development, the PATHRAE model is used to simulate discharge of contaminated groundwater at the surface water POE. The PATHRAE "groundwater to river" pathway assumes that the entire contaminant flux from the disposal facility is discharges (as modified by radioactive decay and chemical retardation) to the surface water POE (i.e. PATHRAE conservatively assumes zero underflow contaminant transport). For COPCs that peak within the

	groundwater contamination that contribute contaminant mass to the surface water at the presumed receptor location.	1000 year compliance period, predicted surface water contaminant concentrations that exceed applicable AWQC are utilized to develop PreWAC values that will meet AWQC at the surface water POE. (c) Consideration of risk to human health and water resources resulting from multiple Bear Creek Valley contaminant sources, within the 1000 year post-closure compliance period, will be provided in a Composite Analysis performed to meet the requirements of DOE Order 435.1
EPA.S.063	Appendix H, Figure H-19 - The figure shows that the highest relative contaminant concentration is anticipated to be observed in model layer 6, followed by model layer 7. Model layers 5 through 8 are identified as the layers intercepted by the hypothetical receptor well. Is the higher relative concentration in model layers 6 and 7 related solely to the presumed well construction? If so, well design should be factored into a sensitivity analysis, specifically determining if a shorter production interval has any effect on observed relative concentration.	Depending on location within the simulated contaminant plume, the choice of well screen (production) interval may or may not have a significant impact on the distribution of contaminant concentrations among model layers. For the revised groundwater well location in the D4 RIFS (refer to Appendix H, Figure H-3), sensitivity of the simulated contaminant concentration in drinking water to the choice of well screen interval has been evaluated in Appendix H Section 4.5.1.
EPA.S.064	Appendix H, Table H-5, Parameters for Use in PATHRAE Modeling and PreWAC Calculations, p. H-59 - The text should discuss the basis for each assumed value and provide references for all other values. Revise the text and Table H-5 to provide the basis for each assumed value and to provide references for the other values.	Table H-5 has been modified to provide basis for assumptions and data sources.
EPA.S.065	Appendix H, Section 4.4.3, PATHRAE Model Results, p. H-60 and Section 4.4.3.2, PATHRAE-HAZ Results, p. H-62 - A fracture-based flow system should be considered for calculation of the groundwater well dilution factor (DF_{well}). At a minimum, a range of values that include preferential transport in fractures that facilitate transport of contaminants to the creek and residential well should be provided. Revise Appendix H to include one or more DF_{well} values that accounts for facilitated contaminant transport in fractures in the PATHRAE and PATHRAE-HAZ model runs.	The impact of fracture-facilitated contaminant transport is not assessed using the current contaminant fate and transport modeling approach (see response to comment EPA.G.25). For the revised groundwater well location in the D4 RIFS (refer to Appendix H, Figure H-x), sensitivity of the simulated contaminant concentration in drinking water to the choice of well screen interval has been evaluated in Appendix H Section 4.5.1. This evaluation provides an indication of risk/PreWAC sensitivity to the value of $DF_{well.}$ In addition, PATHRAE model sensitivity to assumed average groundwater velocity and dispersivity values has been evaluated in revisions to Appendix H.(Section 4.5)
EPA.S.066	Appendix I, Table I-3, Summary of EMDF Conceptual Design Cost Estimate, p. I-16 -The Perpetual Care Fee element in this table includes a notation; however a footnote is not provided with the table. Revise Table I-3 to include this footnote.	Footnote added to table to note that the 15% G&A and fee are not applied to the Perpetual Care Fee or the RI/FS development.

CERCLA D3 RI/FS COMMENT AND RESPONSE SUMMARY

Comments by: **TDEC Division of DOE Oversight**
Comments Received: August 6, 2015
Title of Document: Remedial Investigation/Feasibility Study for Comprehensive Environmental Response, Compensation, and Liability Act Oak Ridge Reservation Waste Disposal Oak Ridge, Tennessee
Revision No.: D3 [to be managed as a D1]
Document No: DOE/OR/01-2535&D3
Date: March 31, 2015

Comment #	Comment	DOE Response
TDEC.G.001	Subsequent to the D2 RI/FS, DOE has taken the position that state regulations governing the disposal of LLRW are not relevant and appropriate to the disposal of DOE radioactive wastes; therefore the state rules should not be considered Applicable or Relevant and Appropriate Requirements (ARARs) for the EMDF. While DOE states it is obligated to abide by DOE Orders, it is also DOE's position that the orders should not be cited as requirements or to be considered guidance (TBC) in Records of Decision and other CERCLA agreements. As a consequence, TDEC rules regulating LLRW were removed as ARARS from the D3 RI/FS, as were DOE Orders listed as TBC. TDEC strongly disagrees with DOE's position and EPA has indicated they disagree as well. It is TDEC's position that the substantive requirements of TDEC 0400-20-11, Licensing Requirements for Land Disposal of Radioactive Waste, are relevant and appropriate to the management and disposal of LLRW authorized by the FFA under CERCLA and, in fact, intrinsic to the CERCLA process. While TDEC agrees DOE Orders are not ARARs as defined in CERCLA, the orders nevertheless represent DOE's regulatory responsibilities under the Atomic Energy Act, as well as its obligation to maintain the facility in perpetuity. Consequently the orders require consideration in Records of Decision and associated CERCLA documentation to the extent that they form a basis for a more stringent requirement than the TDEC rules. The expectation is that the more restrictive requirement will apply, as is typical of the CERCLA process. The above does not preclude DOE from pursuing the EMDF under its own authority, subject to state oversight as provided by the Tennessee Oversight Agreement.	Agreement has been reached on including ARARs for NRC-based TDEC rules regulating LLRW as 'relevant and appropriate' and DOE Order (Manual) references as to be considered (TBC) guidance.
TDEC.G.002	There is currently no consensus between DOE, EPA and TDEC regarding which laws are applicable and/or relevant and appropriate. Until agreement is reached on ARARs, there will be no way to determine if a given proposed site, facility design, and associated waste acceptance criteria will meet CERCLA remedial action goals. If agreement cannot be reached on ARARs, DOE should use the remaining capacity at EMWMF judiciously and, if EMWMF capacity is inadequate to accommodate all waste streams generated by CERCLA actions that are necessitated by imminent risk to human health and the environment, pursue disposal options outside of CERCLA for those waste streams. These options could include on-site disposal of radioactive waste under DOE authority, on-site facilities permitted for mixed waste, and off-site disposal.	Agreement has been reached on ARARs to be included in the RI/FS, with only some minor points to be worked out.
TDEC.G.003	The proposed location for the EMDF conflicts with siting criteria for TSCA, Solid Waste, and	There are no Solid Waste requirements in the ARARs table that the (D3 version)

	LLRW disposal facilities and associated guidance issued by the EPA and NRC. More specifically, the EMDF, as proposed, would be located approximately 650 yards from the nearest DOE boundary and over steep slopes (>30%), shallow watertable, zones of upwelling groundwater, wetlands, seeps, springs, a stream, and complex geohydrology. While not a natural feature, the extensive underdrain system proposed to collect groundwater beneath the facility and discharge it local streams, provides a direct and rapid pathway for the dispersion of contaminants to Bear Creek and via Bear Creek to Poplar Creek and the Clinch River: a condition the siting requirements specifically attempt to avoid. While the siting requirements for LLRW disposal facilities tend to be the most restrictive, the location proposed for the EMDF also fails to meet siting requirements for TSCA and Solid Waste disposal facilities. For example, the TSCA rules require: the bottom of the landfill liner to be greater than 50 feet from the historical high water table; there be no hydraulic connection between the site and standing or flowing surface water; and the landfill be located in an area of low to moderate relief. The TDEC Solid Waste Rules require subtitle D landfills to be located at least 200 feet from the normal boundaries of springs and streams. As the TDEC rules regulating LLRW facilities have been removed from consideration in the D3 RI/FS, a discussion of the these requirements relative to the proposed EMDF location is provided in Attachment A. While there may be no site on the ORR that will meet all the siting requirements, it seems likely there are better location(s) that could accommodate the bulk of the waste, if more rigorous sequencing, segregation, recycling, and size reduction of waste were practiced. A Site-Wide Radioactive Waste Management Program as required by DOE Order M 435.1-1 would be expected to facilitate such an effort. In any case, it is TDEC's expectation that the EMDF meet all pertinent regulations, unless officially waived and the waiver appropriately documented.	proposed location or the revised (D4 version) proposed locations do not meet. DOE agrees that there are two siting requirements under TSCA, and one siting requirement under NRC-based LLRW (identical to one of the two TSCA requirements) that the proposed locations do not meet as written. Regarding the NRC-based LLRW requirement at 10 CFR 61.50(a)(8) and TDEC 0400-20-11-.17(1)(h), justification has been given to TDEC and EPA that, while this is a relevant requirement, it is not appropriate and therefore it is not included in the ARARs tables. Regarding the TSCA requirement at 40 CFR 761.75(b)(3), a TSCA waiver is requested in the D4 document revision to two parts in that requirement; justification is given (See Chapter 4 in Appendix H). Under TSCA, provisions are made to receive waivers if suitable justification can be made (justification that demonstrates the proposed operation of the facility "*will not present an unreasonable risk of injury to health or the environment from PCBs when one or more of the requirements of paragraph (b) of this section are not met*". Of the two TSCA requirements, one (requiring a 50-ft buffer below the facility liner system to the high seasonal water table) is very routinely granted by EPA to sites around the country. Justification to receiving this waiver (based on equivalent protectiveness provided by a 10-ft buffer of specific hydraulic conductivity and based on waste characteristics expected regarding PCBs and no unreasonable risk to the environment and public from those PCBs by not meeting the requirement) is given in the document. In addition to that justification, evidence is given whereby the second part of the TSCA requirement (regarding the connection between ground water and surface water) is met through engineered features. Justification for receiving a TSCA waiver for the EBCV Site, from the topography requirement given at 40 CFR 761.75(b)(5), is given in the D4 RI/FS. See Section 4.2 of Appendix H. Regarding the distance to DOE boundaries, refer to the response to TDEC.S.3, which discusses the groundwater divide and ridge that is located between the public and proposed facility locations. The issue of building on existing terrain >30% in slope, in zones of upwelling groundwater, and over a stream might be mitigated by selecting a different site and/or reduction of landfill footprints. Some issues however will be present regardless of the location chosen within Bear Creek. Shallow water table, wetlands, seeps, springs, and complex geohydrology have been well documented all along Bear Creek Valley. The siting configuration presented in the D3 RI/FS was developed based on the criteria that consolidation of ORR Brownfield locations and providing adequate volume were high priority for a new landfill. The D4 will look at other alternatives that do not place such a high emphasis on these two factors. The density of seeps and springs in Bear Creek means that complete elimination of any underdrain systems for a new landfill is not feasible. Additionally, the TSCA waiver will be required for any of the presented siting options in the revised D4 RI/FS. The RI/FS identifies these possible waivers; however the final decision on waivers granted by regulators is solidified in the ROD. The RI/FS assumes the most rigorous sequencing possible; virtually all of the waste soils are used as fill in the document volume analysis. Segregation,

		recycling, and limited size reduction (to meet physical WAC) are performed at the generating project site, as discussed in the RI/FS (refer to Section 5.1.5). DOE agrees a site-wide plan could address management of waste in terms of the methods to reduce waste as mentioned in this comment. However, this is a programmatic issue and as such is not discussed in the RI/FS.
TDEC.G.004	To overcome limitations of the location proposed for the EMDF, DOE proposes various engineered barriers,[1] but fails to provide substantial technical justification of their equivalency over time in the risk assessment and funding for their maintenance and monitoring beyond 100 years. Due to the long-term hazards presented by uranium and other long-lived radioisotopes, NRC's view has been that engineered barriers (e.g., cap components, drains) can improve performance, but are expected to degrade over time and become ineffective. Consequently, State and NRC LLRW regulations rely heavily on the natural characteristics of a site to isolate wastes in the long-term and, thereby, protect the public health and environment. As stated in TDEC Rule 0400-11-.17(1)(a): *The primary emphasis in disposal site suitability is given to isolation of wastes, a matter having longterm impacts and to disposal site features that ensure that the long-term performance objectives of Rule 0400-20-11-.16 are met, as opposed to short-term convenience or benefits.* In this context, NRC's Performance Assessment Working Group in NUREG 1573 recommends any credit given for engineered barriers in performance assessments be specified and technically justified on a case-by-case basis. For periods over 500 years, NUREG 1573 advises it is unreasonable to assume any physical engineered barrier can be designed to function long enough to influence the eventual release of long-lived radionuclides.[2] While the risk assessment in the RI/FS assumes some engineered components degrade (synthetics),others retain their initial functionality indefinitely. For example, clay components in the cap are assumed to retain the same hydraulic conductivity for a million years and, thereby, their ability to restrict water infiltration into the waste to 0.43 inches/year. This despite the degradation of the geomembrane and drainage layer; challenges presented by the location; the potential for differential settlement of the cap; no funds allocated for maintenance past 100 years; and evidence that the hydraulic conductivity of compacted and amended clays can increase over relatively short periods. It is also unclear how the underdrain could be repaired, if it clogged or otherwise failed over the course of time and at what expense, given it would be covered by 2.5 million cubic yards of waste (a large proportion of which would have been created by adding clean soils to fill void space). All engineered barriers are subject to long-term degradation and are apt to require maintenance to remain protective of human health and the environment over the course of time. This needs to be reflected in the EMDF risk and performance assessments and taken into account in the cost analysis.	DOE's view coincides with NRC's view that engineered barriers can improve performance, but are expected to degrade over time and become ineffective. Modeling parameters (e.g., infiltration rate) have been adjusted in the D4 version to demonstrate this degradation over time. This degradation is partially accounted for in a two-fold increase in the hydraulic conductivity of the amended clay layer in the cap. Additionally, differential settlement of the cap is accounted for in an assumed erosion of the top layer of the cap and a decrease in the lateral drainage afforded by the drainage layer over the clay layers of the cap. Justification for the longevity assumed for various engineered features has been improved in the document (see Appendix H, Section 4.1.2). Regarding the cost to maintain the cap through the 1,000 year compliance period, these were included in the D3 RI/FS through the application of a Perpetual Care Fee. However, in response to other comments on this D3 document, DOE has evaluated the Perpetual Care Fee against a 1,000 year maintenance period (which includes two $7M repairs to the cap) The Present Worth of the perpetual care fee exceeded the cost of 1,000 years of maintenance, so the perpetual care fee was included in the lifecycle cost. Justification is given in the document (see Sections 6.2.2.4.8 and 7.2.2.3) regarding the longevity of the underdrain materials and its performance. Redundancy such as using both a blanket drain and trench drain is utilized to provide factors of safety for long-term underdrain function. Some clogging could occur over the period of compliance, but by oversizing the system, specifying the correct materials, incorporating multiple drain layers, and executing proper site prep before construction, even with diminished long-term function the drain system would be capable of managing the reduced water flow expected in the underdrain post-closure. Note that this engineered feature (underdrain) does not serve the purpose of "influenc(ing) the eventual release of long-lived radionuclides" as quoted by the commenter from NUREG 1573 and therefore is not categorized by that document as having a 500 year functioning period. The purpose of the underdrain is to maintain the groundwater table well below the waste/liner/buffer. By initially providing a hydraulic conductivity 4 to 5 orders of magnitude higher than surrounding materials it is highly unlikely that the underdrain would clog to the point that it would stop functioning during the compliance period (clogging to the point of non-functioning would require that

[1] As defined in NUREG 1573 an "*Engineered barrier is a man-made structure or devise designed to improve the land disposal facility's ability to meet the performance objectives of 10 CFR Part 61 described in Subpart C, meaning the ability to isolate and contain waste, to retard and minimize possible release of radionuclides to the environment*."

[2] U.S. Nuclear Regulatory Commission. NUREG- 1573: *A Performance Assessment Methodology for Low-Level Radioactive Waste Disposal Facilities: Recommendations of NRC's Performance Assessment Working Group*. October 2000. fhttp://pbadupws.nrc.gov/docs/ML0037/ML003770778.pd (Last visited 07/06/2015)

		the hydraulic conductivity in the underdrain decrease by at least 5 orders of magnitude, a phenomena that is highly unlikely to occur). The long-term implications of eventual failure of the underdrain system (and reduction in the thickness of the unsaturated zone) for EMDF performance are considered in sensitivity evaluations of the groundwater model suite (MODFLOW/MODPATH/MT3D) and the PATHRAE model. These evaluations are described in Appendix H Section 4.5
TDEC.G.005	This RI/FS maintains that many toxic, hazardous, and radioactive substances can be disposed in the proposed EMDF with no limits on concentration or restrictions on chemical form. The analysis is based on a risk assessment that uses limited exposure pathways for a resident located where the calculated future risk is minimal in comparison with that computed for a resident at many alternate locations in Bear Creek Valley. The risk assessment relies on assumptions of homogeneity and equilibria that result in best case scenarios for transport of most hazardous substances in ground water. The model does not incorporate degradation of key barrier layers in the facility, even over geologic time frames, resulting in unrealistic estimates of infiltration rates over thousands of years. The risk assessment does not consider other sources of contamination in Bear Creek Valley. The risk assessment presented in this document is therefore unusable to establish waste acceptance criteria that would protect human health and the environment. To the extent possible, the methodology described in "*Performance Assessment for the Class L-II Disposal Facility*" (ORNL, 1997, ORNL/TM-13401) should be used as a template for development of a credible WAC. TDEC recognizes this document as a competent radiological performance assessment for a Bear Creek Valley site.	DOE strongly disagrees that the RI/FS maintains that many toxic, hazardous, and radioactive substances can be disposed in the proposed facility without limits. DOE recognizes and indicates in Chapter 2 and again in Section 6.2.3 of the RI/FS that many wastes are not acceptable (excluded) from disposal in an on-site disposal facility. They are explicitly stated as being unacceptable for disposal in the facility in Chapter 2 and again in Section 6.2.3, and ARARs are included that address many of these exclusions. This includes any waste that is not acceptable in a RCRA subtitle C or TSCA hazardous waste landfill, with the exception of the radionuclides (because they are not addressed by RCRA or TSCA). Additionally, listed RCRA waste is noted in Chapter 2 as excluded from disposal in any on-site facility. For radionuclides, the modeling performed to determine preliminary analytic waste acceptance criteria (PreWAC) results in limits on more than half of the radionuclides that are modeled (in excess of 30 nuclides). The number of nuclides limited by this modeling for an ORR facility far outnumbers nuclides with limits imposed by any other disposal facility, federal or commercial, currently operating. Other limits imposed on nuclides for administrative reasons (e.g., transuranic limits or greater than class C limits) are summarized in a new flowchart and table (see Revised Section 6.2.3 of the main document). The D3 version of the RI/FS stated that these administrative limits would be specified in a WAC Attainment (or Compliance) Plan; however, the D4 now explicitly states these limits. Appropriate (or even any) numerical limits for some of the excluded contaminants may not be able to be mathematically determined through the modeling that is completed, which is based on the subsurface movement of the contaminants and factors-in the propensity of the contaminant to remain attached to soil particles as well as the radioactive decay of the contaminants, and time it takes for contaminants to reach a receptor. Exposure pathways examined in the model include a farmer drinking water from a well. This is by far the most conservative pathway analysis for a future receptor – it is not a "limited exposure pathway". This scenario is significantly more conservative than the proposed (EBCV) site allows as this site is located in a future DOE-controlled industrial use area, which restricts use of groundwater as a drinking source, and would allow a scenario whereby under CERCLA a worker is the receptor, with a much more limited exposure than is used in the RI/FS and for the determination of waste limits. In addition, more conservative assumptions for groundwater well location (closer to the cell and along the axis of maximum contaminant concentration) have been made for the risk assessment and PreWAC development in the D4 revision if the RIFS. Note the document (revisions in Appendix C) specifically discusses that the decision on how to treat Hg-contaminated debris lies first with the demolition

		contractor/project, and that treatment may occur via multiple different pathways that might also include off-site disposal or possibly on-site treatment by macroencapsulation. Thus the RI/FS addresses hazardous waste disposal under RCRA and TSCA statutes and proposes disposal of all hazardous waste per those requirements. Modeling to further limit hazardous waste disposal is not required by RCRA or TSCA rules. However, as this is a CERCLA facility, demonstration of meeting the NCP requirements (risk range and hazard index) must be completed. As well, within the 1000 year post-closure compliance period, the performance of the facility is demonstrated through modeling to meet applicable ambient water quality criteria in surface water and maximum concentration limits in possible drinking water. Meeting these limits through modeling imposes further limits, if necessary, on acceptance of nuclides and hazardous contaminants thus ensuring protection of the public and the environment. DOE disagrees that "best case" scenarios of transport were modeled. Overly conservative assumptions were made regarding the degradation of certain key barriers (geosynthetics failing at 100 years). DOE has agreed to incorporate more degradation of key barriers (clay and drainage layers) in combination with less conservative assumptions regarding geosynthetics that will result in a higher infiltration rate over times exceeding 1,000 years, with the understanding that modeling past 1,000 years carries a high degree of uncertainty. Plume maps of contaminant travel outside the on-site facility show very little interaction with other on-site sources. DOE O 435 requires an assessment of the combination of all sources in the area of an on-site disposal facility. This Composite Analysis (CA) has been completed and will be shared with regulators once the DOE review has been completed.
TDEC.G.006	TDEC acknowledges that there are very few, if any, preferable sites on the Oak Ridge Reservation to dispose of radioactive, hazardous, and toxic waste than the site selected in this RI/FS. TDEC does not believe that there is a site on the Oak Ridge Reservation that would accommodate a contiguous land-based waste disposal facility of the size DOE has proposed and meet TDEC rules that would apply to either a permitted radioactive waste disposal facility or a new commercial hazardous waste landfill. Likewise, we have not located an area with the requisite footprint that could be permitted under toxic waste rules. The basis for waivers of siting requirements must be founded on both a robust facility design and waste acceptance criteria that restricts the contaminant loading of any substances that are likely to persist past the expected life of the engineered features. As opposed to a good site, which has intrinsic characteristics that will provide a buffer to attenuate a future release and sufficient time to implement a corrective action, if necessary, the protectiveness of design and restrictions on waste inventory rely on human implementation and are subject to human error. In this RI/FS, the proposed waste acceptance criteria hardly limit the loading of toxic substances at all. More mercury would be allowed in the facility than was lost to the environment at Y-12, and an amount of depleted uranium comparable to that disposed in Bear Creek Burial grounds could be accepted. The strategy offered in this document leaves only the facility design as a single line of defense against future releases of contamination. This approach seems inconsistent with the approach DOE typically takes toward worker health and safety, nuclear criticality, compliance with environmental permits or any number of other issues that might involve risk to human health and the environment, where multiple lines of defense are preferred. TDEC	DOE agrees with TDEC, that the ORR has limited land that is suitable for use as a land disposal facility for radioactive and hazardous waste. However, of the limited land available, several sites are now identified in the D4 RI/FS (as opposed to only a single site that was presented in the D3 RI/FS) that are suitable for siting a land disposal facility. All require waivers to certain siting criteria, in particular the TSCA requirement to provide a 50 ft buffer between the base of the liner and the historical high water table, as well as a waiver to the site having a connection between groundwater and surface water. Engineering features described in the RI/FS provide constructed substitutes for these siting criteria (for example, underdrains will serve to break the contact between groundwater and surface water in the landfill footprint, and the hydrogeologic buffer provided, while not 50 feet in depth, will provide equal protection with a material having a higher hydraulic conductivity). More justification and description of these features, as well as support for their expected lifetimes, is given in the revised D4 document, Sections 4.1.and 4.2. DOE strongly disagrees with the statement in the comment that "more mercury would be allowed in the facility than was lost to the environment at Y-12." If this were true, EVERY waste lot accepted in the landfill would have a concentration of mercury in excess of 700 ppm. In fact, mercury containing waste debris and soils only accounts for a (conservatively) estimated 15% of all waste to be

	does not think this strategy toward waste disposal is acceptable.	disposed in a future on-site facility. Additionally, all mercury (D009) waste that is accepted in an on-site facility must meet RCRA disposal requirements – that is, if the waste demonstrates the toxicity characteristic (D009) it must be treated to meet land disposal restrictions stipulated under 40 CFR 268.40, 268.45, and 268.49. From characterization results on the Alpha-5 building (the most contaminated mercury-use facility), an estimated 95% of waste that exceeds a 247 ppm concentration of mercury would require treatment; and the characterization indicated that only 12% of the facility's structure would require that treatment (which if extrapolated to all mercury-use facility waste means that of the 15% of Hg suspect waste, only 1.8% would be considered mercury-contaminated (D009) and would require treatment). Furthermore, elemental mercury waste is excluded from the landfill (it is a liquid). Elemental mercury waste that has been treated (amalgamated) will be treated at off-site facilities and will therefore be disposed off-site as well. Likewise, a similar analysis could likely be made regarding the statement that the limits on depleted uranium would allow more source than is present in the Bear Creek Burial Grounds. The strategy offered in the RI/FS does NOT only rely on the facility design; a significant amount of work was completed to determine preliminary waste acceptance criteria, based on hypothetical future receptor exposure that greatly limits the contaminant inputs to the facility. The PreWAC were also limited to meet maximum concentration limits (MCLs) of contaminants in future drinking water, per the Safe Drinking Water Act. The revised version of the RI/FS (D4) also determines if PreWAC limits must be further lowered to ensure that appropriate ambient water quality criteria in surface water are met per the Clean Water Act to protect water resources and ecological receptors during the 1000 year post-closure compliance period. As a note, the analytic PreWAC that have been calculated in the D4 RI/FS are more stringent that those put forth in the D3 RI/FS. Additionally, the D4 RI/FS will include some administrative WAC limits such as greater than Class C limits (see Section 6.2.3).
TDEC.G.007	As opposed to the EMWMF, where DOE Orders are listed in the Record of Decision as "To Be Considered" guidance for on-site disposal of CERCLA generated waste, this RI/FS does not include DOE Order requirements. As DOE states it is obligated to abide by its orders, it is TDEC's position that DOE demonstrate that the proposed facility will comply with the requirements of DOE Order M 435.1-1 by completing a performance assessment, composite analysis, preliminary closure plan, and preliminary monitoring plan for the proposed facility. Based on a full review by DOE's Low-Level Waste Disposal Facility Federal Review Group, DOE should secure a disposal authorization statement, prior to decisions under CERCLA. TDEC anticipates that such a demonstration of compliance with the requirements of DOE Orders will prevent inconsistencies with the regulatory approach under CERCLA and address inadequacies in site selection and characterization and fate and transport modeling that remain problematic in this RI/FS.	DOE intends to obtain a DAS for this facility, with a preliminary DAS expected prior to the ROD. OREM intends to work with the appropriate review groups at both OR and DOE-HQ to achieve the preliminary DAS, and has begun this process. Moreover, as each requirement under DOE O 435.1 is completed, the resulting analysis will be provided to TDEC and EPA for review. However, DOE does not expect to receive full approval via a DAS by LFRG prior to submitting this RI/FS. As this RI/FS does not constitute a decision under CERCLA, but rather a compilation of information to support future decisions (e.g., the ROD), DOE does not interpret this comment as requiring a DAS prior to the RI/FS submittal. As a note, the fate and transport modeling conducted under the D4 RI/FS has been significantly modified to address comments put forth by both the state and EPA. Site selection has been broadened in the D4 RI/FS to include additional sites as well as a hybrid alternative (small site and off-site disposal combined). Regarding characterization, TDEC has in fact stated that further characterization is not warranted until a site is selected.
TDEC.G.008	The approach to waste disposal of future generated CERCLA waste mirrors the approach taken	The statement "*the Oak Ridge Reservation does not offer a potential disposal site*

	almost twenty years ago to authorize waste disposal at the EMWMF. Despite doubts that the EMWMF will ultimately afford long term protection of human health and the environment, TDEC does believe that the EMWMF has provided risk reduction in the near term. The facility provides isolation of contaminants that were migrating freely into the environment, both offsite and onsite near ORR boundaries. The EMWMF has also allowed for timely demolition of deteriorating structures that contained significant inventories of radioactive material and has provided a cost effective disposal option that has facilitated brownfield development. However, the Oak Ridge Reservation does not offer a potential disposal site that provides better intrinsic isolation of contamination from the environment or property boundaries than many of the areas where contaminated facilities or environmental media are currently located. This leads to questions about the degree of risk reduction that can be achieved by consolidation of contaminants in a single disposal facility on the ORR, particularly for contaminants that persist in the environment for centuries and millennia. At present, few areas remaining on the ORR are scheduled for clean-up to free release status, which leads to further questions about the degree of risk reduction that may be realized by relocation of contamination, even in the short term. DOE does not provide, either in this RI/FS or in CERCLA documentation that authorizes clean-up actions on the ORR, a comprehensive analysis of the reduction in risk that would be achieved through on-site disposal, including the potential for environmental releases during the CERCLA action and during transport to the disposal site. Consequently, TDEC suggests that attempting to build a facility that will meet all CERCLA goals and still accommodate all waste expected to eventually be generated from the demolition of legacy buildings and soil removal actions may be misguided. To justify the use of CERCLA to authorize on-site disposal of waste generated by on-site CERCLA actions, reduction in risk due to consolidation of waste and isolation of contamination should be used as a tool to screen candidate waste streams for on-site disposal. If, based on projected land-use, no significant reduction in either short term or long term risk can be clearly demonstrated for a CERCLA action that relocates the contamination to an on-site disposal facility, the waste generated by the proposed activity should not be a candidate for on-site disposal of CERCLA waste.	*that provides better intrinsic isolation of contamination from the environment or property boundaries than many of the areas where contaminated facilities or environmental media are currently located."* is true, but misleading. It is true, because essentially the locations, or "sites", of those contaminated ORR facilities and media as they currently exist are in the same or similar environmental situations as any site would be that might be selected for an on-site disposal facility on the ORR. Those facilities/media sit on the same subsurface formations, in the same valleys, and receive the same rainfall. However, DOE does not intend to place waste resulting from cleanup of those contaminated facilities/media at an on-site disposal location without first preparing the site, incorporating all the engineered features including natural materials (e.g. clay, siliceous rock) that transform a "site" into a land disposal facility, operating that facility under strict policies (including numerical waste limits) to maintain protection of human health and the environment, and closing that facility using man-made and natural materials that greatly limit the disposed waste from exposure to elements (most specifically rainfall) that would leach those contaminants into the environment in an unacceptable manner over extensive time frames. The statement is misleading, because without a doubt, engineered features of a land disposal facility – buffers, liners, cap, leachate collection and treatment, underdrains, etc., along with limitations on acceptance of contaminants at that facility as determined through detailed risk assessments, which ensure acceptable human health/environmental risks are met for an extraordinary amount of time – will afford a significant reduction in risk for the final disposal of contaminated facilities/media as compared to the "do nothing scenario" implied by this comment, a scenario in which facilities/media in their present state, left unchecked in the environment and exposed to elements over long periods of time, will deteriorate resulting in contaminant transport that will eventually present a much higher and unacceptable risk to public health and the environment. TDEC and EPA comments have questioned the results of the risk assessment completed in the D3 RI/FS, and DOE has responded with a revised D4 risk assessment incorporating requested changes, which ensures protection as required under CERCLA. The waste limits (PreWAC) set by this risk assessment are a "tool to screen candidate waste streams for on-site disposal" as indicated is needed in this comment. [Note that the RI/FS discusses the development of a WAC Attainment (Compliance) Plan that is developed through tri-party agreement if an on-site facility is the selected alternative. This document further describes and limits acceptance of waste in an on-site facility.] The statements in this comment seem to disregard the extensive investigations, studies, and subsequent decisions that have been made under CERCLA concerning the cleanup of ORR contaminated facilities and media that are independent of the situation analyzed by this RI/FS. This CERCLA Disposal RI/FS is concerned with the safe and compliant disposal of the majority of waste (but not all waste as is stated by this comment) resulting from remedial decisions that have been made outside of this document (waste exclusions are delineated in the RI/FS). Those recommendations and decisions on cleanup of individual facilities and media clearly indicate the path for risk reduction, in most of those cases, is demolition/remediation and disposal of the waste. This CERCLA

		investigation and future decision is concerned with where to dispose of that CUMULATIVE waste (not on an individual basis as is implied by this comment). The cumulative management of the majority of waste is the concern of the RI/FS. Three alternatives are assessed. The "No Action" alternative is, again, independent of the decisions to accomplish cleanup, but concerns the decision to NOT consider disposal of the waste in a cumulative manner. The No Action leaves disposal decisions to the individual projects. A result of this would most likely be disposal (by truck) to off-site commercial facilities, accomplished on a project-by-project basis. The remaining alternatives are off-site disposal (via a "cumulative", concerted approach) and on-site disposal (via a new landfill sited on the ORR). Multiple criteria under CERCLA are used to differentiate the alternatives, and select the most beneficial one. The most significant CERCLA criterion is protection of human health. The cumulative off-site disposal (Alternative) of this large volume of waste, in toto, in terms of short-term risk based on historical factual data, is estimated to result in numerous fatalities/injuries (due to waste transport) compared to on-site disposal. The No Action (individual sites shipping waste via truck in most cases) would result in at least four times as many fatalities. The On-site Alternative conducts a risk assessment that maintains the human health risk within the accepted cancer risk range: 1 in 10,000 to 1 in 1,000,000 chance of contracting cancer for a resident farmer (a hypothetical, future situation) through setting contaminant limitations on waste that may be disposed on-site. These results provide the most compelling and decisive comparison of the alternatives from a human health protection standpoint, which supports on-site disposal over off-site disposal (or no action). Other comparisons are made and have merit – for example, off-site arid disposal facilities offer better long-term risk reduction to human health than do on-site facilities – but do not compel selection of one alternative over the other as does "risk of multiple fatalities (single to double digits), projected based on historical and factual data" versus "risk of fractional cancer incidents, projected based on hypothetical future scenarios".
TDEC.G.009	Shallow groundwater and steep slopes are part of a formula for structural instability. An inadvertent intruder will not adequately evaluate this threat and the risk to future resident farmer(s) in event of structural failure needs to be evaluated. Further, Appendix H does not include an inadvertent intruder scenario and states it will be performed as part of DOE order compliance. The EMWMF intruder scenario assumes the intruder will not come in contact with material in steel boxes and considering steel deteriorates in the ground over time, this does not seem protective. An intruder scenario should also be included for EPA and TDEC review.	Structural failure is closely examined in final design. The terrain, slopes, and ability of the site and design to accommodate waste, and the capacity (height) of the waste capable of safely being disposed is evaluated and engineering calculations carried out to ensure stability. Stability in terms of earthquake analysis is determined as well in detailed design, and again, only acceptable risk is allowed. More detail will be added to the D4 RI/FS to explain how this issue is dealt with. The intruder analysis is required under DOE O 435.1 and will be completed; results will be provided to TDEC and EPA for review. Any results that indicate an adjustment to the Preliminary WAC is needed will be incorporated in the finalization of WAC. DOE agrees that intruder scenario will not consider the intruder to be stopped by steel box.

TDEC.G.010	There are a number of uncertainties that complicate the evaluation of the cost of various alternatives that are discussed in the document. Are there any total operating costs per cubic yard of waste disposed at EMWMF? If not then it's difficult to perform an objective evaluation for off-site disposal, transportation, volume reduction, etc.? With respect to the cost of volume reduction, the longer the delays on implementing the use of volume reduction equipment, then the lower the cost benefit analysis becomes for the use of volume reduction equipment.	Operating costs for the on-site alternative are included in the RI/FS cost evaluation. These costs are based on the current, actual costs for operation of the EMWMF (see Appendix I, Section 3.2.2.3 page I-25 where the operational cost, annual, for EMWMF was provided as the basis of the cost for the on-site alternative). Any cost of volume reduction that is analyzed in this RI/FS is for future waste and a future state or condition. The comment implies that purchase and use of VR equipment should be undertaken now, and factored into the analysis as existing equipment. Such an action is outside the scope of this document, and is a programmatic matter.
TDEC.G.011	Based on the information submitted in this document, TDEC does not agree that a waiver for placement of mercury in the disposal cell prior to treatment is appropriate. Thermal mercury treatment or macro encapsulation at the point of generation should be considered.	Treatment of mercury-contaminated waste (including thermal treatment) is discussed in Appendix C. It is not an option for selection in any alternative. A possible regulatory path (Corrective Action Management Unit) under RCRA is discussed in Appendix C.
TDEC.S.001	**Page ES1, Paragraph 3: …"** *The EMWMF RI/FS (DOE 1998) was the first document in the CERCLA process that led to the construction and operation of EMWMF. As a follow-on to that process, this RI/FS utilizes relevant information from the EMWMF RI/FS with revisions and updates to describe and analyze current conditions.***"** The EMWMF RI/FS discussed in paragraph 3 of this page did not anticipate a number of problems encountered during the construction and operation phases of EMWMF. Due to inadequate facilities to handle water at the EMWMF, as well as sloppy practices during the implementation of removal actions and during transport of waste to the facility, environmental releases of contaminants that had previously been isolated from the environment occurred. Groundwater levels beneath the EMWMF footprint proved higher than predicted and intruded into the facility buffer despite the installation of an underdrain system. The approach to waste characterization and waste acceptance was project specific and not readily amenable to regulatory audit. After approval of the EMWMF RI/FS, Proposed Plan, and Record of Decision, TDEC staff had the opportunity to review a number of groundwater studies done in Bear Creek Valley and to conduct a tracer test in the Maynardville Limestone adjacent to the EMWMF. Additional insight into the hydrogeology of Bear Creek Valley has raised additional concerns about the validity of fate and transport modeling used in the 1998 RI/FS, which was questioned in comment submitted by TDEC in a letter prior to RI/FS approval. Consequently, when scoping for an additional CERCLA waste disposal facility began, TDEC requested that the new facility have technically defensible waste acceptance criteria (WAC) that would allow easier verification of WAC attainment and that the facility not be built over a "blueline" stream, thus avoiding many problems with groundwater levels below the facility as well as a direct connection of the site to surface water. The regulatory framework that was used to authorize the EMWMF is used as a template for the EMDF, but key issues which were not satisfactorily resolved for the EMWMF during the past decade of operations have not been addressed in any revision of the document now under review.	A Lessons Learned section has been included in the conceptual design discussion in the RI/FS that addresses some of the issues brought up in this comment. Individual responses are provided here to comments: "..due to inadequate facilities to handle water at the EMWMF"…Leachate collection piping has been sized larger for the future on-site facility to accommodate higher leachate volumes. Upgrades at the EMWMF have occurred since its inception. The original RI/FS and ROD for the facility envisioned a much smaller operation and it was sized accordingly. Several water management components have been upgraded since that time, and upgrades continue to occur. For example, about 1 M gal of contact water tank capacity has been added; contact water ponds provide approximately 2 M gal of capacity; operational and equipment changes over the years have significantly accelerated the ability to fill, sample, and analyze contact water; and leachate storage tanks' capacities were increased by 60%. Finally, the future proposed facility will add an additional 1.5 M gal of leachate storage capacity. "..sloppy practices during the implementation of removal actions and during transport of waste to the facility, environmental releases of contaminants that had previously been isolated from the environment occurred ." This unsubstantiated statement does not refer to design, construction, operation or in fact any aspect of an on-site disposal facility. Additionally, DOE would like to note that, in terms of the ongoing cleanup efforts, with removal and disposal of millions of pounds of waste through demolition of contaminated facilities and remediation of contaminated media there will undoubtedly be some minor releases and/or incidents. DOE would make every effort to contain such a release, and if a release were to occur, it would be immediately dealt with. "Groundwater levels beneath the EMWMF footprint proved higher than predicted and intruded into the facility buffer ….". DOE disagrees. The issue referred to here is the presence of elevated pneumatic piezometer readings (located beneath the waste, in the footprint). The pressure being measured may indicate elevated groundwater levels or the waste mass being added to the footprint in this area. The situation continues to be monitored and additional data are being gathered to allow an informed assessment. The 2013 UCOR Report (*Engineering Feasibility*

		Plan for the Elevated Ground water Levels in the vicinity of PP-01, EMWMF) addresses these water level issues in great detail. The D3 RI/FS conceptual design combats the groundwater issues that EMWMF encountered in several new ways. The EMDF design includes a much more extensive underdrain system. The system is placed directly along the various paths of the NT valleys across the site to capture and drain shallow ground water and is installed during initial construction, not retrofitted after construction. The design employs greater use of structural fill to build up the site higher above the water table. The underdrain trenches create lowered base level elevations for the post-construction water table several feet below the existing NT valley floor elevations. The proposed site is located farther up Pine Ridge, reducing the effects of upgradient recharge. The upgradient trench/French drain system captures and diverts surface water runoff and topsoil stormflow zone water, further reducing recharge to the water table in upgradient areas. Particularly important in contrast to the EMWMF, the upper headwater valleys of the EMDF stream is completely cutoff from surface water recharge and supplanted with extensive underdrain features. The groundwater studies and the nature of TDEC's "additional insight into the hydrogeology" of BCV are not specifically described here by TDEC. But the well-developed karst flow system within the Maynardville Limestone and adjacent Copper Ridge Dolomite along the southern axis of BCV was well known and thoroughly documented in the BCV RI Report in 1997, prior to the 1999 EMWMF ROD (See Chapter 2, and Appendix C & D of the BCV RI Report for extensive details). By 1997, it was very clear that rapid ground water flow and commingling between Bear Creek surface water and Maynardville ground water (and related contaminant plumes) occurs. The 2001 TDEC tracer testing provided additional information to support the likelihood of rapid flow within the karst network that was clear by 1997. In fact, the Maynardville Limestone is not located adjacent to the EMWMF or other proposed EMDF sites in BCV. These site footprints are separated from the Maynardville by the outcrop belts of the Dismal Gap (Maryville) and Nolichucky Shale formations where limestone karst features are absent. These formations are several hundred feet across and composed of predominantly clastic rocks which provide a "buffer" zone between the footprints and the Maynardville karst, wherein ground water contaminant migration is likely to be attenuated and considerably slower. The hydraulic conductivity of fracture networks in these formations have been demonstrated to be typically one or more orders of magnitude less than hydraulic conductivities in the Maynardville (See for example Table E.1 in the ORNL Performance Assessment for the WBCV LLWDDD site). DOE agrees that fate and transport modeling of BCV is difficult but urges TDEC to work with DOE by providing more specific comments and recommendations related to modifications and improvements to the current suite of models to improve the accuracy and realism of modeling results. The fate and transport modeling conducted in the D3 RI/FS has been updated and refined in the D4 RI/FS, to reflect the potential for higher rates of infiltration and contaminant migration through the vadose and saturated zones. These modifications, as well as other modifications to assumptions, have resulted in a more stringent PreWAC, and address the concerns raised by this comment and

		similar specific TDEC comments. The D4 RI/FS review of tracer tests in Section 2.13.5 of Appendix E has been revised to more clearly define the differences between ground water flow and contaminant transport within the predominantly clastic fractured rocks that underlay most of BCV versus that within the karst flow system of the Maynardville Limestone and Copper Ridge Dolomite. "The approach to waste characterization and waste acceptance was project specific and not readily amenable to regulatory audit." And ".. that would allow easier verification of WAC attainment .." Verification of WAC compliance is outside the scope of the RI/FS, but is discussed in the document as it is part of the development of a WAC Attainment (Compliance) Plan, which is to be developed as a tri-party primary document. While individuals at TDEC have indicated vocal and written concern over constructing an on-site facility over a blue line stream and requested more justification for doing so, TDEC as an entity has not in writing requested that it "not be built over a blueline stream". The Phase I investigation of the EMDF Site 5 location next to the EMWMF was coordinated with TDEC staff and intended to ameliorate any concerns that TDEC (and EPA) might have concerning Site 5 as a viable location. TDEC approval of and comments on the work plan (TDEC letter dated November 27, 2013) for that investigation did not indicate that the site would be rejected on the basis of its location across the upper NT-3 valley or make any recommendations for avoiding Site 5 on the basis of its footprint across a "blue line" stream. DOE would certainly have not implemented the Phase I investigation if there had been indications from TDEC (or EPA) that Site 5 was inappropriate. It should be made clear that TDEC's assertion in this comment that the site not be located across a "blueline" stream contradicts with their written approval for conducting the Phase I investigation. "..key issues which were not satisfactorily resolved for the EMWMF during the past decade of operations have not been addressed in any revision of the document now under review". DOE feels that the revision of the RI/FS (D4 version) to be submitted based on these comments and those received from EPA on the D3 version of the RI/FS will satisfactorily address the issues raised (including site hydrology issues, PreWAC limits, and lessons learned), and additionally the D4 version offers additional sites for consideration as well as a hybrid alternative that combines a small on-site facility with off-site disposal.
TDEC.S.002	**Page ES1, Paragraph 3:"** *As a follow-on to that process, this RI/FS utilizes relevant information from the EMWMF RI/FS with revisions and updates to describe and analyze current conditions. Consistent with the EMWMF RI/FS, this RI/FS analyzes three alternatives:* **"** Despite some analysis of combined off-site and on-site disposal options (see comments on section 5.4), the three alternatives presented in this document do not provide the flexibility needed to evaluate optimum waste disposal options for future waste generated by CERCLA actions in Oak Ridge. There is little justification for this choice of alternatives, other than consistency with the EMWMF RI/FS, and a no-action alternative does not provide a baseline risk that can serve as a comparison for risk reduction. The choice of alternatives seems to	The revised RI/FS includes several new alternatives, including (1) additional Bear Creek Valley on-site location at West BCV; (2) additional dual site option, two footprints, one in East Bear Creek Valley to the west of EMWMF and one west of the Bear Creek Burial Grounds, and (3) a Hybrid Alternative that includes a small on-site facility (site directly west of EMWMF) and off-site disposal of the remaining CERCLA waste. EMWMF modeling is continuing to be updated. Through the water FFS, a path to update the EMWMF ARARs is being pursued.

	reflect the assumption that another waste disposal facility similar to the EMWMF can be legally sited under CERCLA on the Oak Ridge Reservation (ORR) without significantly more stringent restrictions on waste acceptance than those in place for the current facility. Reassessment of performance modeling and an evaluation of the attainment of applicable or relevant and appropriate requirements (ARARs) at EMWMF are overdue, and should be completed before the FFA parties consider authorization of a similar waste disposal facility. Suggestions for additional remedial alternatives are given in comments on page ES3.	
TDEC.S.003	**Page ES1, Paragraph 4:** *"Unlike a typical remediation project, the purpose of this RI/FS is not to evaluate alternatives for cleaning up a contaminated site. The purpose of this RI/FS is to develop, screen, and evaluate the alternatives for waste disposal against CERCLA criteria designed to address statutory requirements and feasibility. The RI/FS provides support for an informed selection decision about disposal of CERCLA waste."* A better discussion of how this RI/FS is consistent with the purpose of the remedy selection process (40 CFR 300.430 (a)(1)) is needed. A baseline risk assessment is not performed, and little is presented in the way of argument that provides information on the actual reduction of risk to human health and the environment by the various alternatives considered. A reader well-acquainted with legacy contamination in Oak Ridge might heuristically infer some significant degree of short-term risk reduction for the on-site disposal alternative and considerable long-term risk reduction for the off-site option, as discussed in Chapter 3. However, the use of CERCLA to authorize waste disposal as proposed in this RI/FS is justified primarily by the largely unstated assumption that consolidation of waste generated by demolition of contaminated facilities into an engineered disposal facility will lead to substantial risk reduction. In cases where buildings are contaminated with hazardous materials that are mobile but not persistent in the environment, a qualitative argument is adequate support for this assumption. To make the case more generally, as is implied in this document, would require a more facility specific comparison of alternatives. The rationale behind the general assumption that consolidation will necessarily lead to risk reduction is undercut further in Oak Ridge by: (1) no current proposed plans for consolidation of significant quantities of contaminated environmental media associated with, or proximal to, the ORR facilities that will generate the bulk of candidate waste streams, (2) the lack of sites on the ORR with geologic and hydrologic characteristics appropriate for long-term isolation of contamination, and (3) no location on the ORR that is not close to property boundaries, leaving little buffer area between the disposal facility and the public, a problem exacerbated by ongoing plans to release additional properties currently held by the federal government.	Consolidation of waste disposal (compared with no consolidation of waste disposal) will lead to timelier cleanup at a reduced cost, with likely risk reduction in the process. This assumption is the result of a comparison between the "No Action", (e.g., no consolidation of CERCLA waste disposal) and ALL action alternatives. The "No Action" alternative leaves decisions on how/where to dispose of a project's CERCLA waste to the individual project/contractor completing that single cleanup (e.g., one building or a small group of buildings). This will then be repeated by all projects (some 100 demolition and remediation projects). This leads to great inefficiencies through repetition - more expenses through repetition and individual contracting and trucking of waste as opposed to transporting by rail or disposing on-site; increased likelihood of waste storage as opposed to disposal; greatly increased short-term risk involved in packaging and transporting waste to off-site disposal by truck when compared to on-site disposal or consolidated rail movement; due to higher costs, extension of cleanup schedules for projects as well as the entire ORR (on the order of decades) which in itself poses greater risk to both human health and the environment as well as to the cleanup completion as a whole; and greatly increased costs due to all of the above. In addition to more timely cleanup and reduced costs, Action Alternatives can offer projects/contractors reduced risk over No Action by providing an existing disposal route, whether that be on-site disposal (landfill) or off-site disposal (consolidated rail) that is readily implementable as opposed to projects/contractors faced with meeting transportation requirements individually, arranging transportation and disposal (likely by trucking that poses higher risk to the public and environment), or storing waste for possibly long time periods (again, posing higher risk to public and environment over disposal). Given the above underlying assumption (words which are added to the revised RI/FS in Chapter 3), and its conclusion that an Action Alternative is needed, versus the No Action Alternative, the next step, and the focus of the RI/FS, is to assess each alternative in its ability to meet CERCLA criteria, and then to compare the alternatives to each other, to support the selection of the alternative that best fulfills the nine CERCLA criteria. While the reviewed version of the RI/FS (D3 version) selected an alternative, this revision to be submitted (D4 version) will not select an alternative, but will complete the assessment described. This comment states that a baseline risk assessment is not completed. This is correct, and a baseline risk assessment (which is the risk posed by "no action") cannot be completed as defined under CERCLA because the waste has not been generated yet and characterization is very limited, and the full implications of the risk (inability to complete cleanup on the ORR, excessive storage of waste, reactions of states to thousands of truck transfers of waste through their cities, etc)

		cannot be quantified. Instead, a risk assessment is completed for on-site disposal (assumed waste placement in an on-site facility – and the risk posed to human health & environment short- and long-term which is based on meeting Remedial Action Objectives) to determine limits on future waste to be expected from a containment perspective, and off-site disposal (transport of waste for disposal). These "preliminary" risk assessments allow for comparison of the alternatives from a human health and environment protection standpoint. Lastly, this comment states that the rationale leading to this RI/FS is further unsupported because: (1) "(DOE has) *no current proposed plans for consolidation of significant quantities of contaminated environmental media associated with, or proximal to, the ORR facilities that will generated the bulk of candidate waste streams."* (2) "(there is) *lack of sites on the ORR with geologic and hydrologic characteristics appropriate for long-term isolation of contamination*" and (3) "(there is) *no location on the ORR that is not close to property boundaries, leaving little buffer area between the disposal facility and the public, a problem exacerbated by ongoing plans to release additional properties currently held by the federal government.*" Regarding (1) above, DOE has current plans (regulatory approved decision documents under CERCLA) to address remediation/consolidation of some contaminated media; those media that are not yet addressed by decision documents are associated with projects (scheduled and funded) in the OREM baseline to develop the appropriate documents and decisions under CERCLA, and are accompanied by projects (scheduled and funded) that have assumptions as to the remedial action to be deployed. Those resulting wastes are considered in the RI/FS for disposal, and yes, there is uncertainty associated with the waste volumes to be generated. That is one reason DOE has proposed in this RI/FS a positive uncertainty in waste volumes to be generated in the future, so that if assumptions result in underestimations of waste, this RI/FS has that additional waste volume accounted for (as opposed to comments that suggest the uncertainty is too high or not necessary). Regarding (2) above, DOE disagrees that there is a lack of sites on the ORR that could effectively isolate waste long-term. DOE has acknowledged and continues to acknowledge that there is no perfect site for long-term isolation, but with engineered features and limited waste acceptance criteria, the several sites proposed in the revised RI/FS (only EBCV site is modeled and in fact demonstrates attainment of CERCLA risk ranges well into the future – other sites included in the RI/FS are expected, if modeled, to demonstrate with acceptable waste acceptance criteria, attainment of CERCLA risk ranges as well) can successfully contain CERCLA waste for the long-term. Short-term containment is provided through engineered features whose longevity is supported in the document. (see Section 7.2.2.3) In answer to (3) above DOE agrees that the proposed sites in Bear Creek Valley appear to be close to the DOE boundary, and therefore close to the public. However, what this comment fails to note is that Pine Ridge sits between the sites and the public, and is a groundwater divide, meaning the groundwater on the DOE side and location of the proposed disposal facility flows away from the DOE boundary and the public, and toward the interior of DOE property. Additionally,

		the comment fails to note that those properties or areas in Bear Creek Valley slated for release to the public, if deemed suitable for waste disposal on-site, would be re-evaluated for future use and would require a re-designation of future land useage.
TDEC.S.004	**Page ES2, Paragraph 1: "***The remedial action objectives (RAOs) for alternatives evaluated in this RI/FS are:* ☐*Prevent direct or indirect exposure of a human receptor to future-generated CERCLA waste that exceeds a human health risk of 10-4 to 10-6 Excess Lifetime Cancer Risk (ELCR) or Hazard Index (HI) of 1 to 3.* ☐*Prevent releases of future-generated CERCLA waste, or waste constituents that exceed a human health risk of 10-4 to 10-6 ELCR or an HI of 1 to 3, or that do not meet applicable or relevant and appropriate requirements (ARARs) for environmental media. This is accomplished through compliance with chemical specific ARARs, maximum concentration limits in waters that are current or potential sources of drinking water considering site-specific background levels, or risk based levels for chemicals without ARARs.* ☐*Prevent ecological exposure to future-generated CERCLA waste.* ☐*Facilitate timely cleanup of ORR and associated facilities"* The data and analyses presented in this document are not sufficient to assure that the remedial action objectives (RAOs) listed in bullets 2 and 3 on this page and stated again in Chapter 4 will be met. Human exposure levels may be kept acceptably low, but this is contingent on institutional controls and development of protective waste acceptance limits. Future impacts to water resources cannot be evaluated with the approach used in this document, which is to assess risk to a hypothetical resident using groundwater and surface water pathways. The receptor is placed at a distance 460 meters from the facility oblique to the direction of flow paths that would originate from the facility. Maximum concentration limits in waters that are current or potential sources of drinking water are evaluated only at this location. Despite the inevitability of future releases from the proposed facility to both surface water and groundwater, the requirements of neither the Safe Drinking Water Act nor the Clean Water Act (e.g., general water quality criteria, as given in chapter 0400-40-03 of Tennessee Rules) are listed as chemical specific ARARs. In addition, this RI/FS predicts (see tables H-6 and H- 7) that peak concentrations in Bear Creek of a number of contaminants of principle concern will, using limits imposed by the pre-WAC established by the risk assessment in Appendix H, exceed either ambient water quality criteria or derived concentration standards that implement *DOE Order (O) 458.1, Radiation Protection of the Public and the Environment*. While TDEC challenges many of the assumptions used in the risk analysis, TDEC does agree with the RI/FS that the preferred alternative will not protect water resources. More detailed comments on evaluation of impacts to water quality can be found in comments on Appendices E, G, and H. The fourth bullet is very general and does not necessarily imply reduction of risk to either human health or the environment. While not inconsistent with the goals of CERCLA, an evaluation of risk reduction specific to the generation and disposal of each candidate waste stream would be necessary to show that this was an appropriate objective in every case where CERCLA waste might be generated.	The D4 RI/FS demonstrates protection of water resources and ecological protection by comparing predicted surface water concentrations of contaminants to the most limiting Ambient Water Quality Criteria (AWQC), and adjusting calculated preliminary WAC (PreWAC) to maintain SW concentrations at or below the AWQC for the compliance period. Additionally, the RAOs have been updated in the revised document to reflect the goal of meeting AWQC. AWQC are promulgated through the Clean Water Act as given in chapter 0400-40-03 of Tennessee Rules, which is referenced as part of the RAO. The Safe Drinking Water Act (SDWA) is indirectly referenced in the RAO (e.g., "compliance with maximum concentration limits in water that are current or potential sources of drinking water...", these MCLs are promulgated through the SDWA). The revised RAO clarifies this. The surface water concentrations given in Table H-6 and H-7 are predictions based on an assumed starting value of 1 Ci/m3 of a contaminant in the landfill. This is NOT the allowable (PreWAC) limit of the contaminant, but rather just a starting value to then calculate the limit. Therefore, the table lists surface water concentrations corresponding to this basis (1 Ci/m3). Those values would be adjusted once the PreWAC limit is determined. This will be clarified in the revised document. For the D4 revision, the model output based on the assumed initial concentration has been removed from the body of Appendix H and is part of Attachment B (the values, as a basis only, will likely be moved to a new attachment). The 4^{th} RAO has been deleted.

TDEC.S.005	**Page ES2, Paragraph 3 et seq: "*WASTE VOLUMES AND CHARACTERIZATION*"** The RI/FS appears to have done a good job of establishing an upper bound for the potential volume of waste to be disposed on-site. However, as stated above, the preferred alternative fails to protect water resources. To form an adequate basis for an alternative that is consistent with all the goals of CERCLA, an estimate should be established for the most probable and minimum waste volumes to be disposed on-site consistent with a more defensible set of waste acceptance criteria and aggressive waste minimization and volume reduction efforts. An attempt to better quantify the uncertainty in waste volume estimate would also be helpful. More detailed discussion of waste volume estimates can be found in comments on Appendices A and B.	As stated in responses above, the protection of water resources in the revised RI/FS is demonstrated through meeting appropriate AWQC in surface waters, through modeling. Further modifications to the parameters in the fate and transport modeling, and assumptions (e.g., dilution field used) have been made and resultant PreWAC are more stringent than D3 RI/FS results. An aggressive approach was taken to waste minimization in that the waste soils were used almost 100% as debris waste fill. This is consistent between the D3 and revised D4 RI/FS versions. Waste volume uncertainty of 25% is justified through a detailed uncertainty analysis included in a new Table 2-5, in Chapter 2. The low and high-end waste volume estimates in this analysis bound the 2.2 M CY capacity defined in both the D3 RI/FS and D4 version of the document.
TDEC.S.006	**Page ES3, Paragraph 4:** "*Demolition of several large facilities at the Y-12 National Security Complex will result in large volumes of mercury-contaminated debris. This debris is assumed to be treated and disposed by macroencapsulation within EMDF, as part of the On-site Disposal Alternative, or transported off-site for compliant treatment/disposal in the Off-site Disposal Alternative.*" This requires waiver of Land Disposal Restriction rules, which has not been granted at this time. This RI/FS does not present sufficient information to evaluate the merits of such a waiver. Thus, a more appropriate evaluation of alternatives would include an alternative with on-site disposal and another with off-site disposal for this candidate waste.	The possibility of conducting in-cell macroencapsulation (ICM) of Hg-contaminated debris will be revised in the D4 version of the RI/FS. It is presented as an possibility; however, the decisions on how a demolition project chooses to treat it's Hg-contaminated debris is outside of this RI/FS, and so the disposal alternatives analyzed do not consider ICM. ICM is discussed as an option in Appendix C and appropriate regulatory pathway is designating the facility as a Corrective Action Management Unit (CAMU), also discussed in Appendix C. As requested by EPA and TDEC in-cell macroencapsulation is not presented in this RI/FS as part of an alternative.
TDEC.S.007	**Page ES3, Paragraph 4: "*Remedial Alternatives*"** As stated in other comments, TDEC does not agree that this document establishes either a technical or regulatory basis for on-site disposal. In conjunction with establishing this basis, other alternatives should be evaluated and carried forward. These include (1) an on-site low level radioactive waste (LLRW) disposal facility authorized under DOE Orders, with off-site disposition of TSCA and RCRA mixed waste, (2) on-site disposal of mixed TSCA/LLRW waste authorized and off-site disposition of RCRA mixed waste, (3) disposal at smaller sites and at sites further west in Bear Creek Valley, and (4) alternatives that consider aggressive steps toward waste minimization and volume reduction. Several of these alternatives were considered in this RI/FS, but were eliminated in preliminary screening due to costs. Given that this document does not provide evidence that the preferred alternative can meet other goals of CERCLA, cost alone is not an adequate reason for eliminating alternatives.	The revised RIFS considers three onsite alternatives encompassing three possible sites in Bear Creek Valley. Additionally, the revised RI/FS does include a hybrid alternative that considers on-site disposal in a smaller footprint landfill in combination with disposal of the remainder of waste through off-site commercial facilities. Because of the very limited size of the on-site facility, the on-site disposal is combined with volume reduction in this alternative. Other on-site alternatives evaluated in the revised RI/FS include a multiple site (Dual Site) option that includes two small footprint landfills, as well as a full size (up to 2.8 M cubic yard) landfill to be located in West Bear Creek Valley (in a Greenfield). DOE does not at this time feel a LLW/Mixed waste facility should be developed solely under DOE authorization because the waste projected to require disposal includes TSCA and RCRA waste contaminants under the authority of EPA and the state. As waste that will result from future CERCLA actions, the disposal of this waste should remain under CERCLA authority and DOE believes this future waste can be compliantly disposed of on-site.
TDEC.S.008	**Page ES4, Paragraph 2:** "*By design, the analytic WAC of a new facility would ensure risk to future receptors would not exceed risk criteria (10-5 ELCR or an HI of 1 in the first 1,000 years and maximum concentration limits in current or potential drinking water). This RI/FS provides results of fate and transport analysis which demonstrate that analytic preliminary waste acceptance criteria (PreWAC) for the proposed EMDF would meet applicable risk and dose criteria and be protective.*" The fate and transport analysis presented in this document is flawed in many respects. The limitations of the models used to predict fate and transport, and the consequent potential for underestimation of future contamination levels in ground water	The D4 RIFS contains substantial revisions to exposure and modeling assumptions. In particular, the location of drinking water wells is now assumed to be along the predicted axis of maximum concentration with the contaminant plume, and largely outside of the influence of other BCV sources of contamination. PATHRAE model parameterization of the vadose zone has been extensively revised. These improvements to the modeling approach are documented in revisions to Appendix H.

	and surface water will be addressed in comments on Appendix H. More generally, as noted in Chapter 3 of this document with respect to long term risk posed by the proposed facility, there is currently considerable uncertainty in any estimate of values for a number of parameters that control future risk. Typical ways to minimize impacts of this uncertainty for fate and transport of contaminants in water would be to construct scenarios that assured safe drinking water limits and ambient water quality criteria were evaluated at all locations potentially impacted by releases from the facility, and to assume conservative values for key parameters controlling contaminant migration. In the analysis presented here, risk and drinking water limits are evaluated with respect to a resident at one location in Bear Creek Valley 460 meters from the facility boundary and generally away from areas that would be more contaminated by releases from the facility. In the application of the models, some parameters key to estimating the future release and migration of radioactive and hazardous constituents have been assigned values that would be considered conservative, as listed on page 82 of Appendix H, but other assumptions and estimates of parameter values lead to lack of conservatism. This appears to result in inconsistent levels of conservatism**,** or lack thereof, for different radioactive and hazardous constituents. If future waste disposal is to be authorized under CERCLA, modeling must be revisited to establish the veracity of the claim made for the analytic pre-WAC and to establish a defensible approach that can be used to develop final waste acceptance criteria. In the CERCLA decision process for authorization of a new on-site disposal facility, TDEC sees two potential roles for assessment of risk to a future resident. An assessment of risk to a receptor drinking from a groundwater source adjacent to the proposed landfill could set limits for waste acceptance that would prevent any further degradation of groundwater in Bear Creek Valley due to future releases from the proposed facility. In addition, an analysis of risk to a resident at some location in Bear Creek Valley that integrates risks from all existing and proposed sources of contamination in the valley would allow an evaluation of the incremental risk that the proposed landfill might add to the risk from the aggregate of sources in the valley. This approach would be consistent with DOE's requirements for performance assessment and composite analysis, which serve similar functions in evaluating the feasibility of radioactive waste disposal at a site. The analysis presented in this RI/FS evaluates risk to a future resident due to contamination from the proposed facility only, but does so at a location where groundwater and surface water are impacted by other sources of contamination in Bear Creek Valley. The risk assessment neglects these additional impacts, and thus serves only as an inadvertent source of confusion rather than as a tool for responsible decision making.	Consideration of risk to human health and water resources resulting from multiple Bear Creek Valley contaminant sources, within the 1000 year post-closure compliance period, will be provided in a Composite Analysis developed to meet the requirements of DOE Order 435.1.
TDEC.S.009	**Page ES-5, Volume Reduction, Paragraph 2, 1st Sentence:** Is a detailed analysis of the claim "*For the On-site Disposal Alternative, VR processing of suitable waste debris was determined to be a net expense; that is, the construction and operation of a VR facility cost more to implement than the savings it would achieve through reducing volume and conserving air space in the EMDF (e.g., building a smaller facility)*" available for review? Also, would not volume reduction be considered a best management practice, as it would ultimately reduce the size of the landfill?	Detailed analysis of VR is included in Appendix B of this document. Many types of VR are discussed in the document, and Appendix B includes explanations of current VR efforts as a best management practice. Most VR efforts are performed, but are performed outside of this CERCLA decision (e.g., performed by demolition contractors, or performed in planning efforts – such as sequencing of waste).
TDEC.S.010	**Page ES5, Paragraph 4:** "*Key assumptions regarding responsibilities of the waste generators are common to both the On- and Off-site Disposal Alternatives. The waste generators are considered to be responsible for removal of waste during cleanup actions; waste characterization and treatment as necessary to meet disposal facility WAC; and local transport to the EMDF (On-site Disposal Alternative) or the ETTP transfer facility (Off-site Disposal Alternative).*"	Costs for characterization for disposal on-site or off-site are dependent on the waste lot, volume of waste, and packaging required to name a few parameters. Ultimately, some facility D&D will require more characterization to dispose of on-site versus off-site, and some may require less. The RI/FS made the assumption that these costs are, overall, similar for on- versus off-site disposal for the program as a whole. This was verified in discussions with the current

	In some cases, this assumption may result in significant errors in total cost comparisons. For example, the K-25 building, which contributed a large volume of waste to the EMWMF, had characterization costs that were of the same order as the disposal costs. Costs for characterization for on-site disposal were driven by the mobility of key contaminants in water and an attempt by the FFA parties to minimize the potential impacts on both EMWMF operations and concentrations of radioactive constituents in ongoing releases of wastewater to Bear Creek, as well as possible impacts from future releases at the facility. Characterization costs were presumably much higher than characterization costs would have been for off-site disposal at a facility in an arid environment. A more holistic approach to cost comparison between off-site and on-site is needed. For example, total cost comparisons that include generator costs for classes of waste with similar contaminants of concern in similar media originating from similar remedial actions would offer more insight than the limited cost analysis performed here.	executing demolition contractor, who reiterated that at the time of demoltion/remediation these costs are re-examined, and if disposal off-site with associated characterization costs are less than characterization costs for on-site disposal (which may be the case for small, individual waste lots) then off-site disposal is selected. Regardless, any differences in characterization costs would be dwarfed by the overall cost of disposing of the estimated waste volume by off-site means versus on-site means. Finally, the granularity of data that would differentiate some of these costs, for small volumes of waste in which it might be more significant, is not available at this time.
TDEC.S.011	**Page ES5, Paragraph 6:** "*Thus VR is included as part of the Off-site Disposal Alternative for Option 1 only (primarily disposal at NNSS). Option 2, Energy Solutions disposal, uses transport containers that are limited by weight rather than volume, thus VR is not cost effective for Option 2.*" This would seem to assume that almost all waste generated in future CERCLA actions on the ORR will be sufficiently dense to be weight limited in transport containers. This statement may be true, but needs more justification, as potential waste types listed in Section 2.1.2 of this document includes waste with highly variable densities (e.g. structural steel versus personal protective equipment).	Waste is only broken down into "debris" and "soil". As such, an average density for debris is assumed that takes into account varying densities of various materials. Wording will be modified to note this.
TDEC.S.012	**Page ES6, Paragraph 1**: "In the CERCLA process, alternatives for remedial action are *assessed against nine evaluation criteria, which include two threshold criteria, five primary balancing criteria, and two modifying criteria. All three alternatives evaluated would meet the two threshold criteria of overall protection of human health and the environment and compliance with ARARs"*. TDEC disagrees with the ARAR selection in Appendix G. TDEC also thinks the approach to fate and transport modeling in Appendix H should be revisited. However, the modeling results do suggest that, if the only limits on waste acceptance were determined by fate and transport modeling to the hypothetical receptor identified in section 2.3 of Appendix H, the proposed facility would likely contaminate groundwater above safe drinking water limits over much of the area within a few hundred meters of the waste. These topics will be addressed in more detail in comments on Appendices G and H.	Significant modifications have been made to modeling and PreWAC determination in the revised RI/FS. See responses to specific comments on Appendix H. The D4 RI/FS demonstrates protection of water resources and ecological protection, within the 1000 year compliance period, by comparing predicted surface water concentrations of contaminants to the most limiting Ambient Water Quality Criteria (AWQC), and adjusting calculated preliminary WAC (PreWAC) to maintain SW concentrations at or below the AWQC. Additionally, the RAOs have been updated in the revised document to reflect the goal of meeting AWQC. AWQC are promulgated through the Clean Water Act as given in chapter 0400-40-03 of Tennessee Rules, which is referenced as part of the RAO. The Safe Drinking Water Act (SDWA) is indirectly referenced in the RAO (e.g., "compliance with maximum concentration limits in water that are current or potential sources of drinking water", these MCLs are promulgated through the SDWA). The revised RAO clarifies this. Regarding groundwater concentrations within a few hundred meters of the landfill, ARARs require groundwater monitoring at predetermined Points of Compliance, located upgradient and downgradient of the landfill to monitor for leaking. ARARs associated with this requirement (Subpart F of RCRA) also require statistical analysis of the monitoring results, and corrective action if the need is indicated.
TDEC.S.013	**Page ES6, Paragraph 1:** "*For the On-site Disposal Alternative, two waivers would be requested:*	EPA comments have directed a waiver request to 40 CFR 761.75(b)(3) be a TSCA waiver request, rather than a CERCLA waiver request, with two waivers

	1. A waiver of one hydrologic condition ARAR would be requested on the basis of equivalent protectiveness provided by the landfill design. *2. A waiver from Land Disposal Restrictions prohibition on placement of untreated waste in the landfill for the purpose of treatment would be requested (as an interim measure)."* The information presented in support of the waiver of a TSCA rule 40 CFR 761.75(b)(3) in this document (pages 9 and 10 of Appendix G) is not adequate grounds for a waiver based on equivalent performance as specified in 40 CFR Part 300.430(f)(1)(ii)(C). The portion of the argument relevant to the water table has merit, but the underdrain does not prevent a direct hydraulic connection to surface water, as groundwater from the site can flow directly under gravitational forces through the drain into a tributary to Bear Creek. Limits on waste acceptance determined by the expected life of design features, the anticipated degradation rate of toxic substances in the landfill, and a technically defensible approach to fate and transport would also be necessary to achieve an equivalent protectiveness. The argument for the waiver from land disposal restrictions is also incomplete. As with other chemical species that have relatively high affinity for adsorption to soils, fate and transport modeling of mercury migration through the vadose zone yields travel times to the water table that are thousands to millions of years. Failures in the landfill design that would result in preferential migration pathways into the environment are likely before the times calculated by the model for contaminants to enter either groundwater or surface water. In addition to modeling fate and transport with more realistic estimates of travel times, details on the final waste form are needed to evaluate realistic scenarios of elemental mercury in equipment or concrete debris that could be inadvertently disposed of in the waste cell. These scenarios should be examined, and the costs of characterization and treatment necessary to prevent elemental mercury in debris from entering the proposed facility should be included in the assessment of cost. Based on our review of the regulatory foundation for the preferred alternative (see comments on Appendix G), a number of additional waivers may be required to provide a proper legal framework for on-site disposal of CERCLA waste. This document is itself inconsistent on the issue, with other potential rules that may require waivers listed on page 32 of Appendix D.	requested, (1) to the 50 ft buffer and (2) to the hydraulic connection of site with standing or flowing surface water. More justification for granting these waivers is included in the RI/FS revision, Appendix G, Section 4.1. DOE continues to support that an underdrain will in part fulfill the justification of a waiver to the TSCA requirement that states the site shall not have a hydraulic connection between GW (GW implied in the TSCA requirement) and SW, because both requirements are referring to SW within the landfill footprint/site not outside of the footprint of the landfill. As stated in NUREG 0902 guidance document, this siting criteria is meant to provide and emphasize the need to accommodate longer travel times, to allow for decay of nuclides as well as attenuation within an unsaturated zone. Modeling of the (EBCV) site indicates sufficient travel times are provided for short-lived isotopes to decay in place (e.g., those with half lives under 100 yr). A waiver to LDR placement will not be requested as was proposed in the D3 RI/FS. In the revised RI/FS ICM is discussed as a possibility in Appendix C and appropriate regulatory pathway is designating the facility as a Corrective Action Management Unit (CAMU), also discussed in Appendix C. As requested by EPA and TDEC in-cell macroencapsulation is not presented in this RI/FS as part of an alternative. Elemental mercury will be removed from equipment and from concrete debris to the extent practicable during pre-demolition activities. This will be clarified in the RI/FS revision of Appendix C. All LDRs will be met by waste accepted at an on-site facility Regarding travel times, modifications to parameters in the fate and transport modeling conducted for the East Bear Creek site in the revised document result in reduced travel times for contaminant transport. Final waste form modeling for ICM treated/disposed waste in a realistic fashion would account for a delay in the release of mercury from waste forms in contrast to the current assumption that mercury is available for release at the interface of the waste and vadose zone. This delay is less conservative than the current scenario modeled. The cost of characterization and treatment at the demolition site is a cost that is covered under the D&D project, and not part of the alternative cost. It is a cost common to either on or off-site disposal and is therefore not included. Waivers required for on-site disposal have been consistently stated throughout the revised RI/FS. The only waivers requested are TSCA waivers.
TDEC.S.014	**Page ES7, Paragraph 3:** *"The Off-site Disposal Alternative (Option 2) estimated cost for disposal of the projected volume of CERCLA waste is $824/yd3 (FY 2012 dollars) or $986/yd3 (Present Worth). This is approximately two times the estimated cost for disposing of the waste in the On-site Disposal Alternative ($399/yd3 [FY 2012 dollars] or $447/yd3 [Present Worth])."* Discussion of cost is contingent on volume estimates and the assumption of on-site disposal in a large, contiguous landfill near the current disposal facility. Since such a facility may not be possible due to siting criteria, the cost estimates are premature. In any case, total cost estimates for on-site disposal versus off-site disposal should be emphasized rather than unit cost.	Total cost estimates are presented in the document itself, in detail in Appendix I and summary forms in Chapter 7. Total cost estimates require a great deal of explanation that is not possible in the Executive Summary, therefore only the costs per yd3 of waste are compared. This comparison is made on a basis of <u>waste disposed</u> which <u>does</u> take into account and remove volume that is occupied by fill in the on-site alternative. It is therefore, an apples to apples comparison. Because the revised RI/FS includes multiple on-site options (e.g., three sites - two are large landfill footprints and the third option includes two small footprints, as well an alternative that offers a small landfill footprint along with off-site disposal is also included), a variety of costs (and ranges) are included. All these

		configurations bound the on-site and off-site alternatives in terms of cost.
TDEC.S.015	**Page ES8, Paragraph 3: "*PREFERRED ALTERNATIVE*"** As stated in the comments above, TDEC does not agree that the preferred alternative will necessarily meet the threshold criteria required for a selected remedy under 40 CFR Part 300.430(f)(1)(i)(A). Consequently, TDEC suggest that the following steps should be taken to work toward authorization of on-site waste disposal under the FFA. 1. Establish an agreement between the FFA parties on which rules are applicable or relevant and appropriate requirements (ARARs). 2. Select a site or sites that can either (1) meet all siting requirements specified in ARARs or (2) be cost effectively modified in such a way that any siting requirements that are not met can be waived. 3. Should ARAR compliance indicate significant limitations on volumes that can be legally and cost effectively disposed on-site, have a commitment by DOE to immediately implement aggressive waste minimization practices, including size reduction of debris and sequencing of soils and debris disposal to minimize use of clean soils as structural fill at the on-site facility currently in use. 4. Obtain disposal authorization from DOE for the proposed site(s). 5. Incorporating restrictions imposed by ARARs and the requirements of DOE Orders with information from site characterization studies and design plans, complete a valid risk assessment for the site(s) which can be used to set limits on waste acceptance for the proposed disposal facility or facilities that will protect human health and the environment. 6. Obtain sufficiently detailed information on characteristics of candidate waste streams for a comparison with waste acceptance criteria. Obtain sufficiently precise volume estimates to make cost comparisons between any potentially feasible alternatives that would include various combinations of on-site and off-site disposal consistent with waste acceptance criteria. 7. At this stage, a valid feasibility study could be written and a preferred alternative selected by the FFA parties. The comparison of alternatives should incorporate a comparison of long and short term risks, life cycle and contingency costs, and equity considerations.	Agree, DOE is attempting to follow a similar path.
TDEC.S.016	**Page ES9, Paragraph 1 et seq**: **"*SITE SELECTION AND CHARACTERISTICS*"** As stated elsewhere, TDEC has not seen evidence that any site on the ORR with sufficient footprint to place a contiguous 2 million cubic yard facility for near surface disposal of radioactive, hazardous, and toxic wastes can meet the threshold criteria under CERCLA, protection of human health and the environment and compliance with ARARs. Attachment B provided with these comments, shows candidate areas on the ORR for radioactive and hazardous waste disposal using current property boundaries. Areas underlain by geologic units prone to dissolution and development of karst features or having slopes in excess of 25% have been color coded. Using only these two criteria, potential candidate sites are restricted primarily to Melton Valley and Bear Creek Valley. Sites in Melton Valley and Bear Creek Valley not already filled with legacy waste are dissected by streams and have high water tables. Large sites are unlikely to meet TDEC Division of Radiological Health (DRH) rule 0400-20-11-.17 (1), *Technical Requirements for Land Disposal Facilities*, which specify site suitability requirements for land disposal of radioactive waste, siting criteria under TSCA rules 40 CFR 761.75(b)(3) and (5), or criteria under TN Rule 0400-12-02-.03 (2), *Siting Criteria for New Commercial Hazardous Waste Management Facilities.* In this RI/FS, only the TSCA criteria are considered to be ARARs, but TDEC rules are arguably both relevant and appropriate, and are more or less consistent with the requirements under TSCA. Attachment A evaluates the site	TDEC is correct in noting that a siting requirement under TDEC Division of Radiological Health (DRH) rule 0400-20-11-.17 (1), *Technical Requirements for Land Disposal Facilities* [that is 0400-20-11-.17(1)(h) which requires that there should be no discharge of groundwater to the surface within the disposal site] is not be met pre-construction. However, DOE feels this siting criteria, while relevant in that it regulates disposal of LLW, is not appropriate because it was written to address LLW land disposal facilities (shallow land burial facilities) that are significantly different in construction than the type proposed by DOE. See Appendix H Section 4.3 for the justification of this position. All proposed locations will require TSCA waiver(s) to two parts of 40 CFR 761.75(b)(3) *Hydrologic Conditions*; justification for these waivers has been revised, and is given in Appendix G Section 4.1. The TSCA requirement at 40 CFR 761.75(b)(5) *Topography*, is addressed in Section 4.2, where a waiver is requested for the EBCV Site. The criteria under TN Rule 0400-12-02-.03(2) referenced in the comment has not been included in the ARARs tables; this criteria requires estimated contaminant travel times that are replaced with more rigorous GW modeling, and this

	chosen in this RI/FS against TDEC DRH rules. Site suitability requirements may be waived under CERCLA, but such a demonstration would require limits on waste acceptance as well as engineered features to isolate waste, enhance stability of the landfill, and minimize site erosion. The role of engineering features serves primarily to prevent a significant release. These are mostly barriers that prevent something (usually water) from going somewhere and that route it somewhere else. The site attributes, on the other hand, primarily serve two different, but related, functions. The first is to minimize the long term effort required to maintain the barriers. Requirements for low to moderate slope are of this nature. Buttresses can be constructed, and are proposed for EMDF, but they will never be as cheap or as effective as flat ground. The second is to mitigate the impacts, in the eventuality of a release. This requires a buffer zone around the facility that provides attenuation of the release until it can be detected and evaluated and, if necessary, prevented from spreading by corrective actions. Due to the presence of streams and rapidly migrating shallow groundwater, sites on the ORR will not provide opportunities to effectively mitigate a release of contaminants. Costs for construction of a buffer comparable to that offered by a site that meets the siting criteria in state and federal rules is likely to be prohibitive.	requirement is therefore not relevant or appropriate. Site suitability has been revised in the document; in addition, PreWAC limits have been revised (in D4 version of RI/FS), and are more restrictive (for EBCV site) than reported in the D3 version of the RI/FS, and administrative limits have been added to the document (see Section 6.2.3); and more discussion is given regarding the topography of the EBCV site, and proposed engineered features (buttresses) that mitigate the minor occurrences of steep slopes in the footprint and address erosion and stability challenges. The comment regarding buffer zones around the waste are acknowledged as pertinent, and the D4 document has an enhanced discussion of the buffer zone provided by the site development and engineering features, as well as the increased monitoring and detection capabilities provided by the underdrain, and ability to deploy mitigation measures if needed. DOE disagrees that construction of a buffer is the only way to ensure comparable protectiveness to that of a site meeting siting criteria. See discussion of the ability to monitor the site and provide for corrective actions if necessary in revised Section 7.2.2.6.
TDEC.S.017	**Page 2-4, Paragraph 1**: "*Material types may consist of various forms of soil and debris. Soil includes soil, sediment, and sludge. Debris includes a mixture of various forms of construction and demolition debris, including, but not limited to, the following:* ☐ *Reinforced concrete, block, brick, and shield walls* ☐ *Thick plate steel, structural steel, large piping, heavy tanks, and bridge cranes* ☐ *Glove boxes, fume hoods, ventilation ductwork, small piping, and conduit* ☐ *Insulation, floor tiles, siding materials, and transite* ☐ *Small buildings, small cooling towers, wood framing, and interior and exterior finishes* ☐ *Asphalt shingles, low-slope built-up roofs, vapor barrier, insulation, roof vents, flashing, and felt* ☐ *Containers, furniture, trash, and personal protective equipment (PPE).*" Some of the waste types defined as debris may contain significant internal contamination. Based on experience at the EMWMF, proper characterization of equipment and other materials that may hold substantial contamination can significantly increase the overall cost of on-site disposal. Another concern is that deposits of contamination held inside equipment may leach at rates that are significantly faster or slower than predicted rates that assume leaching from soil-like materials or rubblized concrete. Consequently, some material types may need to be considered on a case-to-case basis to evaluate their long-term performance in a landfill.	DOE agrees, that different waste types/materials will present different leaching rates of contaminants from that material. The leaching of contaminants from these other materials (e.g., concrete etc.) simply place those contaminants into the surrounding soil within varying amounts of time. The transport modeling completed using PATHRAE is accomplished assuming that contaminants are homogenously dispersed throughout a "soil-like" waste. While this may be nonconservative in some limited cases, overall it represents the highest probability of the condition that will exist in the landfill since soil is used as fill and therefore surrounds the various waste forms. Additionally, the flux of contaminants out of the waste "soil" is assumed to occur at the interface of the bottom of the landfill, without any "depth" of the waste forms/soil being given credit for attenuation. Finally, there is not enough information concerning future waste generation at this time to complete a "case-by-case" evaluation of waste form leaching.

TDEC.S.018	**Page 2-5, Paragraph 4: "*2.2 RI/FS WASTE VOLUME ESTIMATES*"** *"The waste volume estimates included in this RI/FS are limited to future CERCLA waste that will be generated from facility D&D and environmental restoration activities on the ORR. Development of waste volume estimates for this RI/FS relies on waste disposal practices and experiences on the ORR to date and reasonable assumptions about planned future D&D and remedial action activities."* A number of factors might influence the actual volume of waste disposed in a future on-site facility, including waste acceptance restrictions, more aggressive volume reduction, and other disposal practices that are different from those of the recent past. Assessment of the feasibility and cost associated with combined on-site and off-site scenarios evaluated in section 5.4 of the RI/FS indicates that costs associated with on-site disposal are significantly lower than off-site disposal only if at least half of the candidate waste considered in Table 2-2 of this RI/FS is suitable for disposal onsite, and then, only if a single large landfill can be used.	DOE agrees that many factors influence the actual volume of waste that will be generated in the future. To that end, for this analysis DOE has conservatively estimated a volume of waste that will require disposal so as to capture a reasonable prediction of that volume with an associated reasonable contingency. In response to Site Specific Advisory Board recommendations and comments, the estimate is conservative so that an evaluation of management of CERCLA waste will not be required again after this second (EMWMF being the first) evaluation is complete. This comment does not appear to be requesting any modification to the document. DOE notes that a hybrid alternative is now included in the RI/FS that will evaluate the use of a smaller on-site landfill, along with volume reduction, and disposal of the remaining volume of waste off-site.
TDEC.S.019	**Page 2-9, Paragraph 1:** "*A straight 25% uncertainty on waste volumes is assumed in this document.*" The assumption of an additional 25% waste volume may create a bias that makes the unit cost of onsite disposal appear cheaper than unit cost estimates based on more realistic assumptions.	Agree, a change in assumed uncertainty would change the $$/yd3, because a different capacity on-site cell would be constructed. Unit cost is inversely proportional to volume capacity, and is not linear. For example, the $$/yd3 for a small landfill (< 1M yd3) would be greater than the $$/yd3 for a larger (>2 M yd3) Thus, the change in unit cost at the volumes involved in this case (going for example from a 2.5 M CY cell to a 2.2 M CY cell) is relatively small (estimating about $14/cy based on recent analysis). Because the cost is used in comparison to off-site, and there is such a large difference between them, this is not a significant differentiator. Additionally, a hybrid alternative has been added to the document that considers a smaller on-site disposal facility in combination with off-site disposal. This alternative results in a much higher $$/yd3 disposal cost for the on-site portion.
TDEC.S.020	**Page 2-9, Paragraph 2:** "*Establish total fill needed using a multiplication factor of 2.26 applied to the as-disposed debris volume. The factor 2.26 is based on a field-determined ratio of total fill density to as-disposed debris density.*" This statement implies that about 5/4 the volume of the as disposed debris volume will need to be added as structural fill. As the densities of soil and debris may differ significantly, it is unclear how the volume ratio can be simply extracted from a field determined density ratio. This factor has also changed significantly over time. Better justification should be given for this number.	This value (2.26) is the total fill to as-disposed debris ratio determined for general construction debris as reported in the 2004 CARAR Appendix A based on the previous years of operations at EMWMF. This factor was adjusted to a low of 1.7, and savings in capacity calculated. A full page table has been added to Chapter 2 that evaluates this particular "capacity savings", as well as other non-conservative assumptions (e.g., amount of UEFPC soils that will be generated upon remediation, and Bear Creek Burial Ground remediation waste) to examine how the volume of waste and therefore capacity need might increase and/or decrease to bound the estimate currently used as the basis in the RI/FS. The current basis in the RI/FS is disposal of 1.9 M CY of waste, and a corresponding capacity need of 2.2 M CY. The analysis in Chapter 2 (new Table 2-5) gives a range of 1.4 to 2.5 M CY capacity needed, and demonstrates that the 2.2 M CY capacity needed for an on-site facility is a reasonable assumption.

TDEC.S.021	**Page 2-10, Paragraph 2:** " *Previous waste volume estimates required a facility size of 2.5 M yd3 and as this is only a conceptual design, the difference between 2.2 and 2.5 M yd3 will allow for final design changes (e.g., slope recalculations, cut/fill changes, height of waste, etc.); the conceptual design has not been modified. As explained in Table 2-4, the additional 25% volume uncertainty adds approximately the volume of one cell (Cell 5) to the projected disposal capacity without uncertainty. The additional 15% capacity is approximately equivalent to the size of cell 6, and as discussed, this contingency in capacity will accommodate final design changes. Establish total fill needed using a multiplication factor of 2.26 applied to the as-disposed debris volume. The factor 2.26 is based on a field-determined ratio of total fill density to as-disposed debris density."* The conceptual design for the landfill accommodates 2.5 million cubic yards when the projected waste volume needed for waste disposal is estimated to be about 2/3 of that capacity. As stated in other comments, TDEC currently has seen no evidence that a 2.5 million cubic yard facility can be compliantly sited on the ORR. Better information on the waste volume and characteristics of candidate waste streams will be necessary to provide for more realistic cost estimates of compliant alternatives, such as the combined on and off-site disposal alternatives discussed in section 5.4 of the RI/FS.	The RI/FS conceptual design accommodates a 2.5 M CY landfill; however, the cost (for on-site disposal) is based on only completing five of the six cells and is therefore calculated based on the volume of waste and capacity needed as pointed out in the comment (e.g., the 2/3 capacity). Likewise, the same volume is used in the off-site disposal calculation. The available characterization data for facilities to be demolished/disposed and media to be disposed of is not detailed enough to allow for an accurate estimation of volumes that would require off-site disposal as opposed to on-site disposal. There are/will be waste streams that are known/expected to require off-site disposal, and those volumes are NOT considered within this RI/FS analysis (for example, K-pad waste, 3026 hot cells, 3042 activated components, etc.). They have been excluded from analysis up front, as they carry a cost of "X", that would be the same for either alternative considered [e.g. X added to both sides]. Typically, until a demolition/remediation project is contracted, the characterization data will not be at a sufficient detail to allow for the analysis seemingly requested in this comment. DOE is considering the disposal of waste that will not be generated for as much as 25 years in the future. DOE does believe from the limited data available that the majority of waste to be generated will be low activity waste suitable for disposal in an on-site disposal facility such as EMWMF. Several options for disposal facility locations on the ORR are presented in the revised RI/FS, including a multiple site option, and a hybrid disposal alternative that disposes of waste on-site and off-site. Ultimately, an on-site facility's waste acceptance criteria (among other potential constraints such as physical limits) will determine the size of the landfill in the on-site alternatives, and phased construction of any on-site facility is planned and discussed in the document, such that the final footprint will only provide the capacity that is required.
TDEC.S.022	**Page 2-10, Table 2.3:** From this table it is obvious that the amount of clean fill planned for use nearly equals the combined total of debris + waste soil. Wouldn't further volume reduction of debris be environmentally judicious?	As explained in Appendix B, clean fill is always necessary whether material is size reduced or not. The quantity of clean fill can be reduced when size reduction of debris is performed because the void space is reduced. However, environmental impact is a trade-off because the mass of debris and contaminant load is unchanged, while in fact the contaminant concentration is increased by VR (e.g., a sum of fractions increase as well) thus presenting a higher risk (risk is proportional to contaminant concentration in the landfill). Fill material also provides media which attenuates the contaminants as they move through the waste over long time periods. Less fill means less attenuation. Finally, the activity of conducting VR provides additional risk to workers through exposure by double handling of waste and airborne dust, and generation of dust requires controls (typically watering to suppress dust) which then generate a secondary waste that requires disposal. As Appendix B points out, the quantity of fill material and the required air space for the landfill is reduced when debris is size reduced, however, the cost of implementing VR is significantly greater than cost savings associated with reduced landfill size. Although not addressed in Appendix B, the energy required for size reduction activities is very high, which would likely increase the carbon footprint for landfill operations. Ultimately VR provides some benefits, but also some disadvantages when land disposing of radioactive contaminated waste. A more thorough evaluation of volume reduction against the CERCLA criteria is included in the revised RI/FS.

TDEC.S.023	**Page 2-14, Paragraph 1: "*2.3 RI/FS WASTE CHARACTERIZATION*"** *"This section discusses characterization of future generated CERCLA waste streams. Because detailed characterization data do not exist for many of the individual D&D and remediation projects, characterization of future waste streams is based on available data for waste disposed at EMWMF to establish contaminants of potential concern (COPCs) and estimate contaminant concentrations. This methodology relies on the assumption that available data for waste disposed at EMWMF approximately represent the waste characteristics of future waste streams."* The assumption that waste characteristics of the waste streams that are candidates for future on-site disposal will be sufficiently similar to the waste characteristics of waste disposed at the EMWMF to allow accurate estimates of on-site waste volumes is not well supported by either data or process knowledge. This is only likely to be true if essentially all candidate waste will be acceptable at the proposed facility.	The sentence immediately following the quoted text here states that "Use of characterization data for waste disposed at EMWMF is limited in the RI/FS to serving as a basis for the transportation risk and natural phenomena risk calculations. " Waste profiles based on EMWMF radiological characterization were developed and presented in this section only to allow for transportation risks to be developed. Ultimately these risks are calculated to compare on-site to off-site disposal transportation risk. The absolute difference would be similar regardless of the profiles developed. The same volume of debris/soil waste is used for both on-site and off-site analyses. These volumes have already excluded waste volumes that are known (via process knowledge or data) to require off-site disposal. Additionally, waste radiological characteristics for ONLY those wastes disposed in EMWMF that originated at ORNL and Y-12 were looked at in detail to give an indication if future ORNL and Y12 wastes would be amenable to disposal in an on-site facility.
TDEC.S.024	**Page 2-14, Paragraph 1:** "*Use of characterization data for waste disposed at EMWMF is limited in the RI/FS to serving as a basis for the transportation risk and natural phenomena risk calculations."* Note that the waste inventory that was not accepted for disposal at EMWMF and was consequently shipped off-site included much of the material that would drive exposure risk. Risks due to nonexposure related transportation accidents may increase proportionally with the volume shipped offsite, but exposure risks are unlikely to do so.	The risk of exposure (radiological) during transportation accident scenarios was calculated on the basis of waste compositions similar to those disposed of in EMWMF. Therefore, the risk per accident was based on a source term representative of waste that might be disposed of on-site. This risk is presented on a single shipment basis in Appendix F. The cumulative radiological risk (all shipments) for accident scenarios will be deleted, as will cumulative radiological risk for workers and on-link populations. Cumulative radiological risk for routine exposure for off-link populations is relevant as it is assumed that the off-link (e.g., residents along the route) continue to live there throughout the length of time shipments are conducted.
TDEC.S.025	**Page 3-3, Table 3.1**: It would be helpful if Document numbers were included for any documents in this table that currently lack them (e.g. Hot Garden).	There are no document numbers for the Non-significant ROD change references; these are usually just letters. All other documents have document numbers in the table or have been added as requested.

TDEC.S.026	**Page 3-8, Paragraph 1:** "*No changes are expected to the pre-WAC/risk evaluation through the Proposed Plan and ROD processes.*" In comments submitted on the 1998 EMWMF RI/FS, TDEC expressed concerns that pre-WAC development was based on modeling that did not have adequate foundations in either science or regulations. A decision was made at that time to approve the RI/FS and address waste acceptance uncertainties at a later date. Administrative limits that prevented acceptance of radioactive waste deemed by the Nuclear Regulatory Commission and Tennessee Division of Radiological Health to be unsuitable for shallow land disposal were negotiated after the EMWMF Record of Decision, but improved performance modeling of the site was never initiated. Other than the administrative limits, waste acceptance limits established in the EMWMF RI/FS were never altered. Additional information on groundwater flow in Bear Creek Valley and changes to the size and scope of the waste disposal operations at the EMWMF have since increased concerns over the protectiveness of the EMWMF WAC, and efforts have been made by the FFA parties to limit waste with high concentrations of radionuclides to disposal in more suitable facilities offsite. Consequently, TDEC asked DOE to revisit performance modeling and WAC development prior to submitting CERCLA documentation for a new CERCLA waste disposal facility. DOE has not addressed this concern, and the D3 RI/FS again postpones any changes to the modeling until after key regulatory decisions have been made, stating, at the top of page 3-8, "No changes are expected to the pre-WAC/risk evaluation through the Proposed Plan and ROD processes." In more detailed comments on pre-WAC development in Appendix H, some preconditions necessary for development of a credible pre-WAC are given and some constraints on modeling parameters are suggested.	Significant modifications have been made to the modeling based on concerns discussed in comments, and are incorporated into the D4 RI/FS. Responses to specific concerns are made throughout this response summary. The quote is taken out of context; the quote is aimed at noting that while changes may be implemented in the PreWAC, they would not come about through the PP or ROD developments (as these two documents do not do evaluations/assessments/calculations that would necessitate a change to preliminary WAC limits). Rather, other assessments (such as the intruder analysis to be completed under DOE O 435, or final design calculations and specifications) might have an effect on/modify the PreWAC into their final limits. Additionally, as discussed throughout the RI/FS, other criteria/limits are incorporated into WAC but are not introduced through the fate and transport modeling. However, the revised D4 RI/FS will include some more limits such as those dictated by transuranic waste definitions and greater than Class C limits. Also, as discussed in the RI/FS, a WAC Attainment (Compliance) Plan will be developed that will be the result of tri-party efforts to revise the approach to implementing WAC, and also report the final WAC limits.
TDEC.S.027	**Page 6-6, Paragraph 2, Line 9:** *"An acoustic bat survey conducted by ORNL personnel did not detect any listed bats, such as the endangered Gray or Indiana bats."* It is strongly recommended that a new bat acoustic survey be conducted at the proposed EMDF site. Although the previous ORNL survey did not detect the federally endangered Indiana or Gray bats, this study may have been completed prior to the recent listing of the Northern Long-eared bat as a federally threatened species. Accordingly, acoustic survey information is needed to determine if the Northern Long-eared bat is present onsite or not present. If an acoustic survey detects threatened and endangered bat species at the EMDF proposed site, then DOE may need to enter into a section 7 consultation with the US Fish and Wildlife Service to address the threatened and endangered species at this site.	As recommended by TDEC and EPA, other candidate sites in BCV in addition to the East Bear Creek Valley site have been added to the revised RI/FS. Additional T&E surveys will be postponed until a site is approved by TDEC and EPA.
TDEC.S.028	**Page 6-20, Floor of Landfill, 1st Bullet, Lines 3-5**: "*The purpose of geotextile as separator layers is to provide a filter that restricts finer particles of a material on one side of the textile from traveling through to the other side in order to reduce the potential for clogging.*" Either the reader is misunderstanding something or there is a problem with this statement. It seems that, if a layer restricts the passage of small particles, enough of these particles would accumulate to cause water movement through these to be slowed and then stopped.	Language has been modified..
TDEC.S.029	**Page 6-21, Facility Underdrain discussion:** Are there any case studies or solid examples that the proposed underdrain would function as described? Strong evidence that the underdrain would be successful is needed.	Additional information has been added. See Sections 6.2.2.4.8 and 7.2.2.3.
TDEC.S.030	**Page 6-39, Facility Underdrain discussion**: The arguments made here for a forested landfill cover may not prove valid. Although initially one may be able to establish the desired mix of vegetation, there are no guarantees that these conditions will remain stagnant over time. Establishment of a climax forest does not mean that conditions will remain the same over time.	[Note – this comment actually references the Cap Vegetation Section (not the underdrain)] Comments noted. It is recognized and accepted that the site will be subject to wind damage (and potential damage from forest fires, tree killing pests, or other

	The collapse of individual trees will open that area for a new succession. The vegetation growing in such a disturbed site may not fit the desired type for the climax-forested landfill. Additionally, disturbances, such as those that have already historically occurred at the site could be an extremely important factor in what the eventual climax forest cover looks like. The downburst that seriously impacted the forest cover at the site in the past couple of years could tremendously change any man-made plans for a final vegetative cover.	factors). The potential impacts from wind-throw are summarized in Section 6.2.2.7.3. The engineering specifications for the uppermost cover layer will be addressed during the detailed design and must address the potential for disrupton of the cap materials from the long-term effects of wind-throw and other potential environmental conditions. TDEC will of course be provided the opportunity to review and respond to the adequacy of those design elements. This section is included only as an option to be considered.
TDEC.S.031	**Page 6-55, Last Paragraph, Lines 4-6**: Can materials bound for Energy Solutions in Clive, Utah not be shipped all the way via rail? Is it being indicated here that the material is being trucked from Kingman, Arizona to Clive, Utah.	Corrected. Removed the wording "or to EnergySolutions in Clive, Utah."
TDEC.S.032	**Page 7-7, Paragraph 2, Line 9: "***There are currently no identified federal- or state-listed threatened and endangered species in the proposed EMDF site area."* This sentence should be struck until the presence/non-presence of the federally-threatened Northern Long-eared bat at the proposed EMDF site can be determined.	Agreed. A review of the ORNL acoustic bat survey results from August 2013 (conducted in support of timber recovery at and near Site 5) indicates that the Northern long-eared bat was detected in the survey, but had not been identified as a threatened species. The text has been revised here, and text and tables have been revised in Appendix E to correct this error, and to note that this threatened species was detected.
TDEC.S.033	**Page 7-9, Paragraph 2:** What guarantees are there that the landfill design will not leak for a 100 years much less 200, 1000 or several 1000's years? Are there currently any landfills that have never leaked?	The section does not guarantee no leakage; however, the whole section has been revised. Justification has been provided for longevity of engineered features. As the revision states, no landfill is impervious to leaking, especially in terms of thousands of years.
TDEC.S.034	**Page 7-10, Paragraph 2**: *"Survival of an engineered landfill structure for thousands of years is not unreasonable since, for example, many British earthen hill forts more than 2,000 years old are remain essentially intact. Native American mounds in the Ohio and Tennessee River valleys, many of which are more than 1,000 years old, have also survived with little erosion, as have similar structures built by pre-Columbian civilizations in the much wetter climates of Central and South America. Detailed design calculations will be conducted, in part, to assess the capability of the landfill design to protect from long-term geomorphic and seismic stresses. If final design efforts identify areas needing improvement, these would be incorporated into the final design."* The concern is not whether a relic of the EDMF will remain after 1,000 or more years, but whether engineered barriers can be relied upon to contain radioactive and hazardous contaminants for the period. Prior to approving a LLRW disposal facility, TDEC requires reasonable assurance the facility will meet the performance objectives of TDEC 0400-20-11-.16 for the compliance period and beyond. Any time credit for engineered barriers needs to be justified on case by case basis.	DOE agrees in part with the comment that justification should be directed mainly at engineered barrier longevity in terms of containing contaminants; however, the quoted text is justification of the facility's ability to resist erosion, which translates into longevity of the final cover in reducing infiltration to some degree. This is clarified in this Section, and more justification concerning the longevity of engineered barriers has been added to this Section.
TDEC.S.035	**Page 7-10, 2nd Last Paragraph, Last 2 lines:** Why is erosion caused by wind throw considered unlikely, since a large portion of the area being considered for EMDF has seen considerable wind throw (from a downburst) in recent history?	The wording has been removed.
TDEC.S.036	**Page 7-18, 7.2.2.6 Implementability (On-site) (top of page, first paragraph, 5th line):** *"Should releases to groundwater go undetected, groundwater in the immediate vicinity of EMDF could be contaminated and minor releases to Bear Creek could occur. The actual risk of exposure from such a release would be low."* The discharge to Bear Creek down-valley from the proposed facility footprint will join that of the creek only until that discharge is known to sink into the bed of the creek (TDEC, 2001) near the western limit of the current EMWMF. This has the potential to impact groundwater many	Interactions between surface water and ground water flow along the entire length of Bear Creek are reviewed in detail in Section C.4.5 (p. C4-14) of the Report on the Remedial Investigation of BCV (SAIC March 1997). Section 7.2.2.6, which focuses on implementability of the on-site alternative, does not address those detailed and complex interactions nor the potential fate and transport of releases from the EMDF. Nor is 7.2.2.6 the place for a detailed discussion of these issues. They are addressed to some degree in other sections of the RI/FS (mostly in Appendix E and H). The Composite Analysis will attempt to address fate and

	kilometers away from the sinking point. This is not addressed in the document.	transport over the broader scale at distances further downstream and downgradient of the EMDF along NT-3 and Bear Creek and incorporating other contaminant sources and contaminant flowpaths associated with those other sources. Results of the Composite Analysis will be shared with TDEC and EPA once completed under the DOE O 435 process.
TDEC.S.037	**Page 7-29, Last Paragraph, Lines 1-3**: DOE states "The No Action Alternative may not be supportive of timely remediation of ORR sites due to lack of a coordinated disposal strategy and could result in actions that are less protective and less costly than either of the action alternatives." Is this statement correct?	This statement was modified to read "and could result in actions that are less protective and ~~less~~ more costly (as a whole) than either of the action alternatives due to each project meeting disposal requirements individually.", since the basis for the No Action assumes that each project manages its own waste independently. As explained in Table 7-4, the waste might be managed in place and has the potential therefore to not be as protective as waste managed in a single engineered facility on-site or off-site. Costs would be expected to be more, taken as a whole, with individual projects paying for compliant treatment/disposal on a case-by-case basis, with possibly sending waste off-site by truck as opposed to concerted efforts to rail ship waste.
TDEC.S.038	**Page 7-32, Table 7-4, Implementability, On-site Disposal Alternative Column, Lines 2-4:** Perhaps some examples or case studies of successfully engineered landfills and evidence that they have been protective of the environment can be provided here or elsewhere in the document.	More information has been added to the document. See 7.2.2.6.
TDEC.S.039	**Page B-6, 1. Introduction:** "*Volume reduction (VR) almost always requires additional effort to characterize or process the waste in a manner that reduces volume and cost. Therefore, it is necessary to evaluate VR methods to determine if the additional effort is beneficial.*" The longer the delays on implementing the use of volume reduction equipment, then the lower the cost benefit analysis becomes for the use of volume reduction equipment with each delay. Volume reduction and the associated savings for off-site and onsite disposal was well documented at BNFL's Three Building D&D Project.	See related comment TDEC.G.10 Despite near-term implementation of size reduction, Appendix B indicates such an effort is not cost effective as executed in conjunction with on-site disposal. Revised D4 RI/FS analysis includes the disadvantages that VR implementation includes (e.g. double handling waste, worker exposure, secondary waste). Appendix B also evaluates size reduction for the Off-site Disposal Alternative and found it to be cost effective if a centralized facility is constructed near an ETTP rail terminal. However, as pointed out in the RIFS, off-site disposal (even with the VR facility) is more expensive and presents more risk (because of transportation risk) than on-site disposal at the EMDF.
TDEC.S.040	**Page B-12.5. Volume Reduction Methods and Benefits:** "*Volume reduction methods evaluated in this report include recycling, project sequencing, improved segregation, and physical size reduction. Advantages and disadvantages are discussed along with cost data collected from various sources.*" Are there any total operating costs of waste disposed per cubic yard at EMWMF to compare to costs of off-site disposal to use a basis for the overall cost of the proposed EMDF? If not, then it's difficult to perform an objective evaluation for off-site disposal, transportation, volume reduction, etc.? Since the proposed EMDF is based on the same operating costs as EMWMF, then EMWMF's total (100%) operating costs should be made available for off-site disposal options.	Yes, the EMDF operating costs are based on the EMWMF operating costs. Those operating costs are included as part of the EMDF lifecycle costs. The cost comparison for on-site disposal includes all costs associated with designing, constructing, operating, closing, monitoring, and long-term S&M to compare to off-site transport, VR, and disposal.

TDEC.S.041	**Page B-22, Size Reduction of Equipment and Structural Steel, Paragraph 2, Lines 8-9:** Here it is stated that "*It is assumed that shearing operations will reduce the void volume of equipment and heavy steel components by 50%, doubling the bulk density*." However, on page B-20 under the discussion for the Shearing Machines on Lines 15-18 it is stated that "*Discussions with former BNFL operations supervisors indicated the typical net weight of the sheared material loaded into a 25 ft3 intermodal container was 52,500 lb. giving a bulk density of 2,100 lb. per yd3. This is triple the bulk density normally experienced for large equipment disposed at the EMWMF (per CARAR density data).*" What is the reason for this discrepancy? The difference between a doubling and tripling of the bulk density is quite significant.	In the evaluation summarized in Table B-6 the size reduction of heavy equipment and steel, the overall bulk density of both material types is 957 lb/CY. Reducing the void fraction by 50% using a shear doubles the bulk density to 1,914 lb/CY. This is reasonably close to the BNFL typical bulk density of the processed material.
TDEC.S.042	**Page B-22, Size Reduction of Equipment and Structural Steel, Paragraph 2:** It appears that the discussion here is saying that after use of the supercompactor, the same ratio of clean fill material will be required as without the use of size reduction methods. Somehow, this doesn't seem right.	From page B-22: "Fill material would still be necessary to occupy void space in the material, although the fill requirement would be lower. In the case of equipment debris, it was assumed that the CARAR clean fill requirement would be reduced from a ratio of 9.58:1 (clean fill volume: equipment volume based on the as-disposed debris volume) to the ratio that would normally be required for construction debris or 2.26:1. In the case of structural steel debris, it was assumed that the clean fill requirement would be reduced from a ratio of 6.63:1 (clean fill volume: steel volume based on the as-disposed debris volume) to 2.26:1." This indicates a 76% reduction in clean fill required for equipment and a 66% reduction in clean fill required for heavy steel. Table B-6 provides the data that results in a reduction in the amount of clean fill of 113,455 CY.
TDEC.S.043	**Page B-22, Last Paragraph:** First, based on comments 41 & 42 above, the cost savings calculated here is questionable. Second, reduced landfill space utilized, smaller size for final landfill, reduced S&M costs after closure, reduced likelihood of waste components leaching (i.e., less exposed surface area, less leaching of components) and other considerations should be evaluated before making the final decision on size reduction.	VR does not reduce the mobility or toxicity of the source material, only the volume. Operation of size reduction equipment increases risk to workers and requires substantial amounts of energy. The volume reduction that is realized results in a reduction in fill material. However, fill material can help retard movement of some contaminants. Size reduction actually exposes more surface area and could possibly increase the leaching of some contaminants. [For example, TCLP testing requires crushing of sample to expose more surface area to a leaching environment thus challenging the waste form more.] Size reduction of this nature (shearing/crushing/grinding) would do the same – expose more surface area to leaching.
TDEC.S.044	**Page B-30, Cost Effectiveness of Size Reduction:** Cost should not always be the ultimate decision factor in determining the benefits of size reduction.	Agree; however, size reduction does not accomplish reduction of mobility, nor does it reduce toxicity. It could possibly increase mobility by exposing more surfaces to leaching. The source itself (e.g., radioactivity or toxic material) is not changed, but its concentration is increased, which increases risk (risk is proportional to concentration of contaminant). Appendix B was revised to evaluate VR based on CERCLA criteria (see new Section 5.4.4.).
TDEC.S.045	**Page B-34, Size Reduction Evaluation Conclusions for the On-site Disposal Alternative:** It is clear that the only factor being considered in whether or not size reduction should be implemented is cost. There is some question as to whether the cost differential may be being artificially inflated. Cost should not be allowed to outweigh all the other benefits of size reduction (i.e., environmental, local economy, etc.).	The cost of VR is not being artificially inflated. DOE does not have a reason t to avoid the implementation of VR and has provided an unbiased evaluation. Appendix B was revised to evaluate VR based on CERCLA criteria (see new Section 5.4.4.).

TDEC.S.046	**Page B-43 & Page B-44 7. LESSONS LEARNED**: Interesting that although the waste operations at both Weldon Springs and Fernald involved volume reduction, none of the lessons learned involve the benefits emanating from that volume reduction.	Weldon Springs implemented size reduction activities at the demolition site through the use of shearing attachments for excavators to increase the quantity of debris per transport event. Though not explained in Appendix B, this lessons learned approach is routinely used in Oak Ridge demolition projects. Shearing attachments are routinely used on excavators to reduce transportation costs and to meet EMWMF waste acceptance criteria. As for the Fernald project, the lessons learned regarding the use of waste soil for fill material is implemented for Oak Ridge projects (as explained in Section 5.2) through project sequencing to maximize the use of waste soil as fill material for demolition debris. Appendix B Section 7 was revised to reflect the Oak Ridge response to lessons learned.
TDEC.S.047	**Page B-44, 8. Summary:** It is quite clear from this summary that the only factor given consideration in this analysis is cost. Although, these "costs" for size reduction have been shown to be greater than not size reducing, in terms of the money being spent in Oak Ridge on CERCLA activities the differences are not excessive. More consideration needs to be given to environmental, NEPA, long term monitoring and maintenance, and possibility of landfill failure where size reduction benefits far outweigh the alternative.	DOE agrees. More consideration was given to advantages/disadvantages provided by mechanical volume reduction by size reducing. Appendix B was revised to evaluate VR based on CERCLA criteria (see new Section 5.4.4). Criteria that come into play with VR are worker exposure; double handling of waste; no reduction in toxicity or mobility of waste (perhaps increase in mobility); increase in risk due to higher concentrations with VR; secondary waste generation with VR. These elements of VR were not well addressed in the D3 RI/FS and are more pronounced in the D4 RI/FS through the CERCLA evaluation. In terms of landfill failure, volume reduction offers no reduction in source mass so there would be no less risk involved. In terms of an intruder analysis, VR increases the concentration (same mass in a smaller volume) and therefore offers a higher risk to an intruder accessing waste.
TDEC.S.048	**Page B-44, 8. Summary:** "*The results of this study indicate that volume reduction methods must be evaluated on a case by case basis and are not always cost effective for disposal of CERCLA waste.* Case by case studies should include building reuse/reindustrialization vs. total building disposal to determine the method and equipment used to generate the waste and thus the associated waste size and costs at the point of generation. This must be taken into account for any case by case comparisons for volume reduction. Reindustrialization requires that the structure of the building be protected and D&D equipment such as large track hoes with shears cannot be used. Many of the volume reduction compacter shear comparisons are built upon false comparisons where the intended reuse of the facilities is mixed with total disposal of facilities thus impacting the associated costs, size and equipment used for point of generation.	Evaluation of building reuse/reindustrialization versus total building disposal would be performed prior to a facility being transferred to the DOE Environmental Management program. A building would only be demolished if this evaluation indicated there would be no possible future beneficial use of the building and if the building was not considered historically significant. As is the case at ETTP, those facilities that are suitable for reuse will not be demolished. Y-12 and ORNL DOE landlords (NNSA and Science) have indicated they have no use/reuse plans for the facilities that have been added to the list of IFDP facilities. Any facilities identified for reuse are not included.

TDEC.S.049	**Page B-53, 1st Row:** "*Feed preparation requirements: Used hand-held plasma cutters and air-arc (arc gouge) cutters to prepare materials for 26' feed box. This was the slow step of the process. The shear operators spent a lot of time in stand-by waiting for material to process. Air-arc cutters were much faster than the plasma cutters, but were much louder due to the use of compressed air, and also emitted a large shower of sparks during operation. This was acceptable for cutting converter vessels because sparks were contained within the vessel. Feed box was 26 ft. long and throat width was 5 ft., allowing cut width of 2-5 ft. Longer boxes are available, up to 40 ft.*" This statement is not applicable to the comparison. For BNFL's Three Building D&D Project, K-33 and K-31 were preparation for a final status survey for reindustrialization of the buildings where the integrity of the building structure was to be maintained, thus hand-held plasma cutters and air-arc (arc gouge) cutters were used. This resulted in manual removal of waste material to protect the building structure, not to prepare material for the feed box. Additionally the logistics of moving material east-west without the benefit of the north-south bridge cranes caused higher costs; this would also not be required with the current mode of demolition for a reindustrialization. A 26' feed box would take less preparation with both methods simply do to the fact it's larger than a dump truck. A compactor shear would perform the sizing to minimize the amount of soil brought in, thus reducing operating costs and maximizing the use of space for the intended purpose of waste disposal.	The information quoted is from Appendix B, Attachment A vendor information, consisting of notes taken during a phone call to Harris Equipment Company, manufacturer of the shear used on the BNFL K-33/31 project. The person interviewed was directly involved in K-33/31 project operations. This information was used to estimate operations and maintenance costs for a shear; however, it was not used to estimate the manpower required to operate a volume reduction facility (see Table B-9) where the estimate was built on assumptions regarding operators for the VR equipment/facility. The information provided by the commenter involves activities that would/would not occur in the demolition facility, which is not included in the scope of this RI/FS remedy.
TDEC.S.050	**Page B-53, 3rd Row:** "*Number of operators: To operate the shear requires one person at the controls, one person to provide feed, and 3 persons to manage the product which involves moving the intermodals into place, distributing the product in the intermodal, and managing the filled intermodal. Intermodals were frequently punctured during loading due to the size, weight, and shape of the metal pieces. The intermodals were placed on a stand after filling and patched as necessary. Placing flat sheets of metal (waste material) in the bottom of the intermodals prior to loading helped reduce punctures.*" With the current mode of demolition consisting track hoes, shears and dump trucks for size reduction the beds of dump trucks have also been punctured; this should also be noted for the onsite disposal option with or without volume reduction. Compactor shears are more efficient at reducing the size/weight of material thus reducing the risk of punctures. Punctures happened several times with LATA Sharp during the removal of K-33 building debris. As a corrective action LATA Sharp also used segregated waste material to protect the bottom of dump trucks. It can potentially be assumed this is still an ongoing problem with onsite disposal? How many personnel does it take to load a dump truck including the truck driver, the equipment operator and the Rad Tech? Compacted and sheared material is not restricted to intermodals for transport; dump trucks and various other containers may also be used. BNFL used intermodals loaded on articulated rail cars for offsite shipment of compacted and sheared waste. Each rail car was designed to hold eight intermodals; however only six intermodals were carried on each car due to the fact the compactor shear was so efficient at volume reduction that the addition of more than six intermodals would exceed the weight limit of one rail car. This efficiency would also be effective with onsite disposal and save waste disposal space.	The information quoted is from Appendix B, Attachment A vendor information, consisting of notes taken during a phone call to Harris Equipment Company, manufacturer of the shear used on the BNFL K-33/31 project. The person interviewed was directly involved in K-33/31 project operations. This information was used to estimate operations and maintenance costs for a shear. We agree that punctures of debris containers is probably an ongoing problem for both off-site and on-site disposal. The Appendix B study quantified the benefits of size reduction of heavy steel for both on-site and off-site disposal alternatives. Size reduction does indeed reduce the air space required for on-site disposal, but the evaluation shows it is not cost effective. Additional information has been added to Appendix B to discuss all pro's and con's of on-site VR in terms of the CERCLA criteria (see new Section 5.4.4). However, as Appendix B explains, size reduction is cost effective for the Off-site Disposal Alternative.

TDEC.S.051	**Page B-53, Last Row:** "*Support equipment: Track hoes used to rake/distribute material within intermodals. Intermodals did not have full-open lids, making it difficult to distribute material in the container. System included 4 air-cooled oil coolers mounted on roof about 85 ft. above the shear.*" Track hoes are currently used for most loading and distributing of bulk waste for onsite and offsite disposal, especially for loading waste into dump trucks. This should be listed for all bulk waste loading, not just the compactor shear option.	This is an attachment to Appendix B, providing backup information obtained from vendors and is not meant to be all inclusive. Comment noted.
TDEC.S.052	**Page B-58, Table B-22, Row 6, "Operating Hours:"** Why are the estimated operating hours for the excavator twice that of the Crusher and Shredder combined?	Estimated hours for the excavator are doubled because two units are required to support crusher and shredder operations. One is required to manage the feed to the processors and the other to load transport vehicles with the size reduced product.
TDEC.S.053	**Page C-4, Paragraph 3, Line 3:** This discussion seems to exclude treated mercury wastes from the risk assessment. Treatment standards do not protect all water pathways. Treated mercury must be included in the risk assessment. An assessment to ecological and human health risk through fish consumption is most critical. The risk assessment must evaluate the treated mixed waste matrix through the same time scale that its constituent waste radionuclides require. Recognize that Bear Creek is already listed by the state as an impaired stream. Impaired streams are protected more than ones that are not impaired.	Mercury was considered as a contaminant in the risk analysis.
TDEC.S.054	**Page C-5, Paragraph 2, Line 4:** Mercury transport is sensitive to small changes in its partition coefficient (Kd) as when waste is in high pH conditions. The predominant Y-12 waste matrix is concrete and concrete has a high pH (good concrete is pH 9-12.5). Furthermore, mercury migrates out of concrete even without water as a transport agent. The discussion acknowledges some of these difficulties, but does not address the long term effectiveness of the treatment method to protect human health and the environment. Macro encapsulation and flowable fill do nothing to mitigate the fact that the source matrix itself is not treated and is a high pH source that mobilizes mercury. Over time mercury will initially exit the waste disposal facility in a high pH condition through holes and cracks in the encapsulation materials. During this breakthrough single digit Kds best describe mercury waste properties as if in a soil-water solution, not a soil matrix. One way to investigate this is to set up an outdoor test facility similar to the Hill Cut Test Facility at SWSA 6. The test could be run with different treatment technologies and different conditions to test the viability of various treatment methods over the years before WEMA starts. As it is, the state has small confidence that in-cell macro-encapsulation can perform over the long term as required by CERCLA.	Macroencapsulation is an accepted treatment for mercury-contaminated debris and is a technology-based treatment standard as discussed in 40 CFR 268.45 and the corresponding TDEC Rule 0400-12-01-.10, paragraph 3(f), Table 1. Appendix C emphasizes the benefits of including mercury stabilization agents in encasement materials, or the use of specialized, non-cementitious stabilization and solidification materials (e.g. sulfur polymer cement) for debris encasement within a macroencapsulation envelope to enhance long-term effectiveness. Appendix C has been revised to address other treatment methods for mercury, and to discuss pre-demolition activities that will be aimed at removing any free elemental mercury from debris. The assumption that all mercury-contaminated debris is treated to meet LDRs prior to acceptance at the landfill for the on-site alternatives has been added to the document. However, in-cell macroencapsulation is addressed in Appendix C as a possible option, along with the regulatory path required to accomplish in-cell macroencapsulation.
TDEC.S.055	**3Page C-6, Thermal and Chemical:** This brief acknowledgement of thermal separation and retort as an option for WEMA waste treatment is the one the state recognizes as protecting human health and the environment. It is a way to recover and separate mercury from the biosphere. The process also purifies mercury to reduce the chance of it being radiologically contaminated when compared to IAEA standards.	Thermal treatment is acknowledged as a possible treatment option for mercury-contaminated debris in the revised RI/FS. The decision on how to treat mercury-contaminated debris resulting from demolition of mercury-use facilities (via thermal extraction, macroencapsulation, other) is outside the scope of the RI/FS (as explained in the revised document).
TDEC.S.056	**Page D-16, 3.2.5 Proposed SWSA 7 Site (1st paragraph this subsection, last sentence):** *"Groundwater occurs in fractures, and drainage is radial, making monitoring more difficult. There is no karst at this site."* It would seem that if it is known that groundwater drainage is radial, then monitoring could be more straightforward. So, how is it known that drainage is radial?	Agreed. Text was revised. Ground water monitoring would not necessarily be any more difficult than at other sites, but might warrant more monitoring wells around the site perimeter for point of compliance release detection. Figures 30 and 31 in ORNL/TM-9314 (December 1984) illustrate the potentiometric surface configuration for April and November 1983, respectively, based on data from several monitoring wells across the proposed SWSA-7 site. The figures indicate

		that shallow ground water would radiate toward neighboring stream valleys surrounding the upland areas of SWSA-7.
TDEC.S.057	**Page D-30, 4.3.2.1 Sensitive Habitats, Paragraph 2:** A number of factors besides contamination are likely particularly in the headwaters of Bear Creek. Being a headwater stream (especially BCK 12.3), and having limited habitat a diverse fish community would not be expected regardless of any contaminants.	Agreed. No response warranted.
TDEC.S.058	**Page E-1 et seq. General comments on hydrogeology relevant to the discussion in Appendix E:** ☐**Monitoring Wells, Macrofissures, Fissures, Fractures. Channels and Conduits.** It has been published for several decades that there is a low probability of intersecting flow features in the subsurface by drilling boreholes. In the gypsum karst of Ukraine, there are caves systems that comprise the densest conduit networks known on the planet. These are also walking sized passages. The probability of intersecting a conduit in that setting whilst drilling is only 17% (Alexander Klimchouk, personal communication). It should therefore be prudent that during any drilling program that this low probability should be considered after the site investigation has been completed. The way that many problems such as inaccurate groundwater velocities and inaccurate flow vectors are shown is that hydrogeological data from boreholes are significantly different from the results of injected tracer tests done at a given site. It should also be noted that data from boreholes mostly represent flow in small fractures and subsidiary channels and fissures and that these do not carry most of the groundwater flux (Worthington et al., 2000). Although a conduit is often conceptualized as a relatively large, walking-sized opening, for groundwater velocity of 0.001 m.s-1 at the onset of turbulent flow, a diameter of only a few millimeters is needed (Quinlan et al., 1997). With this in mind, groundwater and contaminants may migrate at about 90 m/day (0.001 m/s) in tiny openings not discernible from drilling or from many other site investigation techniques, except tracing. **Hydrogeology, (statistics of finding features remotely).** There are only 5 well clusters being used to evaluate this site. The statistics of finding openings of a certain width in the subsurface are discussed by (Benson and La Fountain, 1987). If a site of 1 acre is being evaluated and an elliptical object (or opening) of 23 meters in diameter is being sought, it would require that at least 10 3-cm drill holes be used to have a 90% probability of finding the object. If the object is 7 meters in diameter, 100 drill holes would be needed, and for a 2.3 meter size 1,000 drill holes would be needed. The point is that 2.3 meters is a very large feature. For an object of 0.25 m it would require more than 80,000 borings. The message is clear, drilling as a method of site evaluation is severely limited. In fact, as many professional have acknowledged the only way to understand groundwater flow and transport in fractured rocks is by tracing and the best way to evaluate transport initially is by injected tracing and analysis of the recovery curve and the inferred hydraulic components. ☐**Groundwater Basin Boundaries.** It is known that topographically-based groundwater basin (catchment) boundaries rarely are consistent with topographic basin boundaries. This is particularly true in carbonate terrains and is also true in fractured-rock terrains involving clastic rocks. ☐**Lithology.** Care should be exercised when making big distinguishing statements about differences between carbonate, shale, and clastic sequences that are close to each other either stratigraphically or geographically. This is particularly true in East Tennessee, where the Nolichucky Shale becomes progressively more of a carbonate rock the further northeast away from the Oak Ridge area. It does not take much carbonate cement or some small amount of calcite in fractures, some very small, to be removed to make a groundwater pathway, and	The commenter points out the difficulties encountered in characterizing a complex hydrogeologic setting. While this complexity is recognized, subsurface investigations and research on the ORR have clearly demonstrated a significant difference between ground water flow and contaminant transport in the predominantly clastic formations of the Conasauga Group in BCV underlying and downgradient of the proposed EMDF sites, versus flow and transport in the carbonate rocks of the Maynardville Limestone further south of the EMDF sites. Appendix E has been expanded to include much more detail describing the results of several tracer test research projects conducted in the fractured clastic rocks typical of the EMDF sites and the results of tracer tests conducted in the karst associated with the Maynardville and Copper Ridge Dolomite. The results indicate that tracer flow rates in the clastic rocks are several orders of magnitude lower than those in the carbonate rocks of BCV and that matrix diffusion in the clastics plays a critical role in attenuating contaminant migration. Relatively rapid flow rates associated with karst environments common to gypsum and limestone rocks have not been documented in the Conasauga clastics. ORR research has also demonstrated that the bulk of ground water flux occurs in the water table interval within saprolite and shallow bedrock, and that fractures and hydraulic characteristics of this interval can be adequately characterized and modeled. DOE believes that the rigorous engineered features (buffer zone, liner systems, and cap) of the EMDF, combined with the attenuating effects of a significant vadose zone and the clastic rock formations surrounding and south of the sites provide a sufficient buffer to contaminant migration that will provide short and long-term protection of human health and the environment. ***Monitoring wells, etc.:*** Comment is acknowledged. DQO sessions are planned for further characterization in support of detailed design with input from TDEC and EPA. ***Hydrogeology:*** While subsurface access by drilling certainly has its limitations, it remains the only practical alternative to access the deeper subsurface. Every site investigation involving taxpayer funds should strike a reasonable balance between data needs and costs. Tracer tests are recognized as a useful method for understanding flow and transport but they are intensive, specialized efforts that in fractured rocks rely on extensive networks of wells/piezometers. The tracer tests conducted at the WBCV site (former LLWWDD site) involved the drilling, installation, and monitoring of over 72 wells/piezometers across an area on the order of only 300 ft long by 80 ft wide (versus the EMDF waste limit footprint ~1800 ftL x ~600-800 ft W) that required 370 days of monitoring to delineate a 100 ppb dye concentration front at 33m (108 ft) from the injection well. Application of tracer tests to any of the EMDF proposed locations must be decided among DOE, TDEC, and EPA employing the DQO process. ***Groundwater basin boundaries:*** The surface water and ground water regimes in

	eventually breakdown the rock thus enlarging the pathway. Examples of this are known where conduits or channels 70 cm high form along a shale bed, where the bed that has been removed is shale and the roof and floor are relatively pure limestone. It is not safe to assume any lithology such as a clay bed or shale is necessarily impermeable, fractures are present especially in geologically older rocks, and where there has been crustal deformation (such as the Valley and Ridge province). These older rocks are not only heavily fractured but many of the fractures are filled with readily soluble minerals such as calcite. Calcite is the most abundant fracture-filling mineral because the components of calcium and the bicarbonate and carbonate ions are common in most waters and it therefore does not exclude filling fractures. ☐**Potentiometric Maps: Assumptions.** The principal assumption made when constructing a potentiometric map is that the site approximates a porous medium. This is not the case for fractured rocks and carbonates because there is convergent flow to channels and conduits. The fundamental assumptions about porous media, function of wells, and validity of potentiometric maps were discussed in comments on the first draft of the RI/FS. These assumptions also apply to any numerical modeling that is performed using porous-media based modeling codes. This means that the fundamental assumptions problem really puts everything in a state of uncertainty. In fact, there is no case that this reviewer has experienced where the assumptions have been tested and not shown to be violated.	BCV (and elsewhere on the ORR) have been extensively characterized, studied, and reported. Results indicate that surface water and ground water regimes from the east end of BCV down to SR 95 are in fact largely restricted to the area between Pine Ridge on the north and Chestnut Ridge on the south. ***Lithology:*** Comment acknowledged. ***Potentiometric Maps:*** See response to comment S.64 below. The uncertainties discussed are recognized, however, available subsurface characterization methods, site conceptual models, and numerical models (EPM or other model types) are all necessary for understanding and simulating ground water flow and fate and transport at any site. The degree to which there is convergent flow to channels or conduits versus non-convergent flow along discrete individual or sets of interconnected fractures to surface water discharge locations is unknown. Many of the seep areas at the EMDF site may be fed by a sponge-like network of closely spaced fractures that do not necessarily converge into master fractures or conduits.
TDEC.S.059	**Page E-15, 2.1 LOCATION AND SETTING, Paragraph 1, Line 4:** Here the expected area permanently occupied by the EMDF is listed as 60-70 acres. In Table D-5 on page D-38 the approximate footprint for the facility is given as 50 acres.	The distinction between the two is, one is the permanently occupied footprint (60-70 acres including cap, monitoring etc.) and the "footprint" of the facility 50 acres (cap only).
TDEC.S.060	**Page E-41 2.3.3 Ground Water Flow (first paragraph in this subsection):** *"…several lines of evidence converge to indicate that flow systems on the ORR are local, not regional."* The Valley and Ridge province in the Oak Ridge area is characterized by folded and faulted Lower Paleozoic sedimentary rocks that unfortunately have a history that predates DOE Operations in the area. Garven et al., (1993) explain the formation of Pb-Zn deposits in the carbonates as being a result of brine migration across the US Midcontinent, mostly in rocks of the Knox Group. This is regional flow of brines driven by physiographic uplift of the Appalachian Mountains and the flow of brines was driven by meteoric waters. A brine (Appalachian type, when plotted) occurs offsite of the ORR, but there are carbonates beneath it with contaminants and fresher water showing that they are certainly not a lower barrier to the groundwater setting. The local flow we see today in any region (in carbonates) is a result of the landscape and geomorphological changes. Just because there is local flow does not mean there is not still active regional flow that is most likely to be deep. This is particularly the case for East Tennessee and the whole mid-continent area. The hydraulic gradients of the shallow profiles are too steep for regional flow, geochemical and isotopic data suggest that the total mass of contaminants is not contained within and does not discharge through the local discharge points. The reference is made to conduits, but there is no definition of a conduit provided. In fact, this was done by Quinlan et al., (1996) where the criteria used were, the minimum velocity for turbulent flow, which resulted in openings of only a few millimeters. In addition there is reference to flow nets based upon water table head measurements. Is it appropriate to draw flow nets, presumably through several different hydrostratigraphic units, that likely have different hydraulic conductivity values? Also, this hydrogeology must be investigated and	Site conceptual models (SCMs) for the EMDF, for BCV (see the BCV RI Report, SAIC 1997) and for the ORR (See the Hydrologic Framework for the ORR – Solomon et al 1992, and various updates and supplements noted in the EMDF SCM) are based on a considerable amount of hydrological and hydrogeological research and related investigations into contaminant fate and transport. The SCMs and supporting data and studies indicate that the majority of ground water and contaminant flux occurs within the topsoil stormflow zone and within the water table interval of the saturated zone. Flux contributions from within the intermediate and deeper intervals of the saturated zone contribute significantly less as fracture density and interconnectivity generally decrease with depth. This is similarly reflected in the ground water and fate and transport models developed for BCV and the site-specific model applied to the EMDF site. The SCMs and modeling suggest that the fate and transport of potential future releases of contaminants from the EMDF would be locally constrained along downgradient flowpaths in BCV, as are existing contaminant releases in BCV. Additional information on the regional scale ground water flow systems and relationships between brine and fresh ground water on the ORR are addressed in the Groundwater Strategy Report for the ORR and in particular in Appendix J to that report "*Hydraulic and Geochemical Boundaries in the Deep Flow System Underlying the ORR*" (See DOE/OR/01-2628/V2&D1, September 2013). This report is referenced for details that may provide an adequate response to concerns raised here. With regard to the final paragraph of the comment, the reference to conduit flow is merely meant to represent the contrast between rapid flow in bedrock conduits well demonstrated within the Maynardville Limestone versus predominant

	properly defined in 3D. Lots of evidence exists in BCV that shows, gradients are downward from the surface, and at depth there are flatter gradients toward the southwest. The simplest explanation for this is recharge and a permeable zone at depth that is influenced by the regional flow in the Valley and Ridge.	bedrock fracture flow within the predominantly clastic sequence between the Maynardville and the Rome at and downgradient of the EMDF site. Plan and cross sectional views illustrating potentiometric surface data (flow nets) can and should be reasonably applied even in complex settings such as those on the ORR.
TDEC.S.061	**Page E-41** ***2.3.3*** **Ground Water Flow (first paragraph in this subsection, 5th line)**:*"….and interconnected cavity conduits in the Maynardville Limestone."* What are "cavity conduits?" I think comments were made in previous versions that talk about cavities, and how it is conceptually more difficult to form a cavity, which is probably a conduit albeit small, that a borehole has intersected.	Agreed. The text was modified to simply state conduits, not cavity conduits.
TDEC.S.062	**Page E-41** ***2.3.3*** **Ground Water Flow (first paragraph in this subsection, 8th line):** *"Flow on the flanks of Pine Ridge occurs mainly in fractures, with little contribution by open conduits."* Quinlan et al., (1996) show that for a velocity of 0.001 m/s a conduit a few millimeters in diameter can sustain turbulent flow. Please explain how it is known that conduits this small are not involved.	See response above. The text as revised to clarify distinctions between karst conduit flow in the Maynardville versus fracture dominated flow that is believed to occur in the predominantly clastic formations that subcrop at and near the EMDF. It is agreed that relatively higher flow rates can occur in small aperture interconnected fractures or conduits. The text will be revised and uncertainties discussed.
TDEC.S.063	**Page E-44** ***2.3.3.2.1*** **Shallow Aquifer Zone (3rd paragraph):** *"Vertical gradients are generally upward and flow toward the reduced hydraulic head in the Maynardville Limestone (Dreier et al. 1993). The nitrate plume from the S-3 Ponds (DOE 1997) and chlorinated volatile organic compound (VOC) contaminant plumes from the Boneyard/Burnyard (BY/BY) and BCBG areas (DOE 1997; BNI 1984) have been reported to extend down-dip in the Maynardville and Nolichucky formations, but these are density-driven flows, and not the result of downward vertical ground water flows."* This is an interesting description since in Bear Creek Valley it is known that parts of the creek immediately downstream of the proposed facility sink into its own bed, which would mean, after the water entered the ground, downward (in places vertical) flows.	This comment appears to warrant no response. With regard to the words "immediately downstream", it should be noted that the contact between the Nolichucky Shale and the Maynardville Limestone is located approximately 1300 ft south of the southern limits of the waste footprint. Karst features and flow conditions are known within the Maynardville south of that contact along Bear Creek, but have not been reported north of that contact.
TDEC.S.064	**Page E-46, Figure E-15:** The potentiometric contours, although dashed, where there are few data, have been estimated and drawn so they closely mimic topography. Should this be expected in a fractured rock with such steep dip? The dip is steeper than the slope of Pine Ridge or the slopes of the stream channels. It is often not the case that the water table configuration mimics the topography. For example, it does not appear to in Melton Valley (Webster, 1996). Since the potentiometric surface has been estimated and is inferred to mimic topography, if it actually does not the actual flow system would be significantly different (Haitjema and Mitchell-Bruker, 2005). This could have a significant impact on groundwater movement (and managing groundwater discharges) underneath the proposed facility. Has it been established that it is appropriate to draw the potentiometric surface to mimic the topography?	Potentiometric surface contour maps, particularly those drawn for the water table, are a fundamental and commonly accepted tool used to define hydraulic gradients, generalized flow directions, and areas of recharge and discharge – even for areas such as the EMDF underlain by a clayey/silty residuum, saprolite, and fractured rocks. They have been (and will undoubtedly continue to be) used at sites all across the ORR wherever hydrogeology is a matter of concern. The Phase I results indicate that the water table occurs and fluctuates within unconsolidated overburden regolith clayey residuum and saprolite, above fractured bedrock, everywhere except for the spur ridge area underlying the GW-976(I) location. The porosity and permeability of the regolith materials are more likely to mimic those of an equivalent porous medium than those in the deeper fractured bedrock. It is therefore not unreasonable to map the water table surface bearing in mind that detailed flow paths may and will deviate at local scales from the generalized flow paths that might be suggested by the water table contours. Furthermore, it is clear from the spring and seep locations identified at the site that shallow groundwater discharges to these surface water features along the valley floors of the NT-2/NT-3 tributaries, and that shallow ground water may also provide base flow to the stream channels in areas beyond just those where springs and seeps occur. As noted in the footnotes to the drawing and in Section 7.2.3.2 of the Phase I Report (Attachment A to Appendix E), the water table contours were drawn under the

		assumption that the water table intersects with these surface water features and contours were dictated and constrained by stream channel elevations along the NT valley floors. The close connections between shallow ground water and surface water were established by research and site investigations on the ORR long ago and are well known. Is TDEC suggesting that we abandon these as tools in understanding and interpreting ground water flow? What would TDEC offer as an alternative? The water table contour maps in the Webster document cited by TDEC include eight wells encompassing very small areas that are roughly 30 ft in diameter and do not show surface topography for comparison with the water table configuration. It is unclear how these maps invalidate the use of such contour maps. It is understood that a precise definition of hydraulic gradients and heads is scale dependent, and in fractured media, dependent on the nature and extent of interconnected fractures and how well those are characterized.
TDEC.S.065	**Page E-47 2.3.3.2.2 Intermediate and Deep Aquifer Zones, (last paragraph):** The deeper wells in carbonates in Bear Creek Valley (the ultimate fate of under drain water) show: a relatively flat hydraulic gradient toward the southwest, and, a zone of higher hydraulic conductivity at depth. This strongly suggests a deep system is present and flow is to the southwest along the strike. Uranium-series data and a signature from S-3 Ponds (in picket wells) support this conceptual model.	Comment noted; the comment is very generalized with no specifics to define the terms such as relatively flat gradients, higher zones of hydraulic conductivity or what is meant by a deep system. No response appears warranted.
TDEC.S.066	**Page E-50, *2.3.3.3* Aquiclude (top of page):** The name aquiclude is used here because: "*the extremely high salinity of this water indicates little or no ground water movement occurs*" It is not correct to imply that the existence of brines at moderate depth means no ground water movement associated with them. A single huge contradiction to this is brine *migration* that resulted in the formation of the Mississippi Valley type Pb-Zn deposits (Garven et al., 1993). These brines were driven at depth across the US Page 32 of 79 Midcontinent, beginning about 400 million years ago, from the uplifted Appalachians to Missouri and beyond and from the uplifted Ouachita uplift to the Michigan basin and beyond. During this time the whole of the US mid-continent was characterized by carbonate rocks formed in relatively shallow seas. The results of this topographically driven brine migration was formation of the largest stratabound Pb-Zn ore deposits on Earth (Garven et al., 1993). Again, *brine migration in the subsurface* caused this. The fact there is a brine, does not mean there is no ground water circulation near or beneath it. TDEC has documented, in an offsite well, continuous groundwater discharge (fresher groundwater) including continuous discharge of BTEX compounds, from a thin carbonate bed, nearly 200 m below the water table, and also beneath and decoupled from an Appalachian brine. There are also other examples of brines in contact with fresh water, near the surface and deep beneath the water table, decoupled and moving independently of each other at velocities of kilometers per day (Beddows, 2004; Lindgren et al, 2004). There is also incorrect reference use. Note also that referring to Nativ et al., (1997) as a "report" is not appropriate, it is an independently peer-reviewed paper in a scientific journal. Also, if this paper, Nativ et al., (1997), is to be discussed, the paper, plus any comments made, plus the *responses by the original authors to those comments* also have to be discussed. *This did not happen*, so it appears that the comments successfully refute the original paper. This is	The results of characterization of existing ground water contaminant plumes within BCV are presented in several series of longitudinal and transverse cross sections in the BCV RI Report and more recently in the Ground Water Strategy Report for the ORR. The cross sections illustrate subsurface conditions, sample intervals, and contaminant concentration isochrons that define dissolved contaminant types and concentrations from source areas along downgradient flow paths mostly in the Nolichucky Shale and Maynardville Limestone. A systematic review of these sections indicates that the deepest portions of the plumes downgradient of source areas do not exceed depths of approximately 500 ft below ground surface. The plumes also do not appear to increase in depth along downgradient flowpaths. The cross sections also illustrate locations where ground water contamination resurges from the SS springs along the margins of Bear Creek. The results provide direct evidence that contaminant plumes developed over several decades in BCV with source concentrations and quantities in excess of any that would be allowed at the EMDF have not interacted with deeper brines at relatively greater depths (reported in EBCV starting at depths of 1,150 ft below surface). The cross sections suggest that contaminant plumes are more likely to occur within the shallower and intermediate levels of the fresh ground water regimes and be influenced by surface water/ground water interactions within karst features along the axis of Bear Creek than the very deep ground water regime or the even deeper zone of brine. Regarding the references to Nativ et al (1997), Secion 2.3.3.3 first makes reference to Nativ et al (1997) which is an ORNL report, not a peer reviewed paper in a scientific journal. The second separate reference to Nativ (1997) was intended to actually reference an article by Nativ et al (1997) published in the Journal of Ground Water [i.e - Nativ, R., Halleran, A., and Hunley, A. 1997. "*Evidence for ground water circulation in the brine-filled Aquitard, Oak Ridge,*

	hardly the case, because the original authors respond to the comments, and successfully defend their original position. This must be correctly referenced and correctly stated in the document. The Nativ et al (1997) reference provides evidence of deep circulation of meteoric water, which is what the evidence from the geology, contaminant and geological history support. In terms of how strong this evidence is, the original authors point out that the stable isotope data show a meteoric water signature at depth. This shows that meteoric water circulates deep beneath the ORR and for it to retain this signature, it must have a substantial volume and be connected to recharge and discharge. The response must be reflected in the document. The way the Nativ et al., (1997) reference is misused and misquoted casts doubt on this document and anything that is written in it.	*Tennessee*" Groundwater, v. 35, no. 4: 647-659], to which Moline et al responded. TDEC is correct in noting the counter response by Nativ et al, not described in Section 2.3.3.3. Interested parties should consult all of the original reports and papers for details, conclusions, and interpretations. A recent 2014 article addressing constraints on upward migration of brine is available in Ground Water, Vol. 52, No. 1.
TDEC.S.067	**Page E-66, 2.6.2.2 Aquatic Resource Monitoring in Bear Creek, Paragraph 1, Lines 2-4:** The statement "*The stream habitats of upper Bear Creek and its tributaries are used infrequently by aquatic biota because of headwater contamination originating from waste disposal sites near the Y- 12 Plant (Southworth, et al. 1992)*" is not quite accurate. Despite its inadequacies BCK 12.34 supports small populations of the intolerant to pollution benthic taxa of Pycnopsyche luculenta, Chimarra sp., Neophylax spp. (perhaps 2 species), Optioservus sp., Rheopelopia sp. and Psilotreta sp. Also, although portions of Bear Creek go dry in the summer, portions of the stream support a rather healthy community of benthic macroinvertebrates. Intermittent streams in the Cumberland Plateau region of Tennessee often support a very healthy fauna. In dry periods much of the benthic fauna may migrate to the hyporheic zone of the stream.	Agreed. Text was revised.
TDEC.S.068	**Page E-67, Paragraph 2, Lines 1-3:** The statement "*Benthic fauna appear to be more sensitive to contaminants than the fish communities; species intolerant of pollution (mayflies, stoneflies, and caddisflies) are absent in the upper reaches of Bear Creek and are increasingly more common downstream*." is not accurate. See comment 65 above.	Comment appears to actually refer back to the preceding comment S.67 (not 65) - Agreed. Text was revised
TDEC.S.069	**Page E-67, Paragraph 3, Lines 3-7:** Regarding the statement "*Fish surveys near the headwaters demonstrate a stressed condition without a stable, resident fish population (Southworth, et al. 1992). A weir located in the creek near Highway 95 acts as a barrier to movement, preventing redistribution of fish species from the lower portions of Bear Creek*.", headwater streams typically don't support very diverse fish fauna. Also, wasn't the weir removed a number of years ago?	Agree. Text was revised. Site reconnaissance indicates that the former weir just upstream of SR 95 has been removed.
TDEC.S.070	**Page E-68, Paragraph 1, Lines 1-3:** Regarding the statement, "*The number of species at BCK 12.4 and NT-3 fish communities is below that of a comparable reference stream (Mill Branch kilometer 1.6), particularly during dry seasons. This has been attributed (DOE 2012) to the greater proportion of stream flow that is provided by contaminated ground water*." Mill Branch 1.6 is a much larger water body than either BCK 12.4 or NT-3. Regardless of other factors, one would expect the fish fauna to differ considerably.	Text was revised.
TDEC.S.071	**Page E-69, Paragraph 3, Lines 6-9:** Regarding the statement "*These results indicate that conditions in NT-3 become less suitable for invertebrate species that normally inhabit small headwater streams as summer progresses, probably due to poor in-stream habitat quality and poorly developed riparian zone (Peterson, et al. 2009)*.", even in pristine headwater streams there is a distinct difference between spring and fall fauna. The majority of the benthic macroinvertebrate fauna emerge as adults in the early to late spring. If there are to be existing populations of these species the following year, they would have to be present in the fall as either eggs or early instar larvae which would be much more difficult to collect and identify.	Comment noted.
TDEC.S.072	**Page E-69, Paragraph 5:** Regarding the aquatic life stream survey, a more extensive survey with more specific identifications would be warranted.	As noted in response above, no additional surveys are warranted until after consensus is reached on a site location among DOE, TDEC, and EPA.

TDEC.S.073	**Page E-70, 2.6.3.1 Terrestrial Flora, Paragraph 1, Lines 7-8:** *Magnolia grandiflora* is mentioned here as part of the understory in the forests of the Oak Ridge Reservation. Although 2 species of magnolia are listed in Kitchings and Mann 1976, neither of them was this species. No mention of *Magnolia grandiflora* was found in the cited document.	Comment noted. Text was revised.
TDEC.S.074	**Page E-71, Paragraph 2:** Along with the whitetail deer, Elk are also occasionally sighted on the Oak Ridge Reservation. See: ORNL/TM-2011/323, *Environmental Survey Report for ORNL: Small Mammal Abundance and Distribution Survey Oak Ridge National Environmental Research Park 2009–2010*, Neil R. Giffen, R. Scott Reasor, Claire A. Campbell. Date Published: September 2011.	Comment noted. Text was revised.
TDEC.S.075	**Page E-71, 2.6.3.3 Avifauna, Paragraph 1, Lines 2-4**: "*Colantes auratus*" should be "*Colaptes auratus*". "*Centurus carolinus*" should be "*Melanerpes carolinus*". "*Dendrocopos villosus*" should be "*Picoides villosus*". "*D. pubescens*" should be "*P. pubescens*".	Text was revised.
TDEC.S.076	**Page E-71, 2.6.3.3 Avifauna, Paragraph 2, Paragraph 3, Lines 1-4, 1:** "*Oporonis formosus*" should be "*Geothlypis formosa*". "*Dendroica pinus*" should be "*Setophaga pinus*". "*Seirus aurocapillus*" should be "*Seirus aurocapilla*". "*Parus cardinensis*" should be "*Poecile carolinensis* ". "*Parus bicolor" should be* "*Baeolophus bicolor"*. "*Buteo lineatus*" should be "*Buteo jamaicensis*"	Text was revised.
TDEC.S.077	**Page E-71, 2.6.4 Results of Recent Surveys at the EMDF Site, Paragraph 1 and Page E-72 :** "*Carpus caroliniana*" should be "*Carpinus caroliniana*". "*C. pallida*" (sand hickory) does not appear to occur on the Oak Ridge Reservation. "*Q. prinus"* (chestnut oak) is not the currently accepted name. Should be "*Q. montana"*. Also, the name "*Q. prinus*" is used twice in paragraph 3 on page E-72.	Text was revised.
TDEC.S.078	**Appendix E – Attachment A., Section 7.2.3.3 Horizontal and Vertical Ground Water Gradients, Page 73, Paragraph 2.** "*It should be noted that the relatively large open hole intervals in the deep wells (and large screened interval in GW-968[I]) result in a composite hydraulic head distributed across the entire interval in each of the deep wells."* There is a transmissive-weighted average of the hydraulic head from the different flow zones in open hole intervals (LeBorgne, 2005). Essentially, the head from the fracture with the greatest yield will control the head in a borehole. Therefore, the uncertainty may not be so undefined.	Agreed.
TDEC.S.079	**Appendix E – Attachment A., North-South Cross Section Through Phase 1 Well Clusters.** It is pretty evident that the model predicted water table [Post Construction, Steady-State Ground Water Flow Conditions] is wrong. There are no engineering changes that would affect the water levels in the Rome formation or upgradient of the proposed EMDF facility, thus this formation will continue to be a source of water above the proposed landfill after construction.	The impacts to existing surface water and ground water conditions following construction, capping, and closure are reviewed in Section 8.2 of the EMDF Phase I Characterization Report (Attachment A to Appendix E), including the remaining recharge zone across the narrow zone along the uppermost part of Pine Ridge underlain by the Rome Formation. A new Section 2.9 has been added to the D4 version of Appendix E to more comprehensively address the anticipated changes to the water table during and after landfill construction. Also, please review Section 8.2 of Attachment A for details supporting the future anticipated water table decline shown on Plate 3. The underdrain system in conjunction with the elevated levels of the geobuffer, liner, and waste above current topography, and the major reduction in infiltration and recharge across the EMDF footprint should result in a significant lowering of the water table surface as shown in Plate 3 and as described in detail in the new Section 2.9. The predicted lowered surface of the water table is reasonable based on current hydrogeological, engineering, and

		modeling insights. The future water table decline should be examined in greater detail during the detailed engineering design process to ensure declines are consistent with design and regulatory requirements.
TDEC.S.080	**Exhibit A.9, Packer Test Documentation, Packer Test Summary Sheet and Table 14 Hydraulic Conductivity Data from Packer Tests, Page 85.** The packer test data looks like a modified Lugeon test for conductivity. No real description was given in the Appendix E for test methodology. However, with a lugeon test there are usually 5 test stages which help determine the lugeon value and its interpretation. If using limited information (which it appears was done), then there should be reporting of the lower and higher conductivity values during the test, rather than representative values.	The packer test methodology is actually presented in Section 4.1.6.2 (p. 14-15) of Attachment A to Appendix E, including the equation on which K values are determined. Results presented in Table 14 are presented for each constant pressure test bracket per tested interval along with the average value for each interval. All values (low/high) are shown in Table 14 with detailed spreadsheet data in Exhibit A.9. References serving as the basis for the testing methodology are provided in Section 4.1.6.2. The tests appear to share some similarities to Lugeon tests but are not directly equivalent.
TDEC.S.081	**Page G-5, Paragraph 2:** *"The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) Section 121(d) (see United States [U.S.] Code Title 42, Chapter 103, Section 9621{d}), as amended, specifies that remedial actions for cleanup of hazardous substances must comply with requirements and standards under federal or more stringent state environmental laws and regulations that are applicable or relevant and appropriate to the hazardous substances or particular circumstances at a site, or obtain a waiver under 40 Code of Federal Regulations (CFR) 300.430 (f)(1)(i)(B) and (C)."* The list of applicable or relevant and appropriate requirements (ARARs) in Appendix G is not complete. If CERCLA is to provide the legal authority for on-site disposal of radioactive, hazardous, and toxic waste on the Oak Ridge Reservation, DOE, EPA, and TDEC should jointly compile a more extensive list ARARs. For example, federal and state rules that implement portions of the Clean Water Act and Safe Drinking Water Act such as water quality criteria that would continue to regulate releases of contaminants to groundwater and surface water from the facility after closure are not listed as chemical specific ARARs in Table G-1. Other examples, discussed on pages G-7 through G- 9 of this appendix, are the substantive portions of TDEC Rule 0400-20-11, *Licensing Requirements for Land Disposal of Radioactive Waste.* See comments on pages G-8 and G-9.	The list of ARARs in Appendix G has been revised with input from both TDEC and EPA, as suggested by this comment. The implementation of SDWA and CWA is addressed through the Remedial Action Objectives (RAOs) in Chapter 4. See corresponding responses to comments on G-8 and G-9.
TDEC.S.082	**Page G-6, Paragraph 6:** *"The On-site Disposal Alternative would comply with all ARARs with the exception of the following two requirements for which waivers would be requested…"* As stated in comments on page G-5, TDEC does not agree that all requirements that are applicable or relevant and appropriate for on-site disposal of CERCLA generated waste in Oak Ridge have been properly identified. Likewise, TDEC does not agree that only two waivers of such requirements would be necessary to legally authorize disposal of radioactive, hazardous, and toxic waste on the Oak Ridge Reservation under CERCLA. One example could be substantive portions of Tennessee Rule 0400-12-02-.03, *Siting Criteria for New Commercial Hazardous Waste Management Facilities*, which are arguably relevant and appropriate. Specifically, part 1 of subparagraph (2) (e) of this rule might require a waiver. TDEC also believes that waivers of some requirements based an equivalent standard of performance (40 CFR 300.430 (f) (ii) (c) (4)) may not be possible, or at least not economically feasible, for the preferred alternative. Examples might include specific siting criteria for radioactive, hazardous, and toxic waste disposal facilities from TDEC rule 0400-20-11-.17, TDEC rule 0400-12-02-.03, and 40 CFR 761.75[b], respectively. In one form or another, these requirements all prescribe that the site provide sufficient buffer to mitigate the impacts of a release from the facility and to implement corrective actions, if needed, to further restrict migration of contaminants. A site constructed over an underdrain that discharges to a stream is unlikely to	Agreement has been reached on including ARARs for NRC-based TDEC rules regulating LLRW as 'relevant and appropriate' and DOE Order (Manual) references as to be considered (TBC) guidance. Justification for waivers proposed, and further evidence for meeting other requirements is given in the revised (D4/D2) document.

	provide such a buffer.	
TDEC.S.083	**Page G-7, Paragraph 4 et seq:** "**3. ROLE OF NUCLEAR REGULATORY COMMISSION REGULATIONS AND DOE ORDERS**" In summary, this section proposes that NRC low-level waste regulations, and more specifically, their analogue in Tennessee Rule 0400-20-11, which contains the licensing requirements for land disposal of radioactive waste, should not be listed as ARARs. The RI/FS argues that these rules are not applicable due to an exemption under the Atomic Energy Act and not appropriate because all requirements of Chapter 0400-20-11 relevant to radioactive waste disposal on DOE facilities have been incorporated into DOE Orders and hence, are redundant. However, the requirements of DOE Orders are not identical to TDEC rules, as acknowledged on page G-8, with TDEC rules offering more prescriptive regulation of site selection and DOE Orders prescribing more detailed guidance for performance assessment. The lines of authority and accountability for enforcement of the requirements written into a Record of Decision (ROD) by the three parties of the Federal Facilities Act (FFA) also differ substantially from those that enforce DOE Orders. If TDEC is to be, jointly with EPA and DOE, responsible for enforcement of the requirements of the ROD, then the ROD should incorporate TDEC rules that state personnel have the experience and training to properly enforce. Disposal of radioactive waste under the authority of DOE Orders could provide an equivalent level of protectiveness to public health and the environment, but it will not provide an equivalent means for TDEC to enforce regulations that assure protection of public health and the environment.	Agreement has been reached on including ARARs for NRC-based TDEC rules regulating LLRW as 'relevant and appropriate' and DOE Order (Manual) references as to be considered (TBC) guidance.
TDEC.S.084	**Page G-8, Paragraph 4, Last Sentence:** "*Conversely, 10 CFR 61 requirements that are not incorporated into DOE O 435.1-1 do not meet the "appropriateness" criteria and, as such, are not regarded as "relevant and appropriate" for DOE environmental restoration sites.*" This is simply a conclusion and not an argument. This text does not provide enough of the background on the process of development of the DOE Order to allow evaluation of this position. Clearly, the state LLW disposal standards are not applicable, but in almost an equally clear fashion they are "relevant and appropriate" in general. Any decisions on specific provisions not being "appropriate" should be made a much higher level of detail.	Agreement has been reached on including ARARs for NRC-based TDEC rules regulating LLRW as 'relevant and appropriate' and DOE Order (Manual) references as to be considered (TBC) guidance.
TDEC.S.085	**Page G-8, Paragraph 5**: "*An example of this process is site selection for a new low-level radioactive waste disposal facility. As discussed in DOE Guide (G) 435.1-1, initial site selection for a new DOE low-level waste (LLW) disposal facility accepting only DOE waste is limited to the DOE reservation, focusing on identifying the best site within the reservation. This is different from the way sites are selected for commercial NRC-licensed LLW disposal facilities, which are selected from large geographic areas where ownership of the land may be under private or public control. Site selection processes for commercial facilities are directed toward identifying sites that meet geographic suitability requirements, considering seismic, hydrogeological, archaeological, and other physical conditions.*" These requirements are to protect health, safety and the environment and are designed to minimize releases to the environment and to mitigate impacts in the event of a release. All these requirements are about managing environmental risk.	Agreement has been reached on including ARARs for NRC-based TDEC rules regulating LLRW as 'relevant and appropriate' and DOE Order (Manual) references as to be considered (TBC) guidance.
TDEC.S.086	**Page G-8, Paragraph 5:** "*While relevant, the suitability criteria are not appropriate since they are not well-suited to the site given the type of facility regulated by the state (a commercial, licensed LLW disposal facility) and the type of facility contemplated by the DOE CERCLA action (a non-commercial, non-licensed LLW disposal facility located on DOE property accepting only DOE waste).*" Refer to the previous comment as well. It is unclear why the performance objectives for a DOE	Agreement has been reached on including ARARs for NRC-based TDEC rules regulating LLRW as 'relevant and appropriate' and DOE Order (Manual) references as to be considered (TBC) guidance.

	site would be different than minimizing the potential for releases and mitigating the impact in the event of any releases. Both public and private wastes are radioactive. Any argument of this nature should involve a comparison of isotopes and characteristics (such as alpha, beta, gamma particles; half-lives, curies, etc.) The commercial/public distinction is irrelevant in and of itself to environment risk.	
TDEC.S.087	**Page G-8, Paragraph 5:** "*This can lead to DOE sites being selected that are located adjacent to or within land previously contaminated.*" The statement referring to site selection on site and in areas of prior disposal leads to the comment that an option not considered would be a site with better hydrogeology that would actually be located in the general area of the Bear Creek Burial Grounds where there have been releases of uranium measured entering the Clinch River. All or parts of this area such as around the S-3 ponds having a remedy not meeting goals in the interim ROD for Bear Creek Valley should be part of the on-site options if this policy were really being applied carefully.	A site that infringed on the Bear Creek Burial Grounds was considered, but was ruled out due to the extent of existing contamination and the extreme cost associated with removing that media and incorporating its remediation in the construction of a new disposal facility.
TDEC.S.088	**Page G-8, Paragraph 5:** "*DOE G 435.1-1 states that "[i]t is not intended that the 435.1 criteria be used as exclusionary conditions to eliminate a site from being considered, but instead provide a measure of evaluation of the site's contribution to performance of the disposal facility. Use of existing facilities on DOE reservations should be considered to the extent practical." (see DOE G 435.1-1, Chapter IV, pp.123–124).*" While Tennessee could accept this argument about 435.1 criteria not being exclusionary in general, many of the specific sites screened in the RI/FS and the ones with the larger capacity are located in areas where there are concerns about depth to water table, karst and perhaps highly-developed karst with conduit flow and very rapid transport in which releases would migrate rapidly and not attenuate. Tennessee would submit that DOE's performance objectives should be to confine the wastes in long-term performance and not just delay the releases or allow the releases to occur gradually because of slow failure of areas of engineering systems that cannot be expected to compensate for a bad site.	DOE recognizes that no disposal facility features, man-made or natural, can contain contaminants in a land disposal facility completely and indefinitely regardless of the intrinsic site characteristics. DOE understands and has stated that East Tennessee is not an ideal area to dispose of mobile waste contaminants. However, DOE further recognizes that engineered disposal facility features can provide a measure of containment that combined with a site's less than ideal features, will maintain risk within an acceptable limit. In terms of the facility DOE is proposing for the ORR, those engineered features, in combination with attaining the CERCLA risk goals through limiting waste entering the facility, will allow compliant and safe disposal of the majority of future CERCLA waste on the ORR. See other responses for descriptions of engineered features.
TDEC.S.089	**Page G-9, Paragraph 1:** *"Since DOE is specifically exempted from NRC regulations and the TDEC rule equivalents, and has equivalent requirements in its internal orders, it is, per EPA's own language, inappropriate and unnecessary to cite these as relevant and appropriate requirements."* DOE is free to use its internal guidance and develop a site strictly for LLW free from the use of these ARARs, but a lot of material is mixed waste and subject to RCRA jurisdiction and Tennessee is an authorized state having its own hazardous waste program of equivalent stringency. And the DOE Orders themselves should themselves be identified as To Be Considered (TBC). So, in addition to state LLW disposal rules including siting criteria, the DOE Order should either be identified in a table as TBC or could be placed in narrative and could control in circumstances in which the DOE order would be more stringent and more protective of the environment.	Agreement has been reached on including ARARs for NRC-based TDEC rules regulating LLRW as 'relevant and appropriate' and DOE Order (Manual) references as to be considered (TBC) guidance.
TDEC.S.090	**Page G-9, Paragraph 2:** *"CERCLA Section 121(d)(4) allows for waivers of ARARs under certain circumstances for CERCLA actions.* It must be said here that it appears that the obvious reason for the arguments about not identifying state LLW rules as "relevant and appropriate" in the previous section is to take shortcuts for waivers of ARARS without adequate factual support and justification.	State NRC-based radioactive (LLW) rules were not included in the D3 RI/FS because DOE is self-regulated under the AEA, and as pointed out, DOE is specifically called out in the regulations as excluded from their enforcement. The DOE has not here, or ever, made decisions to intentionally avoid federal or state environmental regulations that may apply.
TDEC.S.091	**Page G-9, Paragraph 2:** *"For this On-site Alternative, waivers for two requirements will be requested, as follows:*	The water level issues noted at the EMWMF are believed to be largely the result of not having installed an underdrain network as part of the original EMWMF

	☐*A hydrologic conditions requirement under TSCA specifies that there be no hydraulic connection between the site and standing or flowing surface water and the bottom of the landfill liner system or natural in-place soil barrier of a chemical waste landfill must be at least 50 ft. above the historical high water table (40 CFR 761.75[b][3]). Construction of a disposal facility at the EMDF site evaluated under the On-site Disposal Alternative would not meet this TSCA requirement.* ☐*The RCRA LDRs (40 CFR 268 et seq.) prohibit the placement of untreated hazardous waste in land disposal units. DOE proposes to treat characteristic mercury-contaminated demolition debris by macroencapsulation in specially constructed forms within EMDF cells. Debris would be treated within a short time after placement, and any stormwater or other liquids would be collected and treated so that no contaminants exit the forms. A waiver will be requested to allow this operational approach to be implemented, as an interim action. Once treatment of the waste forms is completed, all applicable and relevant and appropriate requirements will have been met."* The argument made for the waiver of the depth to water table required by 40 CFR 761.75[b][3] is not unreasonable, but has proven not to be true in the case of the EMWMF, where water levels have been and may continue to be near the top of the buffer in some areas under the facility. The argument for waiving the requirement that there shall be no hydraulic connection between the site and standing or flowing surface water would only be valid if the water from the proposed underdrain were permanently prevented from entering NT-3, the discharge point for the underdrain and a tributary to Bear Creek, or any other surface waters, prior to treatment. While the Demolition and Decontamination (D & D) of the West End Mercury Area buildings is not within the scope of this RI/FS, some of the characterization has been referenced in this draft RI/FS. There are concerns that some mercury that can be recovered as free mercury would then need to be subject to recovery as free mercury and treated by RMERC. Although there is precedent for this Page 39 of 79 approach in Hanford, http://pdw.hanford.gov/arpir/pdf.cfm?accession=0090734, the documentation is at much greater level of detail. Specifically, the level of detail in this draft report is inadequate for the state to evaluate either the basis for macro encapsulation effectively under RCRA or the larger issue of whether the proposed off-site cell treatment is protective under CERCA 121(a). The methods used to characterize and demolish the buildings that will generate waste containing mercury at concentrations above LDR, the method of transportation to the disposal facility, and the placement of debris in the facility may all impact the effectiveness of various encapsulation technologies.	design, and subsequent retrofitting of a single underdrain that did not extend up along the entire length and trace of the former NT-4 stream channel/valley floor. This is particularly true for the upper section of the former NT-4 valley where the noted high water levels have been detected (near PP-01) and where no underdrain exists to allow for more active local ground water drainage. With regard to a waiver for hydraulic connections, the underdrain is clearly designed to act as a drain for shallow ground water, not as a drain for surface water. The original stream channels with intermittent seasonal flow will be eliminated during construction and remaining upslope surface water sheet flow runoff and topsoil stormflow zone runoff would be captured and diverted to the sides of the landfill. The underdrain system is within the upper ground water zone, drains ground water from the water table and upper intermediate ground water intervals and is isolated from any surface water runoff. The underdrain is a relatively high permeability subsurface gravel channel that drains ground water flowing mostly laterally below and across the EMDF footprint and is not equivalent to standing or flowing surface water. Ground water drainage below the EMDF would exit at the underdrain outfall locations into existing surface water stream channels along NT-2/NT-3 tributaries and subtributaries *outside of the landfill footprint*. It is not technically feasible or cost effective to eliminate all elemental mercury from Y-12 facility demolition debris. Appendix C revisions emphasize pre-demolition mercury abatement and recovery measures to ensure that mercury content of demolition debris is as low as reasonably achievable. Recovered elemental mercury and secondary wastes associated with mercury abatement will be sent to onsite or off-site facilities for treatment and disposal as necessary. The D4 RI/FS has been modified and in-cell macroencapsulation (ICM) of mercury debris at an on-site facility is presented only as a possibility for consideration in Appendix C; ICM is not part of an alternative in the revised document. Appendix C presents a discussion of the RCRA regulatory path to include ICM for an on-site remedy. See revised Section 5.1.4.
TDEC.S.092	**Page G-10, Paragraph 5: "***The waiver for temporary placement of untreated wastes within one or more landfill cells is justified on the basis that it is an interim action that is a part of a total remedial action that will achieve the LDR requirements at completion, as allowed under CERCLA section 121(d)(4)(A) and 40 CFR 300.430(f)(1)(ii)(C)(1). An April 24, 1991 memorandum from the EPA Office of General Counsel (L. Starfield) to S. Golian, Chief, EPA Remedial Guidance Section, and L. Boornazian, Chief, EPA CERCLA Compliance Division, concurred with a very similar approach at the Wasatch Chemical Superfund site (accessed at www.epa.gov/superfund/policy/remedy/pdfs/memo42491-s.pdf). This waiver request is limited to temporary placement for treatment, and does not affect other aspects of LDR compliance.* Refer to earlier comments about lack of detail in evaluation of this proposal and, more specifically, how it would be equivalent to a CAMU. The website for the ROD is: http://www.epa.gov/superfund/sites/rods/fulltext/r0891048.pdf	The D4 RI/FS has been modified and in-cell macroencapsulation of mercury debris at an on-site facility is presented only as an option for consideration in Appendix C; ICM is not part of an alternative in the revised document. Appendix C presents a discussion of the RCRA regulatory path to include ICM for an on-site remedy. See revised Section 5.1.4.

	And this ROD is not nearly as relevant as the Hanford example discussed above. Here we reiterate our previous concerns regarding both the CAMU- equivalency for placement and the high concentration mercury waste sometimes in free elemental form. Even if an ARAR waiver were granted, concerns remain about the in cell approach for macro encapsulation and protectiveness for the debris waste streams from the WEMA and the concentrations of mercury in this debris. Protectiveness of the remedy is one of two threshold criteria that must be satisfied and cannot be waived like an ARAR, see CERCLA 121(d)(1), 42 USC 9621(d)(1): '*Remedial actions selected under this section or otherwise required or agreed to by the President under this chapter shall attain a degree of cleanup of hazardous substances, pollutants, and contaminants released into the environment and of control of further release at a minimum which assures protection of human health and the environment. Such remedial actions shall be relevant and appropriate under the circumstances presented by the release or threatened release of such substance, pollutant, or contaminant. It must be said here that it appears that the obvious reason for the arguments about not identifying state LLW rules as "relevant and appropriate" in the previous section is to take shortcuts for waivers of ARARS without adequate factual support and justification.*'	
TDEC.S.093	**Page H-8, Paragraph 1:** "*The purpose of this Appendix is to develop preliminary analytic concentration limits for contaminants of potential concern (COPCs), referred to as Preliminary Waste Acceptance Criteria (PreWAC), which would meet the applicable risk and dose criteria specified in the remedial action objectives (RAOs), using fate and transport analysis based on a resident farmer scenario for the proposed Environmental Management Disposal Facility (EMDF).*" TDEC does not agree that the resident farmer scenario used in this document is adequate to provide a basis for demonstrating that the preliminary WAC computed here for the proposed facility will protect human health and the environment. The resident farmer scenario does not consider groundwater impacts except at the point of water extraction 460 meters from and oblique to flow paths from the proposed disposal facility. Impacts to surface water quality are not considered except in the context of their contribution to human health risk via livestock watering and plant irrigation.	The revised PreWAC in the D4 RI/FS have been calculated under the bounding assumption that, within the 1000 year compliance period, appropriate TDEC AWQC are met at the surface water point of exposure in Bear Creek to demonstrate water resource protection and ecological protection.
TDEC.S.094	**Page H-8, Paragraph 1:** "*This analysis provides the basis for demonstrating that the proposed EMDF conceptual design and site would be protective of human health and the environment and be a viable disposal option for most future Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) waste.*" Because sites on the Oak Ridge Reservation offer little in the way of environmental buffer to attenuate releases of hazardous or radioactive material, robust facility design and restrictive waste acceptance criteria are the only avenues available for effective protection of human health and the environment in Tennessee. Consequently, a detailed site characterization, detailed design, and final waste acceptance criteria are necessary to show that CERCLA remedial action objectives will be met, and should be completed prior to seeking regulatory agreement for authorization to dispose of future CERCLA generated waste on the ORR.	The revised RI/FS presents more justification of the facility design that demonstrates robustness and longevity of engineered features, which are given credit for maintaining protectiveness of the public and environment. More restrictive PreWAC are the result of incorporating comments by both TDEC and EPA regarding modeling and modeling assumptions. DOE feels the revised RI/FS demonstrates fully that on-site disposal in a new engineered facility is feasible, and meets the CERCLA RAOs. However, as a feasibility study that now includes multiple siting options, and not a decision document, detailed site characterization is not at this time proposed by DOE. Detailed design is not undertaken for a site that may not be approved by all parties. Final WAC will be a tri-party undertaking, to be fully defined in a primary WAC Attainment (Compliance) Plan. It is noted that portions of administrative WAC have been added to the revised RI/FS, as well as a flowchart delineating waste that is excluded from on-site disposal (see Revised Section 6.2.3 for new flowchart and table of administrative WAC limits).

TDEC.S.095	**Page H-8, Paragraph 3:** "*A negotiated waste acceptance criteria (WAC) attainment process was developed for the EMWMF(DOE/OR/01-1909&D3), which involves the designation of four separate types of WAC requirements (DOE 2001a) to define and limit acceptable wastes. Similar triparty negotiations would result in a WAC attainment process for this proposed on-site facility to be documented in a primary Federal Facility Agreement (FFA) document, the WAC Attainment Plan (see Section 1.2 for more information).*" Based on experience at the EMWMF, TDEC does not believe that a negotiated WAC is the best way to protect human health and the environment. TDEC was concerned with the validity of fate and transport modeling to establish analytic WAC for the EMWMF, so negotiations between FFA parties were used for the EMWMF as a means to establish protective WAC. Based on current information, TDEC is not convinced that the resulting WAC will be protective in the long term. WAC should be derived from a credible risk assessment that is consistent with whatever WAC limitations may ultimately be imposed by the requirements of DOE Orders. DOE should obtain a Disposal Authorization Statement for any new radioactive waste disposal facility on the Oak Ridge Reservation prior to finalizing the CERCLA risk assessment and establishing waste acceptance criteria.	DOE will seek a preliminary DAS before ROD approval. The process has begun, and a preliminary/draft Composite Analysis has been completed. Results of reviews by LFRG will be shared with TDEC and EPA. This LFRG involvement will also supersede the establishment of WAC in a primary WAC Attainment (Compliance) Plan. Additionally, see the revised RI/FS for a modified Preliminary WAC (PreWAC) that places more stringent limits on multiple isotopes.
TDEC.S.096	**Page H-9, Paragraph 5:** "*The sum of fractions (SOFs) calculation method is applied to each waste lot to account for the presence of multiple contaminants. To consider incorporation of that waste lot into the entire EMWMF landfill, a volume-based weighting factor is applied to the SOF of each waste lot for all waste lots already in the landfill, waste lots proposed for acceptance in the landfill, and some forecasted future waste lots to determine a "landfill-wide" SOF. This method is referred to as the volume-weighted sum of fractions (VWSF), which allows an evaluation of the acceptance of a waste lot into the disposal facility as a whole.*" TDEC has requested repeatedly that the approach used at the EMWMF to establish waste acceptance criteria (WAC) and implement WAC attainment be changed for any proposed facility for land disposal of CERCLA waste. When waste density is highly variable, as has been the case at EMWMF, the volume weighted sum of fractions method discussed here creates a disconnect between the measure of radioactive or hazardous material in the facility and the actual mass or Curie content in the waste, which is the quantity that drives risk. If the less dense material is cleaner than the more dense material, the facility may be loaded with more contamination than the risk assessment based directly on mass or activity would allow. TDEC experience at the EMWMF has also shown that having no fixed limits (other than administrative WAC) that exclude waste from the facility complicates auditing and validation of compliance with WAC.	DOE agrees that the approach used at EMWMF (VWSF) will be modified, as is written on the next page (H-10) of the document (underlining added for emphasis): "If on-site disposal is the selected remedy as determined by the CERCLA process, final analytic WAC for a new facility will be developed based not only on mobility in the environment and hypothetical receptor exposure, but also on external exposures to inadvertent intruders as required by DOE Order (O) 435.1, and will continue to demonstrate achievement of the RAOs and any applicable or relevant and appropriate requirements. They will be documented in a primary, tri-party-approved FFA document (WAC Attainment Plan). Administrative, ASA-derived, and physical WAC, along with a process to determine attainment of the WAC, will be negotiated and documented in the WAC Attainment Plan. <u>The method or process to determine attainment of the WAC may differ from the attainment process described above (VWSF) for the EMWMF."</u> The quoted text in this comment was only discussing the current method used at EMWMF, as it states.
TDEC.S.097	**Page H-14, Paragraph 2:** "*An inadvertent intruder (e.g., someone digging through the final cap and being directly exposed to the waste after landfill closure) will be examined as part of the DOE O 435.1 compliance.*" Risk assessment under CERCLA should include sufficient exposure scenarios to be compatible with those mandated under DOE Orders and those prescribed by Tennessee rules for disposal of radioactive waste."	DOE agrees. The risk assessment in the RI/FS is noted clearly as developing Preliminary WAC. DOE O 435.1 requires an intruder analysis, and one will be completed for the selected site within the next year. Results of this analysis will be provided to regulators for review. If any modifications to Preliminary WAC are required upon completion of the intruder analysis, those will be made prior to finalization of the WAC, and documented in the tri-party Primary Document, WAC Attainment (Compliance) Plan.
TDEC.S.098	**Page H-14, Paragraph 3: "***In accordance with current practices in Tennessee, the upper, more active weathered bedrock part of the unconfined aquifer (nominally a 30–50 ft. stratum between the water table and competent bedrock) would not be used for domestic water supplies.*"	The TDEC Rules (0400-45-09-.10) indicate that at least the upper 19 ft of overburden materials are normally isolated from water wells to protect from potential surface contaminants that may impact shallow ground water. TDEC well completion records available for the Bethel Valley and Clinton quadrangles indicate a mean depth of isolation casing of 77 ft below ground surface (median

	What is the basis for this statement? A variety of practices are used in the state. See Tennessee Rule 1200-4-9-.10, Well Construction Standards, for information on compliant well completion in Tennessee."	values closer to 60 ft). At the current (D4) hypothetical water well locations, the assumed well screen interval corresponds to 80 to 160 ft below ground surface, consistent with the local field data. Modifications to the depths and intervals of the water well intake zone may result in higher or lower concentrations depending on relationships between the assumed well location(s), construction details, and the 3D plume concentrations. For the revised groundwater well locations in the D4 RIFS (refer to Appendix H, Figure H-3), sensitivity of the simulated contaminant concentration in drinking water to the choice of well screen interval has been evaluated in Appendix H Section 4.5.1.
TDEC.S.099	**Page H-16, Paragraph 1:** "*A further key assumption in the resident scenario development and risk evaluation is the location of the hypothetical receptor. As this is the location at which the proposed alternative must meet the CERCLA defined risk criteria (e.g., 10-4 to 10-6 Excess Lifetime Cancer Risk [ELCR]), it is appropriate to look to CERCLA guidance on placement of the future hypothetical receptor. Per EPA's Risk Assessment Guidance for Superfund Volume I Human Health Evaluation manual (Part A) [EPA 1989], this placement or location is the "exposure point."* TDEC performed a limited analysis of the sensitivity of the pre-WAC to the receptor location. The goal was to compare the pre-WAC proposed in the RI/FS to a pre-WAC generated if the pathway analysis included a scenario with the receptor using ground water that was much less diluted by clean recharge. The advection-dispersion equation solved by PATHRAE in the saturated zone can be expressed in terms of dimensionless variables, and the analytical solution will depend only on the Peclet number, a Courant number, and time constants that are representative of the time for radioactive decay, the time for release from the source, and the time required for solute to advect to the point where the Peclet number is unity. The latter quantity is a measure of the strength of dispersion. When the time for release of a contaminant from the model boundary into the model domain, which is controlled in PATHRAE by either the release rate from the source or the migration time through the vadose zone, is large enough, and when the time for decay is large compared to the travel time in the saturated zone, the peak concentration will be comparable to that calculated assuming a permanent continuous source. In that case, differences in dilution would account for most of the concentration differences that would result from modeling to a different location of the hypothetical receptor. Consequently, the sensitivity analysis was restricted to examples with longlived radionuclides. Relocating the receptor closer to the source could have much greater impacts on groundwater concentrations of isotopes with shorter half-lives. Pre-WAC for Tc-99, with a half- life substantially longer than the time to peak concentration, is listed as 69,300 pCi/g. If the receptor were assumed to be either immediately downgradient of the facility or near the facility underdrain that is shown in the conceptual design, the dilution factor would be near 0.1, as shown in Figures H-16 and H-17. The proposed underdrain, like the underdrain at the EMWMF, would presumably be able to supply several gallons per minute of water continuously even under drought conditions, and might be a usable water supply even when individual wells were dry. Then Tc-99 at peak concentration should be more or less determined by a ratio of the dilution factor estimated at the new receptor location to that calculated for Bear Creek, or 0.1/.00254. This would result in a concentration in the underdrain or near the facility of slightly less than 40 micro Curies per liter. Since the effective uptake comes primarily from the drinking water pathway, the relocation of the receptor would result in an excess cancer risk of about 2.4E+0 due to Tc-99 exposure The pre-WAC for technetium 99	The assumed location of the groundwater (drinking water) well does have a significant impact on the level of dilution, estimated risk, and resulting PreWAC for a given contaminant. The D4 revision assumes that the groundwater well is located 100 m from the waste facility boundary, along the axis of maximum concentration within the simulated contaminant plume. Additionally, for COPCs that peak after 1000 years post-closure, the groundwater point of exposure remains at 100 m from the waste facility boundary, along the axis of maximum concentration within the simulated contaminant plume.

	calculated using the methodology outline on page H-70 would then be about 25 pCi/g. Another example is U-238. The pre-WAC in Appendix H, Table H-8 includes a pre-WAC of 103,000 pCi/g. With an order of magnitude dilution, then a pre-WAC of 33 pCi/g is calculated. There is about a 4 order of magnitude difference in 33 and 103,000. Therefore, a WAC of 103,000 pCi/g proposed for U-238 in the RI/FS could pose an excess lifetime cancer risk of 3 in 10.	
TDEC.S.100	**Page H-16, Paragraph 1:"***This is the point where MEI contact with the highest contaminant concentration is made "if the site is currently used, if access to the site under current conditions is not restricted or otherwise limited (e.g., by distance), or if contact is possible under an alternate future land use." In this case, the proposed EMDF site is within Zone 3 of Bear Creek with a future land use designation of "DOE-controlled Industrial Use," access is restricted by DOE, and for the foreseeable future will be under DOE control as described in the BCV Phase I ROD (DOE 2000). This future land use designation has been supported and approved by public stakeholders in the End Use Working Group (documented in the Final Report of the Oak Ridge Reservation End Use Working Group, July 1998). Accordingly, the nearest possible exposure point for a future hypothetical resident, and point of highest expected concentration based on ground water and surface water flows, would be the intersection of the "DOE-controlled Industrial Use" Zone 3 boundary with Bear Creek shown in Figure H-3, approximately 1.5 miles to the west of the EMDF.* As stated in comments on Appendix G, water quality rules are not listed as chemical specific ARARs. The risk assessment performed here does use MCLs at the receptor location as an end point for modeling, but does not look at ground water protection more generally, and does not include protection of surface water quality or ecological risk. For the proposed EMDF to meet criteria specified in CERCLA Section 121 (d)(1), future releases from EMDF must assure protection of human health and the environment. In addition to evaluating the risk levels required by CERCLA, we interpret this to mean that future releases cannot cause pollution that violates stream classified uses in Bear Creek or downstream. Bear Creek is a tributary to East Fork Poplar Creek, Poplar Creek and the Clinch River. By evaluating risk for a single, hypothetical receptor, the EMDF RI/FS does not consider the designated uses of Bear Creek, East Fork Poplar Creek, Poplar Creek, and the Clinch River and it does not evaluate the impact of the calculated pre-WAC allowed releases on these surface water uses. The Clinch River, Poplar Creek, East Fork Poplar Creek, and Bear Creek are all classified for fish and aquatic life and recreational use. The Clinch River downstream is also classified for domestic water supply. Certain radioactive, hazardous, and TSCA pollutants pose or may pose a threat to human health through ingestion and/or recreational use (e.g. fishing consumption), or a threat to aquatic life or other ecological risk. These potential pathways are not modeled in the risk assessment and need to be evaluated and included in the development of the pre-WAC. In fact, the pre-WAC should be made to constrain the cumulative impact from any proposed new sources and any existing sources, such as the Bear Creek Burial Grounds and S-3 ponds secondary sources and plume so that the potentially impacted streams or ecosystems will not suffer further degradation. TDEC did some limited modeling with the RESRAD code to evaluate WAC sensitivity to	The D4 RI/FS demonstrates protection of water resources and ecological receptors, within the 1000 year compliance period, by modifying analytical PreWAC if necessary to meet MCLs (or a 4 mrem/yr dose limit) at the groundwater point of exposure, and similarly by limiting predicted surface water contaminant concentrations to Ambient Water Quality Criteria (AWQC), and adjusting calculated PreWAC accordingly. Consideration of risk to human health and water resources resulting from multiple Bear Creek Valley contaminant sources, within the 1000 year post-closure compliance period, will be provided in a Composite Analysis developed to meet the requirements of DOE Order 435.1. Po-210 has a half-life less than 5 yr (specifically it is 0.38 yr half -life), it was therefore excluded from consideration in the D3 RIFS. Review of the decay chains that include Po-210 suggests that parent nuclides are sufficiently limited to address potential risks. In the D3 RIFS, Table H-6 and H-7 contain the predicted SW concentration based on the assumed 1 Ci/m3 waste concentration, and do not reflect the protectiveness provided by the risk-based analytical PreWAC. In the D4 revision of Appendix H these model output data are included in Attachment B, and replaced with the final calculations to derive the final PreWAC (which will take into account AWQC in addition to meeting risk range) to clarify. Antidegradation concerns are being addressed, in part, by deriving risk-based discharge limits for radionuclides as part of the Integrated Water Management Focused Feasibility Study (UCOR 2016).

	water quality driven endpoints, and pathways that might incorporate the effects of progeny. RESRAD modeling based on a source concentration of 103,000 pCi/g uranium-238, the pre-WAC concentration specified in Table H-8 of this Appendix, identified polonium-210 as a progeny and fish consumption as a potentially significant exposure pathway. While a more realistic fate and transport analysis than can be achieved with RESRAD might not reveal an actual risk to a recreational user of Bear Creek, TDEC cannot accept a risk assessment that makes no attempt to incorporate water quality criteria, cumulative effects, and a more detailed analysis of the effects of progeny resulting from radioactive decay. For a number of the contaminants of potential concern modeled in Appendix H, peak concentrations in Bear Creek listed in Tables H-6 and H-7 (pages H-64 through H-69) are above DOE derived concentration standards that limit releases to surface water or ambient water quality criteria. Specifically, any new or expanded discharge to Bear Creek must comply with the Antidegradation Statement of the Tennessee Water Quality Control Act and rules, meaning that no measurable loading is authorized for the parameters causing the stream to be impaired. For now, these parameters include mercury, cadmium, nitrates, and PCBs. Likewise, under Tennessee rule 0400-40-03-.07, groundwater is classified as general use groundwater. Therefore, except for naturally occurring levels, general use ground water: (a) shall not contain constituents that exceed those levels specified in subparagraphs (1)(j) and (k) of Rule 0400-40-03-.03; and (b) shall contain no other constituents at levels and conditions which pose an unreasonable risk to the public health or the environment.	
TDEC.S.101	**Page H-16, Paragraph 2**: "*Ultimately, a much more conservative approach is preferred, and the receptor location was selected based in part on historical records (prior to DOE's land ownership) that indicate several homes were located along Bear Creek in the general area being considered (Tennessee Valley Authority Maps and Surveys Division Quadrangle map 1935, 1941, see Appendix E, Figure E-5 and Section 2.1).*" The implication here is that the receptor location is quite conservative with respect to locations outside of the zone 3 boundary. However, TDEC dye tracing results indicate that groundwater and surface water travel times from the approximate location of the hypothetical receptor to the zone 3 boundary are on the order of only a day. This allows very little additional time for decay or degradation of radioactive or hazardous substances and little opportunity for mass transfer processes to remove solutes from the water. Reasonable dilution factors at hypothetical locations for a receptor along the dominant groundwater flow paths outside the zone 3 boundary in Bear Creek Valley can be estimated from the hydrologic balance over the watershed. Using the optimistic assumption that only 1 centimeter of water infiltrates through the landfill annually, the hydrologic balance still gives dilution of only 103 to 104, less than the 105 determined for the groundwater extraction well. Even though the RI/FS uses less dilution for the surface water pathways, the receptor location used in the RI/FS thus represents more or less a best case scenario rather than a more conservative approach. If modeled with realistic groundwater travel times in the karstic Maynardville limestone, most locations downgradient of the facility outside of zone 3 would yield higher risk than that at the chosen location. The water well location in this RI/FS does not lie along the primary groundwater flow paths that emanate from the landfill footprint, and most of the recharge to the well and the creek is derived from water not impacted by the facility. Perhaps the only less conservative locations would be either upgradient of the proposed facility itself , uphill from the dominant flow paths down Bear Creek Valley, or at the Clinch River.	The assumed location of the groundwater exposure point does have a significant impact on the level of dilution, estimated risk, and resulting PreWAC for a given contaminant. The D4 revision assumes that the groundwater well is located 100 m from the waste facility boundary, along the axis of maximum concentration within the simulated contaminant plume. This new assumed location yields groundwater dilution factors on the order of 10^{-2} to 10^{-1}. Evaluation of model sensitivity to assumed average groundwater velocity is presented in Appendix H, Section 4.5 The Composite Analysis developed to meet the requirements of DOE Order 435.1 will provide assessment of risk at locations farther downstream in BCV within the 1000 year post-closure compliance period, and considers multiple Bear Creek Valley contaminant sources.
TDEC.S.102	**Page H-18, Paragraph 1**: "*DOE performed this analysis of the proposed low-level waste disposal facility using a performance-based approach with little to no reliance on long-term*	Cover system performance assumptions have been modified in the D4 RIFS revision and are summarized in table H-3. For the period exceeding 1,000 years,

	maintenance and the man-made components of the landfill (i.e., geosynthetics) for a performance period of 1,000 years beginning at closure of the landfill." TDEC agrees that long-term performance of the proposed facility should be based on characteristics of the landfill and the site that do not require substantial long-term maintenance. However, the conceptual model used to provide the basis for inputs to the fate and transport model should not assume that either the amended clay barrier layer in the cap or the clay liner will last indefinitely. Note that differential settling of the cap sufficient to create concave upward surfaces at the interface of the drainage layer with the barrier layer that could pool, on average, about 1 centimeter of water over only 10 percent of the barrier surface for one rainfall each month might double the projected infiltration rate. While it may be reasonable to suppose that the geosynthetic materials in the cap and liner will greatly restrict infiltration for decades, or even centuries, performance modeling should allow for degradation of clay layers prior to the one thousand year time frame of the model (or 1 million years in the case of modeling to peak). The time period for which infiltration rates can be assumed to be only one centimeter annually is one of many details in the fate and transport model that needs to be revisited and agreed upon by all FFA parties prior to approval of this RI/FS.	degradation of the amended clay layer is assumed to result in a 2-fold increase in hydraulic conductivity of the layer. Additionally, differential settling is assumed post-1,000 years and is accounted for in modeling by clogging the drainage layer of the cap (decrease in hydraulic conductivity by a factor of 100). These modifications result in an increased infiltration rate of 1.3 in/year after 1,000 years. For COPCs predicted to peak after 1000 years, PATHRAE modeling for PreWAC development conservatively assumes an infiltration rate of 1.3"/yr beginning with geosynthetic liner material failure at 200 years post-closure.
TDEC.S.103	**Page H-18, Paragraph 1**: "*Isotopes that peak beyond 1,000 years are modeled under the recognition that the modeling results for these much greater time lengths have a higher degree of uncertainty."* While TDEC generally agrees that there is a higher degree of uncertainty over time, this would seem to be cause for more conservative assumptions that account for the probable deterioration of all the landfill components over time, not just geosynthetic materials. The only changes made in the modeling in this RI/FS would seem to be a higher target for risk.	The risk target of 10^{-4} ELCR adopted by DOE for the RI/FS analysis past 1,000 years is within the acceptable risk range of CERCLA. However, due to the uncertainties introduced in extrapolating models so far in time, a deviation from the 10^{-6} point-of-departure risk level is warranted past 1,000 years. Modeling in excess of 1,000 years into the future, and then even 10's of thousands of years into the future as is the case here, is fraught with uncertainty. The time steps are necessarily larger, and results become less reliable. With error bars on results that have become extremely large relative to those results, it is necessary to relax goals (e.g. risk or dose targets). DOE recognizes this in limiting the compliance period to 1,000 years for a landfill in Order 435.1, with sensitivity analysis implemented past 1,000 years. The NRC likewise limits the compliance period (in proposed language for 10 CFR 61 – current NRC regulations do not address the time frames) to 1,000 years. After 1,000 years and to 10,000 years, the NRC has proposed a dose goal 20 times higher than that of the proposed 1,000 year compliance period.
TDEC.S.104	**Page H-20, Paragraph 1: "***An overview of the models used, conceptual design and site features provided, and major calculations performed are as follows:"* The description of the models does not include a summary of the equations used or any analytical or numerical techniques used to solve the equations, nor does it address all the consequences of uncertainties in key parameters that are inputs to the models. A description of the key equations and a more detailed sensitivity analysis to certain model inputs should be provided. In the case, of HELP, MT3D, and MODFLOW/MODPATH, the codes and manuals are readily available for download from government web sites. To our knowledge, this is not the case for the latest versions of PATHRAE HAZ and PATHRAE RAD. A more detailed summary of the PATHRAE model is necessary.	The text cited in this comment is from the introductory overview (Section 3.1) The text describing the PATHRAE model in Appendix H Sections 3.2.4 and 4.4 has been revised to provide additional detail and clarity. A more complete set of PATHRAE sensitivity analyses has been added to Appendix H in Section 4.5
TDEC.S.105	**Page H-25, Paragraph 1:** "*The waste layer is assumed to consist of contaminated soil, cement-stabilized soil-like materials, cement-solidified waste, and debris (rubble). These wastes are assumed to be placed in lifts to minimize void spaces within the waste layer. Void*	While there are no requirements for materials having sorptive properties, EMWMF typically uses soil or soil-like material for filling voids within and around non-bulk waste. The fill material is selected based on several parameters,

	spaces are filled with soil or soil-like material to provide structural strength and reduce settling due to waste compaction. For modeling purposes, all waste is conservatively assumed to be soil-like (see Section 4.4 of this Appendix).” The assumption of soil-like waste may lead to conservatism for many waste forms that may have contamination confined in the interior of inert material. However, definition of the waste types in Section 2.1.2 of the RI/FS includes tanks, piping, glove boxes, and ventilation ductwork. There are no proposed requirements that material having sorptive properties similar to that of soil be used as structural fill around such debris. At the EMWMF, limestone gravel has historically been used around irregular objects rather than soil-like material. Under circumstances where the waste may corrode over time and contain unfilled voids, release rates from the waste may exceed those based on the assumption of equilibria between leachate and a soil-like material. Since the radioactive isotope or chemical is assumed to be adsorbed, this lack of conservatism will be exacerbated when the true chemical form is highly soluble, as in the case of uranyl fluoride deposits in compressors used in the gaseous diffusion process.	including function, performance, availability, ease of placement, and cost. The selected fill, in descending order of preference, is typically: • Soil-like waste – The most cost effective fill, provided it can be placed and compacted in the voids. • Clean soil fill (predominantly clay) – Typically, the least costly non-waste fill, provided it can be placed and compacted in the voids. Also, provides an effective water barrier. • Gravel (typically crushed limestone) – Somewhat flowable and typically used under the haunches of large single debris items where it is difficult to place and compact soil. • CLSM – The most flowable fill material. Typically used where access to the voids is limited. Somewhat difficult to place. Best used for a “campaign” of grouting. • Concrete – Most costly and used only in special situations. A typical example of the use of fill is illustrated below, in this case for placing the second lift of converters. Note that the interior voids of converters are filled before they are delivered to EMWMF. • Designate an area well away from the in-cell catchments. • Unload converters and place atop the compacted clay layer that is above the first lift of converters. • Position converters in an orderly arrangement with several inches between items to allow filling of voids. • Place crushed gravel (pea gravel size) around the converters so that it fills the voids under the haunches and between the items. Continue placing the stone to about half the depth of the converter. • Place clay from that point upward. Compact the clay between and around the converters. • Place clay over the layer of convertors to achieve a minimum 8-inch final compacted thickness. Since 2001 the amount of soil and soil-like fill used placed in the EMWMF landfill is: • Waste soil: approximately 250,000 yd3 • Clean fill soil: 403,000 yd3 • Clean fill stone (including CLSM): 90,000 yd3 Based on these EMWMF operating statistics, soil is the most prevalent fill material used (nearly 90%), and as the best available data point upon which to

		base an assumption for the future cell, is indicative of the most representative waste form for modeling purposes of the future condition. Furthermore, no attenuation by the soil within the waste matrix is taken.
TDEC.S.106	**Page H-26, Paragraph 6:** "*7. Performance Scenario – The performance of the conceptual design (cover and liner specifically) was assumed to change over time. Three stages were defined as follows:* *A. Stage 1: The best case, short-term performance of the cover/liner systems is assumed. All layers fully function. This stage is assumed to continue through the first 100 years following closure of the landfill. The composite barrier (the compacted and amended clay layers and geosynthetic layers) in conjunction with the overlying lateral drainage layer serve to divert infiltrating water away from the underlying waste and transport the water to the perimeter drainage system, thus minimizing infiltration into the waste. This is a very conservative assumption, supported by research that indicates the service life of HDPE geomembranes exceed 500 years and may reach over 1,000 years at temperatures of 20° C as expected in the case of the EMDF (depth below ground surface ensures temperate conditions); based on the thickness of the proposed geomembrane (40 mil) (antioxidant depletion lifetime in the membrane is extended with thickness); humid environment/moderate rainfall; and protected (depth under overburden) location of the geomembranes. (Benson 2014, Rowe et al. 2009, Needham et al. 2006, Mueller and Jakob 2003, Bonaparte, et al. 2002; Hsuan 2002; Koerner et al. 2001; Giroud 1984)* *B. Stage 2: Gradual failure of the cover/liner systems is assumed. This period is assumed to last for 100 years, extending from year 100 following closure, through year 200 following closure. A linearly increasing infiltration rate is assumed between Stage 1 and Stage 3 results.* *C. Stage 3: The worst case, long-term performance of the cover/liner systems is assumed. It is assumed that all geosynthetic materials degrade and are ineffective at 200 years and beyond. Layers are assumed to be degraded and no longer function (i.e., Layers 5, 11, 12, 13, 14, and 15 are removed from the model). Erosion of the cover is assumed to occur resulting in a decreased thickness of the top soil/rock layer. Layer 1 thickness is reduced by 20%.*" A key component of the Appendix H risk assessment and determination of the pre-WAC (pre-Waste Acceptance Criteria) is how much leachate exits the landfill and enters groundwater or the underdrain after engineering controls fail in a few hundred years. DOE modeled this through the HELP model. DOE's presentation of their HELP modeling shows that, worst case, DOE expects about 0.42 to 0.43 inches of water per year to percolate through the waste and enter groundwater or the underdrain. DOE used this to model whether the peak concentration of pollution for a specific contaminant impacts a receptor living near Bear Creek during the first million years after engineering controls fail. This modeling helps determine which constituents need waste acceptance criteria (WAC). Waste assumed to be placed in EMDF was modeled as a soil-like material and consequently differential settling or differential compaction was not mentioned in Appendix H. Modeling the 50 foot thick waste layer as a soil-like material is inconsistent with many of the materials needing disposal. Further, based on experience with EMWMF, DOE will not perform size reduction of the waste placed in EMDF. Lack of size reduction could result in long term differential compaction/differential settling that disturbs cap drainage layers and causes ponding or micro-fractures in cap layers. Differential compaction/ differential settling could result in DOE's predicted volume of leachate entering groundwater or the underdrain being low by an order or more. If sensitivity analyses were run to evaluate differential compaction and settling, it was not referenced in the RI/FS Appendix H.	Cover system performance assumptions have been modified in the D4 RIFS revision and are summarized in table H-3. For the period exceeding 1,000 years, degradation of the amended clay layer is assumed to result in a 2-fold increase in hydraulic conductivity of the layer. Additionally, differential settling is assumed post-1,000 years and is accounted for in modeling by clogging the drainage layer of the cap (decrease in hydraulic conductivity by a factor of 100). These modifications result in an increased infiltration rate of 1.3 in/year after 1,000 years. For COPCs predicted to peak after 1000 years, PATHRAE modeling for PreWAC development conservatively assumes an infiltration rate of 1.3"/yr beginning with geosynthetic liner material failure at 200 years post-closure. For the D4 RIFS revision, erosion of the protective soil layer is assumed to be 20% after 500 years, and 50% after 1000 years post-closure. It should be noted that the 1mm/100 yr erosion rate identified in the D3 Appendix H, Attachment B does not enter into the PATHRAE calculations for pathway #1 (groundwater to river), so the cap erosion assumption is only relevant in the HELP model analysis. Assuming limited erosion of the protective soil layer is justified in the cover system performance scenario given that natural erosion rates vary widely in space and time as a function of many variables, and severe erosion of the landfill cover is unlikely under anticipated future land use. In the conceptual design, the size gradation of the materials in the protective soil /erosion control layer is specified to limit physical degradation of the cover system, and applying an average soil-loss based erosion rate of 1mm/yr beyond 100 years does not account for the protective effect of including coarse materials in the erosion control layer. Final specification of the surface layer materials could be linked to an estimated maximum long-term erosion rate.

	DOE's worst case scenario (Table H-2) did not assume differential compaction. DOE's worst case scenario did assume the top 48 inch soil layer (Table H-1) erodes 20% or 9.6 inches. However, Table H-2 includes a thickness of 5 feet (60 inches) instead of 38.4 inches. Tennessee Department of Environment and Conservation's Division of Solid Waste Management estimates that a fully closed, grassed, well-maintained landfill should have erosion on the order of two (2) tons of soil per acre per year. Assuming about 120 pounds per cubic foot and that the landfill is completely grassed and well-maintained for the first 100 years after closure (Stage 1, RI/FS page H-26) there may be about 0.233 millimeters (mm) erosion per year or about 0.92 inches erosion in the first 100 years after closure. As opposed to the 1 millimeter erosion per century input to PATHRAE in attachment B of Appendix H, The DOE code RESRAD assumes a default erosion rate of about 1 mm per year. If a 1 mm per year erosion rate is assumed for stages 2 and 3 (Stage 2 and 3, RI/FS page H-26) after maintenance is discontinued, then about 4 inches erosion per 100 years may be expected assuming erosional rills, farming, fires, etc. do not cause an increased erosion rate. Under this scenario, it would take on the order of 240 to 350 years to erode 9.6 inches and it only takes about 1300 years for the initial 48 inch top soil layer to entirely erode away. If the 48 inch soil cover essentially erodes away in the first 1300 years, the clay layer will degrade significantly as an effective hydraulic barrier during the first 1300 years after closure. A more credible "worst case" scenario would allow infiltration rates to increase by an order of magnitude during the first few hundred years, and allow the infiltration rate to increase to the same recharge rate as that assumed for the surrounding area by 1000 years. These increased infiltration rates would not only provide some conservatism, they would reduce the time to peak concentration at a receptor location and allow development of WAC without modeling for time periods that might require consideration of climate change and other long term phenomena.	
TDEC.S.107	**Page H-28, Paragraph 1:** "*Clay layers in the final cover system are below 8 ft. of overburden. The clay layers are assumed to retain their hydraulic conductivity parameters based on the depth below ground surface, which ensures there is no direct exposure to freeze-thaw conditions and no desiccation; no cracking/tunneling due to roots or burrowing animals/insects; little temperature or moisture variation; and the layers are subjected to high pressures (approximately 60 kPa). Research has actually shown decreasing hydraulic conductivities with increased confining stress as is associated with significant overburden pressures (Boynton and Daniel 1985; Albrecht and Benson, 2001).*" This discussion seems to assume that moisture content in the clay liner will not vary significantly even after the geomembrane is degraded. The geomembrane will, at some point, degrade sufficiently at discrete locations to allow significant wetting and drying in the amended clay layer below, leading to desiccation cracks. While the overburden pressure may help to close desiccation cracks, 8 feet of soil and rock overburden (reduced to about 7 feet for stage 3) does not correspond to 60 kPa of effective stress. In fact, Albrecht and Benson, cited above, state in the summary, "Tests at various effective stresses show that an effective stress of at least 60 kPa was needed to close desiccation cracks so that hydraulic conductivity is < 10-7 cm/s. This effective stress is higher than that found in most cover applications, suggesting that desiccation damage to covers will be permanent."	Cover system performance assumptions have been modified in the D4 RIFS revision and are summarized in table H-3. For the period exceeding 1,000 years, degradation of the amended clay layer is assumed to result in a 2-fold increase in hydraulic conductivity of the layer. Additionally, differential settling is assumed post-1,000 years and is accounted for in modeling by clogging the drainage layer of the cap (decrease in hydraulic conductivity by a factor of 100). These modifications result in an increased infiltration rate of 1.3 in/year after 1,000 years. Additional revisions have been made to Chapter 6, section 6.2.2.4.8 to address this concern.
TDEC.S.108	**Page H-36, Paragraph 2:** "*Six distinct hydraulic conductivity zones were used in the UBCV Model to represent the eight geologic units that exist in BCV (Knox Dolomite, Maynardville Limestone, Nolichucky Shale, Maryville-Rogersville-Rutledge formations, Pumpkin Valley shale, and Rome shale/sandstone). Anisotropy ratios (Ky versus Kx [Kz]) of 5:1 (for weathered bedrock zone) and 10:1 (for fractured bedrock zone) were used to represent the preferred fracture/bedding orientation of the geologic units. In this case, Ky represents the conductivity*	DOE agrees that there are significant uncertainties in groundwater modeling related to hydrogeologic heterogeneity

	parallel to strike, Kx is the horizontal conductivity perpendicular to strike, and Kz represents the vertical hydraulic conductivity." Anisotropy values significantly higher than those used here may be necessary to properly simulate groundwater flow paths. Evidence from tracer studies and contaminant migration pathways on the ORR demonstrate that heterogeneity in the subsurface is on a very small scale with respect to hydraulic conductivity perpendicular to bedding (centimeters to decimeters for permeable fracture zones that seem to provide the most transmissive zones in shale rich formations and generally smaller for discrete continuous fractures in carbonate units). Hydraulic conductivity may be much less variable over considerable distance parallel to bedding, creating the effect of stratabound flow. Based on the variability of hydraulic test results on the ORR, the magnitude of local hydraulic conductivity variations is likely to be quite large, particularly in the direction perpendicular to bedding. This heterogeneity is on a scale smaller than the dimensions used for model discretization, and unlikely to be captured by grouping of model cells into only a few zones for purposes of assigning distinct hydraulic conductivities to the subsurface. Consequently, prediction of local hydraulic head values as well as flow direction at specific locations with MODFLOW is questionable. TDEC staff supposes that insufficient data may be available for a more refined model calibration, but cautions that the model results have limited value when used for the purposes of prediction of local flow direction and hydraulic head.	
TDEC.S.109	**Page H-41, Paragraph 1:** "*New ground water monitoring wells installed under Phase I characterization efforts, within the proposed EMDF area, have been used in UBCV Model calibration, and well head values were in general agreement with the model-predicted values.***"** What were the actual and predicted values of hydraulic head for the wells installed under the Phase 1 characterization effort? Were the hydraulic head residuals greater or less than those determined in the regional flow model calibration?	Based on the Phase 1 monitoring data, changes in the assumed groundwater recharge rate were made for the Rome formation to improve prediction of water table elevations on the upslope portion of the EBCV site. Modeled predictions were within a few feet of the measured annual average water table elevations for all shallow well locations, except for the GW-976 well location on the spur ridge.
TDEC.S.110	**Page H-41, Paragraph 3:** "*The water balance conducted for the calibrated current condition UBCV Model compared observed and predicted ground water discharge rates. Ground water sinks (drains cells in the model) discharge to Bear Creek directly and to surface drainage features that also flow into Bear Creek eventually. The model predicted ground water discharge above the Bear Creek/NT-3 junction is 0.31 ft3 per second (cfs). For comparison, the average flow rate measured at the junction location is 0.55 cfs (Appendix E, Section 2.4.3.1), which includes both base flow (ground water discharge) and surface water runoff. The water balance error for the UBCV Model was about 0.34% and is within the typically accepted limit of 1% (EPA 1996).CERCLA process that led to the construction and operation of EMWMF.As a follow-on to that process, this RI/FS utilizes relevant information from the EMWMF RI/FS with revisions and updates to describe and analyze current conditions.***"** TDEC agrees that the recharge rates and hydraulic conductivity values in the calibrated MODFLOW are reasonable for the purposes of computing Darcy flux and a water balance. Consequently, the general relationship between overall dilution computed using MODFLOW results and the steady state MT3D model as a function of distance from the facility footprint (see Figures H-16 and H-17) yields useful information, even if the specific location of any given plume isopleth may not be accurate due underestimation of anisotropy or the scale of heterogeneity in the subsurface.	Requires no response or changes.
TDEC.S.111	**Page H-48, Paragraph 1: 4.3.2 MT3D Model Assumptions.** *"Assumptions made in running the MT3D code are as follows:* *1. Changes in the concentration field will not measurably affect the flow field.*	The MT3D assumptions 3 and 8 have been revised in the RIFS D4 revision.

	2. Transport is modeled as three dimensional and transient until a steady state condition is reached. *3. Only advection is considered; other processes (dispersion and retardation) were not assumed. This is a conservative assumption because other processes will reduce the contaminant peak concentrations, as dispersion and retardation terms represent the contaminant spreading in the environment, thus flattening the peak.* *4. The MOC solution method, best for advection only, was used for the simulation to minimize the potential error from numerical dispersion.* *5. The well pumping rate is 240 gallon/day, based on its use by a family of four.* *6. The well is cased to 70 ft. Water is drawn from model Layers 5–8, corresponding to 70–150 ft below ground surface.* *7. The well was assumed to be located nearby on the BCV floor between the EMDF and Bear Creek (see Section 2.4), at a distance of 460 m from the edge of the landfill. This location is also consistent with topographical and geological features, lithostratigraphic and hydrogeological data, and ground water modeling results.* *8. The landfill is represented by a uniform, constant leaching source (assigned a unit leach rate of 1.0), which is assumed for the duration of the simulation. This represents a conservative approach as in reality the source will be depleted as leaching proceeds. The code is run for a single, non-specific contaminant source.* *9. Steady state is reached at peak leaching, based on a constant, non-depleting contaminant source."* TDEC believes these modeling assumptions provide a reasonable basis for deriving some measure of dilution at various locations in the model domain. Estimation of dilution otherwise may be problematic. Incorporation of dilution effects directly into the differential formulation of the mass balance adds an additional term to the conventional advection/dispersion equation solved analytically in PATHRAE. However, since contaminant transport is being modeled separately but in parallel with the dilution calculations, the claims of conservatism in assumption statements 3 and 8 above are not valid. The attenuation of the peak concentration due to the finite nature of the source and mass transfer processes such as dispersion and adsorption is accounted for in PATHRAE.	
TDEC.S.112	**Page H-49, Paragraph 1:**"*This calculated average ratio of the concentration at the well relative to leachate concentration from the cell, 0.000015, equals the DFwell"* A reasonable bound on dilution factors can be deduced from a water balance over all of zone 3 in Bear Creek Valley. Assuming about half of precipitation is lost to evapotranspiration and 1 centimeter infiltration annually over the 10 to 20 acre footprint of the waste, the resulting bulk dilution factor for the entire upper Bear Creek watershed lies between 0.001 and 0.0001. A more realistic dilution factor near the integration point below the confluence of Bear Creek with NT-8 (where the bulk of groundwater and surface water have already been mixed along the karst pathways) would employ an order of magnitude higher infiltration, based on some expectation of cap degradation, and the dilution factor would be between 0.01 and 0.001. Anything less than this average (for example, the DFwell derived in this Appendix needs some extraordinary justification, and is clearly not conservative, as it is less concentrated than the average value leaving the zone of restricted use. To be somewhat consistent with RCRA LDRs (which typically use a total dilution/attenuation factor of .01 between leachate concentrations and drinking water MCLs), it is hard to justify using a DF less than 0.01. On the other hand, there is some justification for using a dilution factor less than 1, since water infiltrating through the waste will be diluted to some degree even under the facility footprint with groundwater	The MT3D simulated contaminant plume (based on assuming a constant unit leach rate from the cell) provides the three dimensional distribution of relative concentrations used to specify a value of DF_{well}, based on the assumptions for well location and well screen interval. In terms of this MT3D model output, there is no positive lower bound on the relative concentration, i.e. uncontaminated areas along the margins of the plume are present. The D4 revision assumes that the groundwater well is located 100 m from the waste facility boundary, along the axis of maximum concentration within the simulated contaminant plume. This assumed location yields groundwater dilution factors on the order of 10^{-2} to 10^{-1}.

	recharge upgradient of the facility.	
TDEC.S.113	**Page H-49, Footnote:"** *2This assumption is necessary, since the exact contaminant concentrations and placement within the landfill will not be known until after the landfill begins operation. An assumption that contaminants are uniformly distributed is conservative because it allows leaching to be modeled in all the formations underlying the landfill, for the entire footprint."* While the assumption that contaminants are uniformly distributed in the land fill may facilitate computation of the leachate concentrations, it may not always be conservative. The release rate into infiltration will depend locally on the infiltration rate, the concentration of the contaminant in the waste, and the rate at which the contaminant is transferred between solid and liquid phases. If most of the water infiltrates along pathways that are initially cleaner or have slower release rates, the assumptions of uniformity will be lead to conservative values of contaminant concentration in leachate. The opposite situation might occur in a few cases in the EMWMF, where infiltration rates through clean fill may be substantially less than through contaminated demolition debris.	DOE agrees this assumption may not always be conservative, but does believe it represents a conservative assumption in most cases, and is a reasonable and necessary assumption based on the fact that no strategy is planned regarding the placement of waste or waste forms in the landfill. The footnote has been revised to remove the indication that it is a conservative assumption.
TDEC.S.114	**Page H-54, Paragraph 1:"***The contaminant concentration in the landfill is depleted by two mechanisms: (1) decay (for radioactive contaminants; no degradation of hazardous COPCs (chemical compounds) is accounted for as they are all assumed to degrade well within 1,000 years; USGS 2006) and (2) leaching via solid-liquid partitioning."* The reference cited here pertains only to volatile organic compounds, not to pesticides, PCBs, dioxins and furans, or other chemical compounds that are more chemically inert and typically biodegrade to other hazardous chemicals. Reported half-lives of most of these more persistent compounds in soils are reported to be less than 100 years, but the degradation rates under the conditions that may exist in a CERCLA waste landfill, expected to be dryer with less microbial activity, are uncertain. A more conservative approach, that allows modeling of chemicals known to degrade slowly past 1000 years, would add credibility to the risk assessment.	For hazardous chemical compounds predicted to peak within the 1000 year compliance period, no chemical degradation is assumed in PATHRAE modeling for PreWAC development. The D4 text has been revised to note that this is a conservative assumption. This comment indicates that for those persistent organics listed, pesticides, PCBs, dioxins, and furans, the reported half-lives are less than 100 years. 1000 yr modeling results in 10 or more half-lives, indicating that those contaminants are no longer present in their original form. If a safety factor of 2 is used, 5 half-lives occur in the period modeled. Given the low expected concentrations of these types of contaminants, 1000 years is a reasonable time limit for modeling transport of hazardous chemical compounds.
TDEC.S.115	**Page H-54, Paragraph 1:** "*Transport of the contaminant is modeled assuming migration through the vadose zone by soil-water equilibrium partitioning followed by migration in the saturated zone also via soil-water partitioning (with an added level of conservatism introduced by decreasing the partition coefficient by a factor of 10), and a receptor (MEI) exposure to that contaminant via discharge of ground water to surface water."* The PATHRAE code assumes a homogeneous, one-dimensional flow field and chemical equilibria between the fluid and solid phases. For the purposes of modeling solute transport from the fluid phase to the solid phase, the assumption of chemical equilibria allows for the maximum possible transfer of material to the solid phase and may thus create a bias toward long residence times for contaminants. Unrealistically long travel times could lead to lack of conservatism for radionuclides that decay significantly during transport. This is particularly true when contaminants move through very heterogeneous media such as the fractured rock aquifers in Oak Ridge, simulated by the saturated zone in PATHRAE. In such cases, equilibrium is rarely achieved. It is also likely that the assumption of homogeneity will lead to underestimation of peak values of contaminants at the receptor location. Heterogeneity in hydraulic properties typically causes an increase in first arrival times and a shorter time to peak concentrations. For contaminants that will undergo significant decay over the mean time of travel to the receptor, these effects may substantially decrease the computed risk. In addition to the heterogeneity in the aquifer,	The D4 revision includes a set of model sensitivity evaluations in Appendix H Section 4.5. These evaluations include consideration of model parameters that influence the modeled contaminant retardation and travel time, including infiltration rate, Kd, vadose zone thickness, aquifer porosity, and aquifer dispersivity. The effect of these variables on predicted peak concentrations of short-lived radionuclides is provided as part of the evaluation. In addition, because PATHRAE does not include vadose zone dispersion, supplementary modeling has been performed to evaluate the significance of this limitation in the modeling approach for developing PreWAC for radionuclides.

	there is likely to be substantial heterogeneity in the vadose zone, except in engineered materials that have not undergone significant degradation. The effects of dispersion in the vadose zone should be incorporated into the model, as well as use effective porosity and partition coefficients. Tracing studies in very similar Oak Ridge hydrogeologic settings indicate that, to conservatively simulate reactive solute transport with the advection dispersion equation used in PATHRAE, assumed effective porosities should be at least an order of magnitude less than the total porosity, and effective partition coefficients should be near zero.	
TDEC.S.116	**Page H-59, Table 5:** "*Table H-5. Parameters for Use in PATHRAE Modeling and PreWAC Calculations.*" TDEC has found potential discrepancies between tables summarizing model inputs and the model input files in Attachment B. An example would be a vertical groundwater velocity of 0.025 meters per year (from page 16 of attachment B), a 1centimeter per year infiltration rate, and a porosity in the vadose zone of 0.25 (from Table 5 of Appendix H), implying an effective porosity greater than the total porosity.	This inconsistency has been corrected in the D4 RIFS revisions. Assumptions for vadose zone parameters used in PATHRAE are described in Appendix H, Section 4.4
TDEC.S.117	**Page H-60, Paragraph 3:** "*The PATHRAE model also determines the equivalent annual water consumption per year for the creek water for each nuclide based on the surface water exposure routes (via crops and livestock), as stated in Section 2.3. PATHRAE uses EU factors (defined in Section 4.4.1) to represent and quantify the annual amount of nuclide (in terms of water volume) consumed by an individual from all pathways (EU includes the volume of well water ingested as well as volume ingested via surface water pathway) (EPA 1987).*" The document does not state whether the PATHRAE library of parameters such as uptake factors and slope factors used to compute the EU factors has been updated over the past twenty years, and TDEC has not yet been able to get detailed information about the PATHRAE codes. Have changes to the risk analyses for all of the pathways analyzed in the RI/FS since the version of PATHRAE used in the analysis been considered?	Yes, the document does give the library of parameters used. Attachment A to Appendix H lists the most recent slope factors and dose conversion factors, and the accompanying text gives the references (EPA 2014 and ORNL 2015) that were used in the modeling. The tables that contain the numbers will be updated to include the references as well. While the parameters used in the uptake of surface water through livestock and food grown locally are original to PATHRAE, the uptake of surface water through these pathways results in such a low (1% or less) consumption/intake compared to drinking water, the slight changes in these parameters would not affect the overall risk of exposure.
TDEC.S.118	**Page H-62, Paragraph 5:** "*Sensitivity model runs were conducted for mercury, since mercury-contaminated debris will be in a macroencapsulated form(s) within the landfill. The controlling release mechanism of mercury in the macro-form (e.g., the Kd in the waste) and potential localized placement within the cells were analyzed.*" Appendix H assumes that mercury contaminated debris that fails TCLP will be macroencapsulated within the landfill. This material includes demolition debris from the Y-12 West End Mercury Area. It is anticipated some of this building material will be impregnated or saturated with elemental mercury. Section 4.4.3.3 of Appendix H assumes this building material will contain about 625 mg/kg of mercury, but provides little detail on the chemical form. The sensitivity analysis was restricted to changing the partition coefficient of the waste, the waste volume, and, in a final analysis, the partition coefficient of mercury during transport in the vadose zone. PATHRAE model inputs gleaned from Attachment B to this Appendix yield a vertical groundwater velocity of 2.5 centimeters per year and a vadose zone thickness of 7 meters, resulting in a groundwater travel time of 280 years. Since PATHRAE solves the transport equation with constant coefficients and the assumption of linear partitioning between liquid and solid phases, the groundwater velocity cannot be increased over time as the barrier layers in the facility degrade. In the model, solute transport will be retarded with respect to the groundwater velocity by a factor equal to unity plus the product of the bulk density of the vadose zone times the soil-water partition coefficient divided by the porosity. Using the values for density and	Assumptions regarding the treatment and disposal of mercury-contaminated wastes have been modified for the D4 revision. DOE recognizes the uncertainty in modeling contaminant fate and transport beyond the 1000 year compliance period, and the limitations inherent in the modeling approach employed for risk estimation and PreWAC development. Model sensitivity evaluations (Appendix H section 4.5.1) include consideration of climatic changes anticipated within the next few centuries.

	porosity and the units and nomenclature of Appendix H, this is 1+6.4*Kd, so the conclusion that transport through the vadose zone controls the time to peak can be generalized. Using the methodology inherent in PATHRAE, any COPC with an assumed partition coefficient greater than 0.4 ml/g will have a travel time through the vadose zone of greater than 1000 years. Likewise, any COPC with Kd > 560 will have a vadose zone travel time of greater than a million years. Note that the time span for which the model must maintain constant infiltration rates, effective partition coefficients and hydraulic parameters in the subsurface will encompass geological changes that are not addressed in the design. These would include the known, small but relevant climate changes that are documented on cycles during the last few thousand years caused by variation of solar activity, and significantly larger climate change variation on a scale of tens of thousands of years to hundred thousand years, caused by the variations of the Earth's axis wobble during the planet's orbit around the Sun that is well documented over the past two million years.	
TDEC.S.119	**Page H-63, Paragraph 3:** "*A Kd of 580 ml/g is a reasonable assumption for the vadose zone, as discussed in Section 4.4.2.3. These results do indicate, however, that Kd in the vadose zone is the controlling factor.*" The partition coefficient of 580 ml/g is a reasonable soil-mercury equilibrium partition coefficient. However, as the geosynthetic liner is ultimately breached and the clay liner begins to degrade, the changes to the hydraulic properties of the liner will not be uniform, and flow through the liner and buffer will not be uniform. The vadose zone beneath the engineered features will have hydraulic properties with significant spatial variation, so after the liner begins to degrade, the assumption that equilibria between the soil and water is achieved everywhere seems unlikely. At this point, flow through the vadose zone should be along preferential paths without enough loss to mass transfer processes to reach equilibrium throughout vadose zone. The sensitivity analysis and implied conclusion that disposal of mercury at concentrations of 625 ppm and higher will not pose a significant risk to human health or the environment is contingent upon slow uniform migration of water through the vadose zone for millennia. The conclusion that mercury can be disposed without limitations on concentration or chemical form is also based on the use of drinking water standards as endpoints for the risk assessment rather than ambient water quality criteria. As noted in other comments, the proposed facility is anticipated to have an extensive underdrain system. The underdrain will provide a direct pathway for future mercury polluted leachate to flow to Bear Creek. The promulgated recreational water quality standard for mercury is 51 ng/L (ppt), resulting from bioaccumulation effects in fish. The allowable TCLP mercury concentration is to 0.2 mg/L (200,000 ppt) in leachate. Concentrations of leachate at the allowable TCLP limit are about 4 orders of magnitude greater than the applicable water quality criteria and so ambient water quality criteria in surface water are likely to control the mercury pre- WAC rather than Maximum Contaminant Levels in ground water. The primary risk from eating fish containing methylmercury include teratogenic (neurodevelopmental effects), mutagenic, or neuro and immunotoxicities, rather than an excess cancer risk Finally, the modeled macro-forms assumed in Appendix H measure 30 feet by 30 feet by 10 feet. It is expected that uncovered macro-forms will contain water due to precipitation. DOE proposed direct dumping large demolition debris into these macro-forms. Dump trucks cannot run on large debris, so it is anticipated smaller material will also be dumped to make a surface that allows dump trucks to fill the cells. Given the potential for elemental mercury to	Expanded model sensitivity exercises have been performed to illustrate the relative importance of vadose zone parameters that influence groundwater travel times (vertical velocity) and mercury transport (Kd).In addition, supplemental modeling has been performed to evaluate the significance of neglecting vadose zone dispersion. The results indicate that vadose dispersion will generally reduce the modeled peak concentration, except for particular radionuclides. Disposal of mercury contaminated waste, including the possibility of in-cell macroencapsulation, has been de-emphasized in the D4 RI/FS. Mercury-focused sensitivity modeling had been removed from Appendix H.

	accumulate in certain areas of the macroform, possibility of inundation of debris, and landfill logistics, TDEC is not convinced that flowable fill can be added in such a way as to assure effective in-cell macroencapsulation.	
TDEC.S.120	**Page H-71, Paragraph 2:** "*Radioactive decay chains in which decay products (daughters) have PreWAC limits were analyzed for cases where the parent isotope may require either establishment of a PreWAC limit (if no limit was determined by the fate-transport modeling of that isotope), or a more stringent limit (if the isotope has an initial fate-transport calculated PreWAC limit). The analysis thus assures that decay of a parent will not result in a daughter concentration exceeding its PreWAC limit. Several decay paths were determined to require this analysis including the following parent - daughter pairs:*" This evaluation of radionuclide progeny addresses only parent-daughter pairs and is incomplete, potentially contributing to inflated pre-WAC values for uranium and transuranic radionuclides. An evaluation of non-cancer toxicity of radionuclides, their progeny, and hazardous substances is also required to evaluate compliance with RAOs and should be included in Appendix H.	There is an evaluation of toxicity (non-cancer) of uranium as well as other hazardous contaminants in the Appendix with appropriate limits determined as necessary. See response to TDEC.S.100, Po-210 was investigated and based on results of that investigation no further requirements to limit parent isotopes were required. Two additional isotopes were added to the modeling: C-113m and Re-187.
TDEC.S.121	**Page H-72, Table 8:** Adjustments to the pre-WAC have expanded the list of radionuclides that have WAC lower than the specific activity of the isotope. However, pre-WAC values for Am 241, Am-243, Cf-249, Cf-250, Cf-251, Cm-244, Cm-245, Cm-246, Cm-247, Cs-137, Ni-63, Pu-238, Pu-239, Pu-240, Pu-241, and Sr-90 all exceed Class C NRC limits at a soil bulk density of 1.6. Since these are limits that are imposed on near surface disposal under even the most favorable siting conditions, the modeling effort in this Appendix appears to give results that are not consistent with an approach that is used widely across the nation.	Agree, there are limits on these isotopes in greater than class C category and in the version of the RI/FS commented on this exclusion was explained (e.g., that waste exceeding class C limits is excluded from disposal in an on-site facility on the ORR).. DOE has modified the D4 RI/FS to address this by including some Administrative WAC in this document, two of those being (1) Greater than Class C limits and (2) TRU waste limits. This change has been incorporated into an extensive revision of Section 6.2.3 of the main document, and see new information contained in Table 6-2 and Figure 6-14.
TDEC.S.122	**Page H-83, Paragraph 1:** "*Table H-11 compares the analytic PreWAC developed for EMDF with the EMWMF analytic WAC. As shown in the table, the analytic PreWAC for EMDF are generally 10 to 100 times higher than the analytic WAC for EMWMF. However, many more isotopes are assigned PreWAC for the proposed EMDF compared to the EMWMF analytic WAC.*" This states the Pre-WAC for EMDF is generally 10 to 100 times higher than the analytic WAC for EMWMF and the higher pre-WAC is based on the distance from the disposal cell to the receptor location, contributing to a smaller dilution factor and increased attenuation due to decay and dispersion modeled in PATHRAE. Another contributing factor to the higher pre-WAC is the underdrain system, which, in the MT3D model, reduces the source of contaminated leachate with respect to clean recharge. A third factor, not mentioned in this discussion, is the use of a 10-4 excess lifetime cancer risk to compute any non-adjusted pre-WAC values of radionuclides.	Revisions to parameters in modeling have resulted in PreWAC that are more restrictive than EMWMF analytic WAC limits. A repositioning of the farmer receptor well, as well as parameter adjustments (resulting in decreased travel times) in PATHRAE have contributed to these changes. This discussion and comparison of EMWMF WAC and EMDF PreWAC has been revised. The third factor mentioned here (reduction of risk after 1,000 years to 10^{-4}) is not a factor, because the same approach was used for EMWMF (e.g., 10-4 at >1,000 yr) and so that does not contribute to differences between EMWMF and EMDF WAC and preWAC.
TDEC.S.123	**Page H-83, Paragraph 7:** "*A hydraulic break will be created by excavating and filling the major existing stream channels within the landfill footprint with highly conductive gravel/cobble sized material. A thinner blanket drain would extend beyond this trench drain to conduct high water seepage to the trench drain. These backfilled existing channels would behave hydraulically as underdrains to allow shallow ground water to move laterally to discharge to surface water outside the landfill. The underdrain system should also help maintain a lower water table under much of the landfill. The underdrain system would act as a preferred migration pathway for contaminant movement under some conditions.*" TDEC agrees that the underdrain will lower concentrations of COPCs in some locations in	DOE has incorporated surface water protection into the D4 RIFS by calculating PreWAC limits that demonstrate surface water AWQC limits are met for those contaminants predicted to peak within the 1000 year compliance period. These results are presented in the revised RI/FS. Conservative mixing assumptions are made in the development of PreWAC in fate and transport analysis. All groundwater discharges to surface water, consequently the mass of contaminants (all) leaching from the landfill are discharged to surface water. Flow identified at the EMWMF underdrain is not necessarily representative of

	groundwater at the expense of surface water. If modeling scenarios were expanded to assure protection of surface water quality, pre-WAC values for some COPCs might be limited by ambient water quality criteria rather than risk to a hypothetical receptor or MCLs in ground water. More realistic scenarios might also look at cumulative effects of all sources on surface water, and would include a more realistic way to incorporate the mixing between surface water and ground water in any carbonate rock formations. With the underdrain at EMWMF, a flow path to carry groundwater and leachate (once engineering controls fail) has already been constructed and is documented to have sufficient flow to be utilized as a future residential water supply. In addition, the MWMF conceptual design and as-built locations shown in EMDF RI/FS, Figure H-26, are not the same and the footprint has expanded significant since the risk evaluation performed for the EMWMF in 1998. The next five year review should revisit the EMWMF risk assessment incorporating relevant potential scenarios and make a determination as to whether groundwater and surface water were evaluated and protected consistent with CERCLA requirements. The updated evaluation should include analysis of what has been put in EMWMF to date and what is proposed to be put in the landfill until closure including constituents for which there is a WAC, constituents for which no WAC was developed, and ingrowth progeny.	flow that might be encountered at another site, in another underdrain. Additionally, this is flow encountered during active operation and open cell faces, and prior to closure of the facility at which time recharge in the footprint will be cut off and underdrain flows should be reduced significantly. The remainder of this comment is not relevant to the RI/FS.