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

Date Issued—September 2012

Prepared by
Professional Project Services, Inc. (Pro2Serve®)
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FIGURES

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ACRONYMS

ALARA	as low as reasonably achievable
ANA	aquatic natural area
ARAP	Aquatic Resources Alteration Permit
ARAR	applicable or relevant and appropriate requirement
ARRA	American Recovery and Reinvestment Act of 2009
B	billion
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
D&D	Deactivation and Decommissioning
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
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
FWD	Federal Waste Disposal
FY	Fiscal Year
HA	habitat area
HCDA	Hazardous Chemical Disposal Area
HDPE	high-density polyethylene
HF	hydrofracture
HI	Hazard Index
HMR	Hazardous Materials Regulations
IFDP	Integrated Facility Disposition Program

IHB	Indiana Harbor Belt
LDR	land disposal restriction
LLW	low-level (radioactive) waste
LMD	legacy material disposition
M	million
MCC	Modular Concrete Canister
MEI	maximum exposed individual
MV	Melton Valley
NA	natural area
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
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
P&A	plugging and abandonment
PCB	polychlorinated biphenyl
PM	particulate matter
PPE	personal protective equipment
PWAC	Preliminary Waste Acceptance Criteria
RA	Reference Area
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act of 1976
RDR	Remedial Design Report
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
S&M	surveillance and maintenance
SNM	Special Nuclear Material
SPCC	safety and spill prevention, control, and countermeasures
SE	Southeast
TBC	to be considered
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 Fort Poplar Creek
UPF	Uranium Processing Facility
U.S.	United States
VR	volume reduction
VTD	Vacuum Thermal Desorption
WAC	Waste Acceptance Criteria
WBCV	West Bear Creek Valley
WCS	Waste Control Specialist
WGF	Waste Generation Forecast
WL	waste lot
WMI	Waste Management, Inc.
WWSY	White Wing Scrap Yard
Y-12	Y-12 National Security Complex

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 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 CERCLA waste.

As lead agency for ORR cleanup, DOE is working with the other Federal Facility Agreement (FFA) (DOE 1992) parties, the U.S. Environmental Protection Agency and Tennessee Department of Environment and Conservation (TDEC), to evaluate alternatives for disposal of low-level (radioactive) 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 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 will serve 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 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. Consistent with the EMWMF RI/FS, this RI/FS analyzes three alternatives:

1. **No-Action:** No coordinated ORR effort would be implemented to manage wastes generated by future CERCLA actions
2. **On-site Disposal Alternative:** 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). The proposed EMDF site is located in East Bear Creek Valley near the existing EMWMF.
3. **Off-site Disposal Alternative:** Transportation and disposal of future waste at approved, off-site disposal facilities.

SUMMARY OF FINDINGS

In the CERCLA process, alternatives for remedial action are assessed against nine evaluation criteria. All three alternatives evaluated would meet the two threshold criteria of overall protection of human health and the environment and compliance with applicable and relevant and appropriate requirements (ARARs). For the On-site Disposal Alternative, a waiver of two hydrologic condition ARARs would be requested on the basis of equivalent protectiveness provided by the landfill design.

Five primary balancing criteria address performance viability of the alternatives. Evaluation of the alternatives against these balancing criteria shows that all three alternatives would likely provide adequate performance and are viable, but that the On-site and Off-site Disposal Alternatives offer advantages over the No Action Alternative. The No Action Alternative may not be supportive of timely remediation of ORR sites due to lack of a coordinated disposal strategy. Two final modifying criteria, state and community acceptance, will be addressed in the Record of Decision (ROD) following state and 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.

The advantages and disadvantages of On-site and Off-site Disposal Alternatives are highlighted by five key criteria: (1) long-term effectiveness, (2) short-term transportation risk, (3) availability of services and materials, (4) land use, and (5) cost.

The On-site Disposal Alternative would be less costly than the Off-site Disposal Alternative, but an additional area of ORR would have to be permanently dedicated to waste disposal, resulting in impacts on future land use and the environment. Both the On-site and Off-site Disposal Alternatives would be protective of human health and the environment long term by disposal of waste in a landfill designed for site-specific conditions. The Off-site Disposal Alternative could isolate the wastes more effectively than the On-site Disposal Alternative long term due to the arid climate and fewer receptors at off-site disposal facilities, but long-distance waste transportation in the short-term could result in more accidents, causing injuries or fatalities. Uncertainty about continued availability of disposal capacity at off-site facilities is considered minimal. However, given the 30 years of anticipated CERCLA waste generation, the On-site Disposal Alternative provides a greater level of certainty than the Off-site Disposal Alternative that long-term disposal capacity would be available at the time wastes are generated.

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 and 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 remain the same as those used for the evaluation that led to construction and operation of the EMWMF (DOE 1998):

- Prevent exposure to future-generated CERCLA waste that exceeds a human health risk of 1×10^{-5} Excess Lifetime Cancer Risk (ELCR) or Hazard Index (HI) of 1.
- Prevent ecological exposure to future-generated CERCLA waste.
- Prevent releases of future-generated CERCLA waste or waste constituents that exceed a human health risk of 1×10^{-5} ELCR or an HI of 1, or ARARs for environmental media.
- Facilitate timely cleanup of ORR and associated facilities.

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 CHARACTERISTICS

The 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 types (regulatory classifications) and material types (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 through Fiscal Year (FY) 2042.

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 2042, including a 28% uncertainty allowance, show maximum capacity of EMWMF (2.18M yd^3) is estimated to be reached in FY 2020. Based on these estimates, the On-site Disposal Alternative assumes a new CERCLA waste disposal facility is operational in FY 2020[1]. 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 by a number of years. A higher funding scenario could result in EMWMF reaching capacity sooner.

The approach used to estimate "as-disposed" waste volumes followed a methodology similar to calculations used to predict as-disposed volumes in the Capacity Assurance Remedial Action Report 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, and volume reduction efforts. The conceptual design capacity of the proposed EMDF site for the On-site Disposal Alternative is 2.5M yd^3 and includes a 28% uncertainty allowance.

The as-generated waste volume estimate used in the RI/FS for FY 2020 through FY 2042 (post-EMWMF) is approximately 2.19M yd^3, including a 28% uncertainty allowance. Approximately 70% of the 2.19M yd^3 is debris. This estimate is used as the basis for analyzing waste shipments in the Off-site Disposal Alternative.

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 the EMWMF. This methodology relies on the assumption that available data for waste disposed at the EMWMF approximately represent the waste characteristics of future waste streams. Data sets of radionuclide contaminants were derived from EMWMF waste data to calculate 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. Chemical contaminants contribute relatively minimal transportation and natural phenomenon risk; consequently, waste characterization information in the RI/FS for chemical contaminants is limited to a discussion of the anticipated chemical constituents.

[1] For purposes of the RI/FS evaluation, operational start-up of a new facility is assumed to begin when EMWMF capacity is reached. However, in order to continue compliant disposal of CERCLA waste materials on the ORR, the operational start-up of a new disposal facility would actually be planned prior to the EMWMF reaching maximum capacity if the On-site Disposal Alternative is selected.

REMEDIAL ALTERNATIVES

Three alternatives were developed and evaluated for this RI/FS: No Action, On-site Disposal Alternative, and Off-site Disposal 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.

The On-site Disposal Alternative would provide consolidated disposal of most future-generated CERCLA waste exceeding the capacity of the existing EMWMF in a newly-constructed, engineered facility. This alternative includes designing and constructing a landfill and support facilities similar in design to the 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. A proposed site for a new EMDF near the existing EMWMF was identified utilizing a screening evaluation that included some of the sites identified in a previous 1996 siting study (DOE 1996) as well as other possible favorable locations.

By design, the WAC of a new EMDF would ensure risk to future receptors would not exceed risk criteria (1×10^{-5} Excess Lifetime Cancer Risk or a Hazard Index of 1 in the first 1,000 years). The RI/FS provides results of fate and transport analysis which demonstrate that Preliminary Waste Acceptance Criteria (PWAC) for the proposed EMDF would meet applicable risk and dose 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 PWAC identified in this RI/FS are a preliminary data set provided to show viability of land disposal at the proposed site. 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.

The approximate area which may be cleared or otherwise impacted by construction and operations would be up to 92 acres for the proposed EMDF site. The landfill footprint would be kept permanently cleared, representing long-term impact on the direct use of land of up to 70 acres. Locating the proposed EMDF immediately east of EMWMF offers advantages of sharing existing EMWMF infrastructure and being in close proximity to existing utilities.

The estimated total project cost for implementing the On-site Disposal Alternative at the proposed EMDF site is \$708M (2012 dollars) or \$499M (present worth).

Under the Off-site Disposal Alternative, future CERCLA waste would be transported off-site for disposal in approved disposal facilities, primarily by rail transport. All waste would be shipped in intermodal containers. Representative routes were assumed for the cost estimate and risk evaluation. Approximately 98% of the waste (non-classified LLW and LLW/TSCA waste) would be shipped to the Nevada National Security Site (NNSS) in Nye County, NV by rail transport from the East Tennessee Technology Park (ETTP) to a transfer facility in Kingman, AZ. 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 treatment and disposal by rail shipment from ETTP directly to the disposal facility at Energy*Solutions*, Clive, UT. Classified LLW waste would be shipped by truck to NNSS.

The estimated total project cost for implementing the Off-site Disposal Alternative is \$1.992 billion (B [2012 dollars]) or \$1.408B (present worth).

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). Except for the cost for purchase of waste containers for transport to off-site facilities, costs associated with these generator responsibility elements are not included in the cost estimates because they are not a differentiator between the On-site and Off-site Disposal Alternatives.

VOLUME REDUCTION

Volume reduction (VR) approaches and potential benefits for the On-site and Off-site Disposal Alternatives are evaluated in this RI/FS. For the On-site Disposal Alternative, VR processing could reduce capacity needs by up to two disposal cells (over 800,000 yd^3 of disposal capacity) and result in estimated cost savings of up to \$72M in 2012 dollars. For the Off-site Disposal Alternative, VR processing could result in an avoided shipping volume of over 300,000 yd^3 and estimated cost savings of up to \$252M in 2012 dollars. The RI/FS provides a comparison between unit costs ($\$/yd^3$ as-generated material) for on-site and off-site disposal with and without VR processing. In almost all cases, off-site disposal costs are significantly higher than on-site disposal.

Incorporating VR efforts in project planning and practical field implementation could result in significant cost savings and reduced need for disposal capacity. The largest cost savings and capacity gain could be achieved with deployment of size reduction equipment on a multiple project or programmatic basis; however, uncertainty factors such as funding, project sequencing, and contracting could impact the ability to implement this approach. The EMDF conceptual design allows the ability to construct the landfill in phases such that cells could be built as needed.

DIFFERENTIATING CRITERIA

No Action Alternative: The No Action Alternative may not support the RAO of facilitating the timely cleanup or release of portions of ORR and associated facilities for beneficial use. Overall remediation and disposal costs and local socioeconomic benefits could be lower if less aggressive remedial actions result from the lack of a coordinated disposal program. 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.

Comparison of On-site and Off-site Disposal Alternatives: Five key criteria differentiate the on- and off-site disposal alternatives: (1) long-term effectiveness, (2) short-term transportation risk, (3) availability of services and materials, (4) land use, and (5) cost.

Long-term Effectiveness: Both the On-site 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. 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 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 Transportation Risk: 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. For both disposal alternatives, the most significant risk of death or injury would result from waste transportation. 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 about the same for both alternatives. Off-site transportation carries a much higher risk due to the public roads and railroads travelled and the long distances involved. 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 (the majority of shipments evaluated in the Off-site Disposal Alternative are by rail).

For the Off-site Disposal Alternative, modeling of radiation exposure during routine and accident scenarios resulted in an estimated total cancer risk (fatal and non-fatal) for maximum exposed individuals that ranged from 1.06×10^{-3} to 7.53×10^{-2}. The collective population risk, which analyzed drivers, persons along or near the route, and handlers, resulted in an estimated excess cancer risk (fatal and non-fatal) ranging from 1.58×10^{-4} to 3.01×10^{-3}. Vehicular risk (risk associated with travel/vehicles) due to emissions and accidents, resulted in an estimate of 25.3 total incidents of illness, trauma, or death. 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 the estimated vehicular risk range in order of magnitude from 10^{-9} to 10^{-5}.

Availability of Services and Materials: Currently services and materials needed for pre-construction investigations, construction and operation of the On-site Disposal Alternative and transportation and disposal capacity for the Off-site Disposal Alternative are available. No impediments to continued operation for the On-site Disposal Alternative are likely to arise. State equity issues and reliance on off-site facilities introduce an 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.

Land Use: Construction of the EMDF would result in significant environmental impacts, mainly arising from rerouting a portion of a tributary and permanent loss of wetlands and forested habitat. The proposed EMDF site, while forested and undeveloped, is adjacent to a brownfield area where the existing EMWMF and former waste disposal sites are located. Land use at the on-site EMDF would be restricted in perpetuity. Land at off-site facilities is already committed to waste disposal.

Cost: The projected cost for the Off-site Disposal Alternative ($1.992B [2012 dollars] or $1.408B [present worth]) is approximately 2.8 times the estimated project cost of the On-site Disposal Alternative ($708M [2012 dollars] or $499M [present worth]).

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.

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. The EM 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, TN 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 Oak Ridge Office (ORO) and originally constructed as part of the World War II-era Manhattan Project: East Tennessee Technology Park (ETTP), formerly the K-25 Site; the Oak Ridge National Laboratory (ORNL); and the Y-12 National Security Complex (Y-12). Figure 1-1 also shows the location of the existing EMWMF site and a potential new facility referred to as the Environmental Management Disposal Facility (EMDF) evaluated in this RI/FS.

The EM 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.

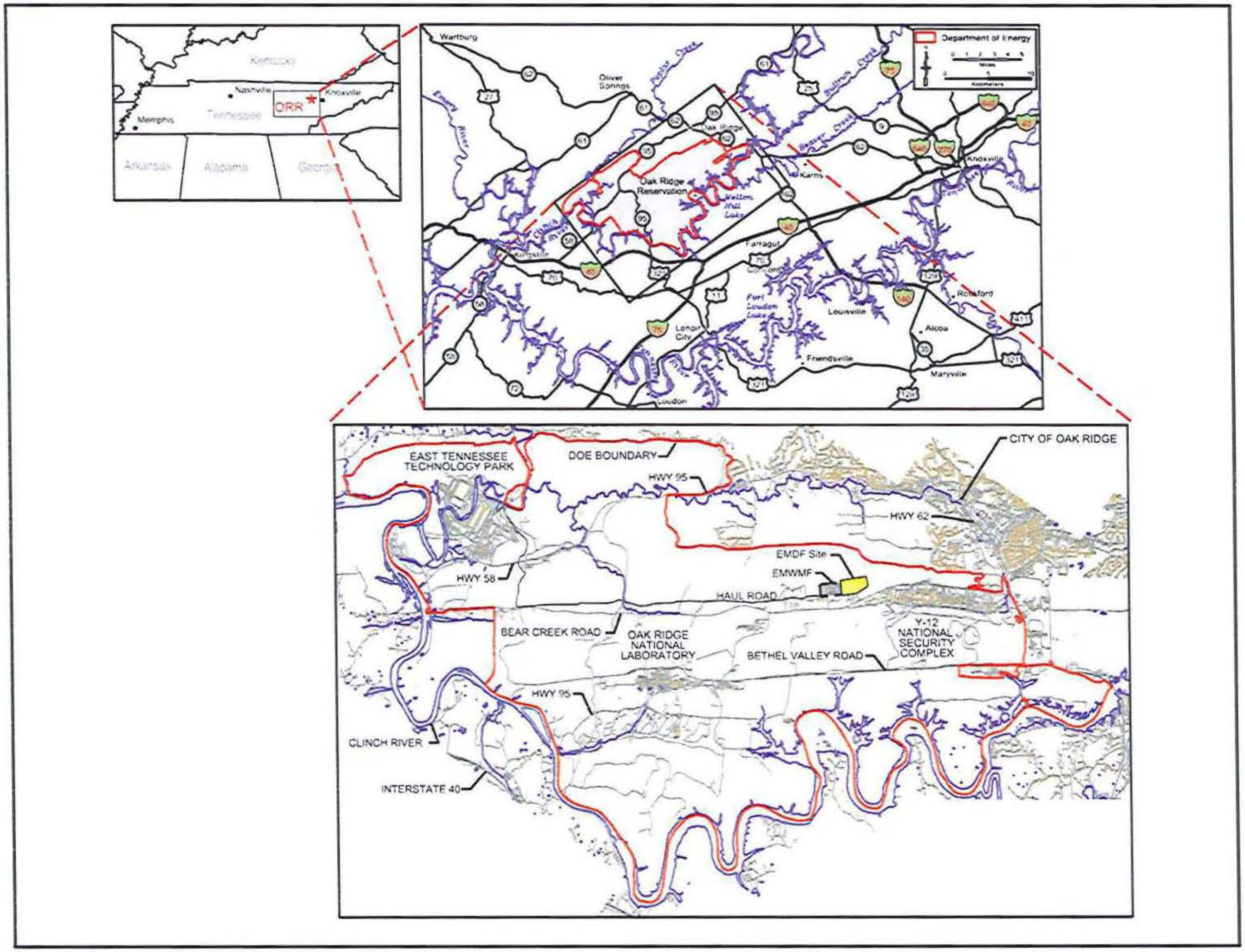

Figure 1-1. Oak Ridge Reservation, EMWMF, and Proposed EMDF Site Locations

The principal mission of the 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.

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, the EMWMF, has been constructed and is accepting CERCLA cleanup wastes. The capacity of the EMWMF is 2.2 million (M) yd^3 as authorized by the ROD and a subsequent Explanation of Significant Difference (DOE 2010b).

A widening of the scope of the EM Program has occurred since the original waste estimates were made in the RI/FS that led to the construction of the EMWMF (referred to herein as the EMWMF RI/FS) (DOE 1998). Extensive, new cleanup actions identified in the Integrated Facility Disposition Project (IFDP) were added by a major modification to the FFA in 2009 (DOE 2009b). Some of the actions have progressed into projects which are being, or recently have been, performed under the American Recovery and Reinvestment Act of 2009 (ARRA). The added cleanup actions significantly increase the volume of CERCLA waste projected to be generated.

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 ORO'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 (radioactive) waste (LLW), hazardous waste regulated under the Resource Conservation and Recovery Act of 1976 (RCRA), hazardous waste regulated under the Toxic Substances Control Act of 1976 (TSCA), mixed waste (LLW and hazardous 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 451.1B (DOE 2010c).

This report will serve as the initial document supporting DOE's 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 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. Consistent with the EMWMF RI/FS, this RI/FS analyzes three alternatives: No Action, on-site disposal in a newly

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

constructed facility on the ORR, and off-site disposal at permitted and licensed facilities. The EMWMF RI/FS analyzed three siting options under the On-site Disposal Alternative:

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

This RI/FS further analyzes a site in East BCV (EBCV) east of EMWMF for the proposed new EMDF (see Figure 1-1) as part of the On-site Disposal Alternative and provides a screening evaluation of other considered sites. The WBCV and WWSY sites were considered along with other candidate sites, but were eliminated from further evaluation as discussed in Appendix C.

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	*Evaluation of Baseline Risk*
4	*Remedial Action Objectives*
5	*Technology Screening and Alternatives Assembly*
6	*Alternatives Description*
7	*Detailed Analysis of Alternatives*
8	*References*
Appendix	**Appendix Title**
A	*Waste Volume Estimates and Waste Characterization Data*
B	*Waste Volume Reduction*
C	*On-site Disposal Alternative Site Description*
D	*Alternatives Risk Assessment and Fugitive Emissions Modeling*
E	*Applicable or Relevant and Appropriate Requirements (ARARs)*
F	*On-site Disposal Facility Preliminary Waste Acceptance Criteria*
G	*Cost Estimates for On-site and Off-site Disposal Alternatives*

As stated for the EMWMF RI/FS, 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 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, *Evaluation of Baseline Risk*, 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.

The remedial action objectives (RAOs) for alternatives evaluated in this RI/FS are specified in Chapter 4 and remain the same as those established in the EMWMF RI/FS.

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 G 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 provides applicable information about the region, updated as appropriate, and the proposed EMDF site. The EMWMF RI/FS is a reference for additional information about the regional environmental setting.

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

Appendix E provides a discussion and listing of applicable or relevant and appropriate requirements (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 WAC was later updated and approved in the WAC Attainment Plan (DOE 2001b). Appendix F of this RI/FS, *On-site Disposal Facility Preliminary Waste Acceptance Criteria*, provides Preliminary WAC (PWAC) for the proposed EMDF 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.

Appendix G provides summary cost estimate information and supporting assumptions for the On-site and Off-site 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 implementation (e.g., Remedial Action Work Plans).
- Development of project-specific waste generation forecasts.
- Accumulation of operational experience and knowledge from waste disposal practices at the EMWMF, including:
  - An approved WAC and WAC attainment process
  - Approved waste profiles with waste characterization data for CERCLA waste streams
  - Annual Capacity Assurance Remedial Action Reports (CARARs) to predict 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, including assumptions to address uncertainties. This process consisted of the following general steps:

<u>Waste Volume Estimates</u>

- Developed RI/FS waste volume estimates of future CERCLA waste on an individual project basis.
  - Used existing waste generation forecast data as modified by best available information from other planning and estimating efforts.
- Developed projected waste generation schedules for the waste volume estimate on an individual project basis.
  - Used information from current planning efforts to predict individual project sequencing within projected annual funding constraints.

<u>Waste Characterization</u>

- Developed representative contaminant concentrations based on waste profile, volume, and weight data for waste disposed to date at the EMWMF.

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 Cost Estimate	Chapter 6 Appendix G	Disposal capacity for new disposal facility (Based on "as-disposed" waste volume estimate)	
	Schedule	Chapter 2 Appendix G	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 D		Waste contamination released by a tornado strike
	Risk (Transportation)	Appendix D	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 F		• 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 Cost Estimate	Chapter 6 Appendix G	Number, waste type, and material type of waste shipments (Based on "as-generated" waste volume estimate)	
	Risk (Transportation)	Appendix D	Number, waste type, and material type of waste shipments (Based on "as-generated" waste volume estimate)	Waste contaminants in waste shipments

EMWMF Environmental Management Waste Management Facility
WAC Waste Acceptance Criteria

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

Wastes generated on the ORR that are excluded from consideration in the RI/FS because disposition will be addressed by other established programs or by the projects generating the waste 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.
- Transuranic (TRU) waste is excluded because it will be treated on-site at the TRU Waste Processing Center for disposal at the Waste Isolation Pilot Plant.
- Industrial/sanitary (nonregulated) 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.

2.1.2 Waste Types and Material Types

For volume estimates to support the RI/FS, waste streams are delineated by both waste types (regulatory classifications) and material types (waste forms). Waste types are LLW and mixed waste. Mixed waste has components of radiological and other regulated waste such as RCRA hazardous waste and TSCA regulated waste (e.g., 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, 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 Code of Federal Regulations (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 EM program Waste

Generation Forecast[3] (WGF) and projected for off-site disposal. Future potential sources of listed waste on the ORR include soil contaminated with a listed groundwater 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. As discussed in Sect. 6.2.2.7, if listed waste is to be disposed at the proposed new EMDF, design modifications for management of contact water would be required.

2.1.3 Wastes that do not meet Disposal Facility WAC

An evaluation of ORR CERCLA waste disposal practices since Fiscal Year (FY) 2002 shows that between 1% and 4% of total CERCLA waste generated annually[4] was packaged, shipped, and disposed at an approved off-site facility. The waste was shipped off-site because it did not meet the EMWMF WAC or because of other project-specific factors. As discussed in Sect. 2.3 and Appendix F, respectively:

- The characteristics of future CERCLA waste generated are anticipated to be similar to CERCLA waste generated since EMWMF began operating in FY 2002.
- PWAC 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 similarity in current and future CERCLA waste generation, approximately 3% of future total CERCLA waste generated waste generated annually is assumed for the RI/FS evaluation to be shipped for off-site disposal regardless of the disposal alternative (on-site or 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 presented below 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 under the On-site Disposal Alternative, or
- Shipped for off-site disposal at an approved facility under the Off-site Disposal 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.

Similar to the definitions in the CARAR (DOE 2012a) completed annually for the EMWMF based on WGFs, there are two types of quantitative waste volume estimates used in this RI/FS as described below:

- "As-generated" waste volume estimate:
  - An estimate of volume 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.

[3] WGF download January 2012

[4] Total excludes CERCLA waste disposed at ORR Landfills

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).

EMWMF disposal experience has allowed for development of formulas that are used to determine the amount of landfill space required for a given volume of as-generated waste material. The CARAR uses these formulas, including density conversion factors, to estimate waste volume after compaction in the landfill. Estimates of compacted waste and required fill material are used to convert "as-generated" volume to an "as-disposed" volume in order to predict future landfill space requirements.

- "As-disposed" waste volume estimate:
  - An estimate of volumes of waste after disposal in the disposal facility, at which point debris wastes, waste suitable for use as fill, and clean fill have been mixed and processed to meet compaction and void space requirements (i.e., used for On-site Disposal Alternative).
  - Physically equivalent to survey results taken quarterly to estimate disposal facility airspace utilized.
  - Includes lower amount of void space than as-generated waste volume because 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 below.

2.2.1 As-generated Waste Volume Estimate

The base as-generated waste volume estimate was developed by using existing contractor WGF data[5] 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.
- Forecasted volumes were modified for specific projects such as ARRA projects and other projects for which updated waste volume estimates were available.
- The schedule for ORR cleanup projects and associated waste generation was revised based on an assumed $420M funding scenario[6] for ORR cleanup projects from FY 2012 through FY 2043, with ORR CERCLA waste generation through FY 2042.

The base as-generated waste volume estimate covers the FY 2012 through FY 2042 timeframe and does not include applied uncertainty. The annual estimate for base as-generated waste volumes ranges from about 10,000 yd^3 per year to 178,000 yd^3 per year as shown in Figure 2-1. Figure 2-1 also shows the as-generated waste volumes with 28% uncertainty applied. The annual estimate for as-generated waste volumes with uncertainty ranges from 13,000 yd^3 per year to 228,000 yd^3 per year.

[5] WGF download January 2012

[6] The RI/FS waste volume estimate is based on an approximation of project sequencing for a scenario that assumes funding of $420M in FY 2012, $421M in FY 2012 through FY 2018, and $421M escalated at 2.3% annually through the end of the program (FY 2043). A rebaselining effort of the EM program in Oak Ridge is currently underway using the $420M funding scenario that will result in a finalized project sequencing.

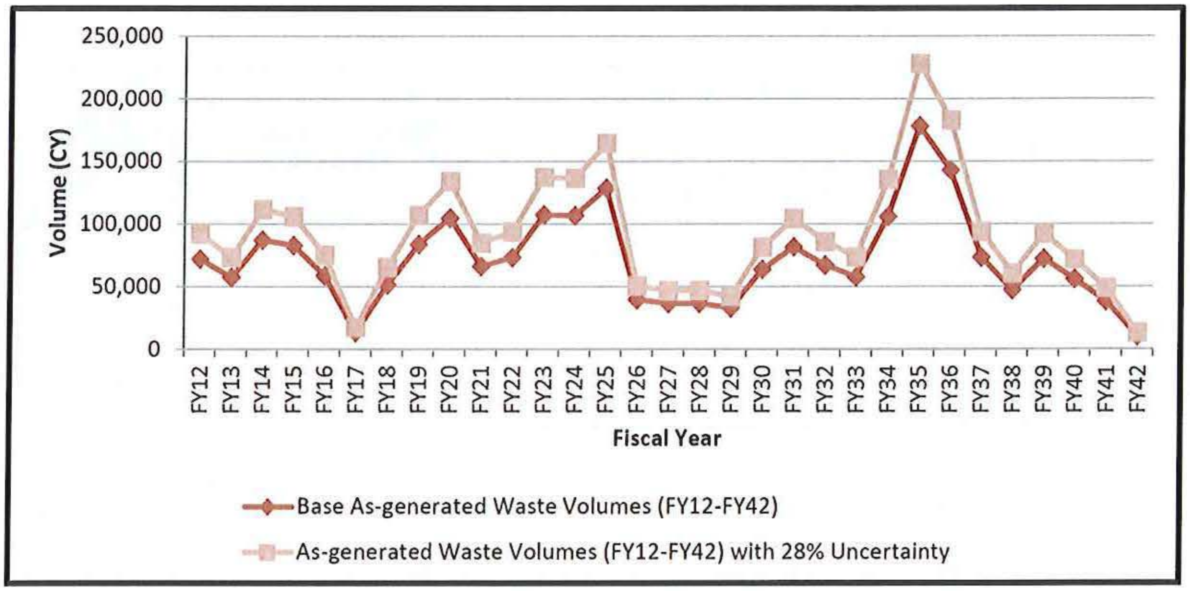

Figure 2-1. As-generated Waste Volume Estimate

Using the modified CARAR approach and assumptions about uncertainty to calculate the as-disposed volume described in Sect. 2.2.2, it is estimated that the EMWMF will be filled to capacity in FY 2020.

The post-EMWMF (FY 2020 - FY 2042) portion of the as-generated waste volume estimate 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.

A summary of the post-EMWMF base as-generated waste volume estimate by material type and waste type is presented in Table 2-2.

Table 2-2. Post-EMWMF Base As-generated Waste Volume Estimate (FY 2020 - FY 2042)

Material Type	Waste Type		TOTAL by Material Type (yd^3)	% by Material Type
	LLW (includes LLW/TSCA)	Mixed (LLW/RCRA, LLW/RCRA/TSCA)		
Debris	1,172,543	21,578	1,194,121	69.77%
Debris/Classified	5,948	550	6,498	0.38%
Soil	498,885	11,975	510,860	29.85%
Total	1,677,376	34,103	1,711,479	
% by Waste Type	98.01%	1.99%		

Table 2-3 presents the post-EMWMF as-generated volume estimate with 28% uncertainty[7] that is used as the basis of the Off-site Disposal Alternative. The 28% uncertainty included in the approximately 2.19M yd^3 of waste shipped for off-site disposal shown in Table 2-3 is equivalent to the uncertainty amount used in the as-disposed waste volume estimate for the On-site Disposal Alternative. The simplified CARAR methodology described in Sect. 2.2.2 applies 28% uncertainty at the end of the as-disposed waste volume estimate calculation.

Of the approximately 2.19M yd^3 of the as-generated waste volume estimate with 28% uncertainty shown in Table 2-3, approximately 70% is material type debris and approximately 30% is soil. Less than 1% of the as-generated waste volume estimated is classified debris waste which requires disposal at a DOE facility. Approximately 98% is waste type LLW or LLW/TSCA.

Table 2-3. Post-EMWMF Base As-generated Waste Volume Estimate (FY 2020 - FY 2042)

Material Type	Waste Type		TOTAL by Material Type (yd^3) with 28% Uncertainty	% by Material Type
	LLW (includes LLW/TSCA)	Mixed (LLW/RCRA, LLW/RCRA/TSCA)		
Debris	1,500,619	27,615	1,528,234	69.77%
Debris/Classified	7,612	704	8,317	0.38%
Soil	638,472	15,326	653,797	29.85%
Total	2,146,703	43,645	2,190,348	
% by Waste Type	98.01%	1.99%		

Appendix A provides further detail about as-generated waste volume estimates by project and year.

2.2.2 As-disposed Waste Volume Estimate

The approach used to estimate as-disposed waste volumes followed a methodology similar to calculations used to predict as-disposed volumes in the CARAR 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, and volume reduction efforts. For debris and containerized wastes, material must be added to fill void spaces. The optimum fill material is

[7] The actual assumed uncertainty is 27.9798%; 28% is a rounded value.

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. Volume reduction methods that could potentially be implemented to reduce disposal capacity needs are evaluated in Appendix B.

The CARAR utilizes 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 program is performed for the CARAR annually and a calculated 95% upper confidence limit (UCL) uncertainty allowance is added to total waste (debris and soil waste) plus clean fill values to account for uncertainty in waste volume estimates and fill demand projections. The UCL-95 uncertainty allowance is applied to future volumes and a lower, overall uncertainty is calculated that takes into account both known as-disposed volumes (with no uncertainty) as well as future volumes with uncertainty allowance. The overall uncertainty reported in CARARs from 2008 to 2012 (DOE 2008a, DOE 2009a, DOE 2010a, DOE 2011a, DOE 2012a) ranges from approximately 5% to 15%. The uncertainty increases with an increase in future volumes that are considered to have low confidence in volume values.

Prediction of as-disposed volumes for the RI/FS used a similar, simplified methodology as described below:

- Started with the base as-generated waste volume estimate developed for the RI/FS described in Sect. 2.2.1.
- Used simplifying assumption of two waste material types (soil or construction debris) and corresponding density conversion factors to calculate as-disposed volumes that reflect compaction of waste in the landfill.
- Established soil demand prediction (volume of clean fill soil needed) using fill debris ratio for construction debris and assuming waste soil that is generated in the same year as waste debris is used as fill. Excess waste fill occurs when more waste fill is generated than is needed for void space management.
- Added an uncertainty allowance for future volumes of total waste (debris and soil waste) plus fill.

As shown in Table 2-4, the projected disposal capacity need varies with the assumed percent uncertainty in future waste and fill volumes applied to the RI/FS as-disposed waste volume estimate.

Table 2-4. Percent Uncertainty and Corresponding Projected Disposal Capacity Need

Assumed % Uncertainty in Future Volumes	Overall % Uncertainty	Projected Disposal Capacity Need (M yd3)	EMDF Cells Needed
0	0	1.7	Cells 1-4
15	11	2.1	Cells 1-5
28	**20**	**2.5**	Cells 1-6

The assumed allowance of 28% uncertainty applied to the as-disposed waste volume estimate corresponds to an overall uncertainty of 20% and a projected disposal capacity need of approximately 2.5M yd^3, which is the conceptual design capacity of the proposed EMDF site for the On-site Disposal Alternative. If the On-site Disposal Alternative is selected as the remedy, the capacity may be further maximized for efficiency and land utilization considering topographic and hydrogeologic features in 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 Cells 5 and 6 could be eliminated if capacity is not needed).

Figure 2-2 shows the cumulative CERCLA waste capacity demand estimate through FY 2042 based on a 28% uncertainty allowance for future volumes. Figure 2-2 also shows the maximum capacity of EMWMF (2.18M yd^3) is estimated to be reached in FY 2020 based on 28% uncertainty in future volumes. Based on this estimate, the On-site Disposal Alternative assumes a new CERCLA waste disposal facility is operational in FY 2020[8]. There is a small amount of excess waste fill in the as-disposed waste estimate, but the amount is minimal (8,429 yd^3) and difficult to identify on the Figure 2-2 graph. The amount of excess waste fill depends on the mix of debris and waste soil volumes projected to be received in the FY. Table A-4 in Appendix A provides a breakdown by FY of the as-disposed waste estimate, including the amounts of excess waste fill projected each FY.

[8] For purposes of the RI/FS evaluation, operational start-up of a new facility is assumed to begin when EMWMF capacity is reached. However, in order to continue compliant disposal of CERCLA waste materials on the ORR, the operational start-up of a new disposal facility would actually be planned prior to the EMWMF reaching maximum capacity if the On-site Disposal Alternative is selected.

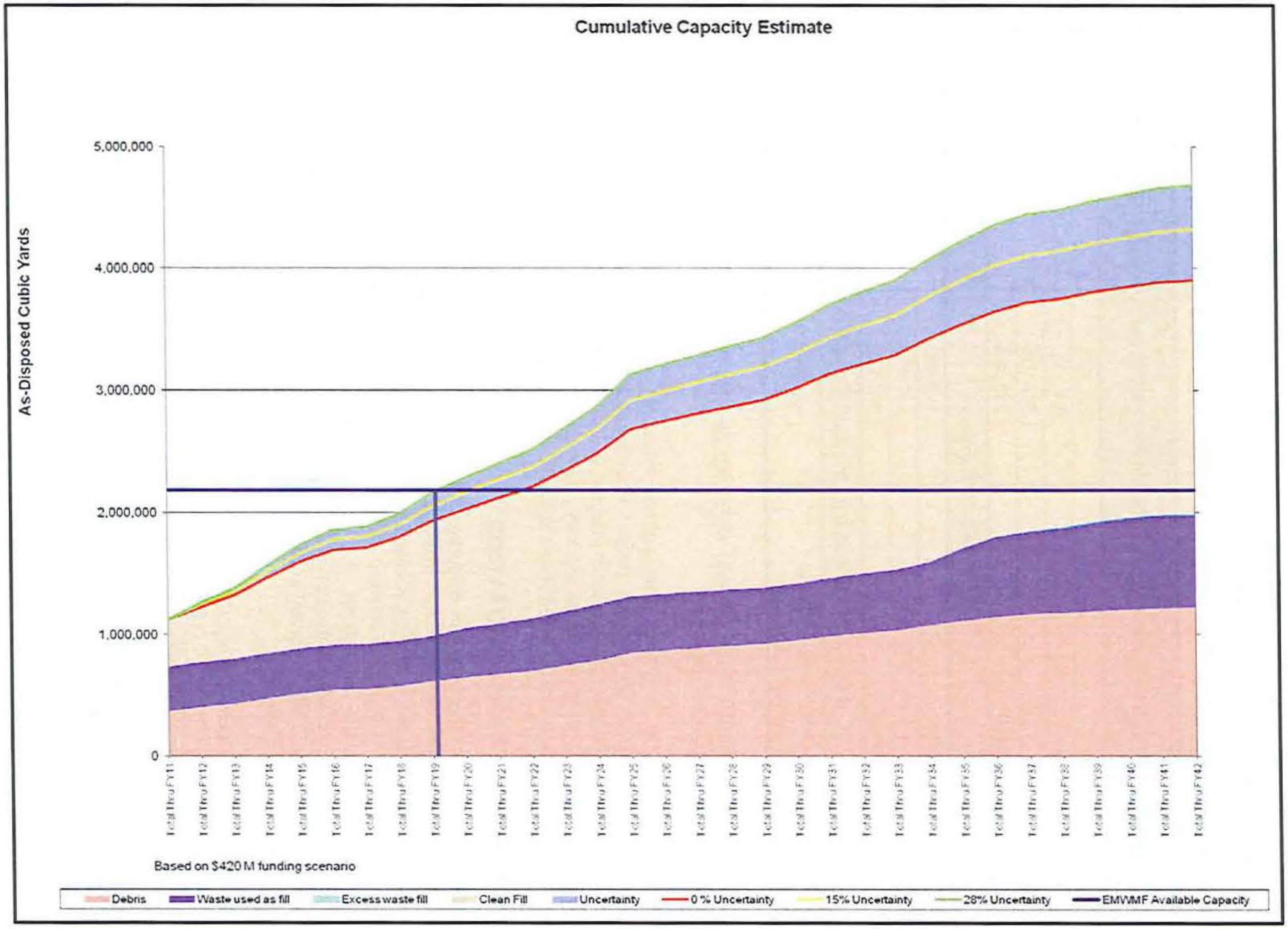

Figure 2-2. Cumulative CERCLA Waste Capacity Demand Estimate

As shown in Table 2-5, the total CERCLA as-disposed waste volume estimate (including waste soil, debris, and clean fill) for FY 2012 through FY 2042 with 28% uncertainty is approximately 3.56M yd^3. At the end of FY 2011, EMWMF had a remaining available capacity of 1.06M yd^3. The estimated post-EMWMF capacity needed of approximately 2.5M yd^3 shown in Table 2-5 corresponds to the conceptual design capacity of the proposed EMDF.

Table 2-5. Estimate of CERCLA Waste Disposal Capacity Needed Post-EMWMF with 28% Uncertainty

Total CERCLA As-disposed Waste Volume Estimate FY12-FY42 (yd^3)		**Total Including Uncertainty Allowance of 28%**
Debris	851,367	3,562,810
Soil	401,570	
Clean Fill	1,530,948	
Total Waste and Clean Fill	2,783,884	
EMWMF Capacity		
EMWMF Total Capacity	2,180,000	1,062,810
EMWMF Used Capacity thru FY11	1,117,190	
EMWMF Available Capacity	1,062,810	
Post-EMWMF Capacity Needed FY20-FY42 yd^3		
Total CERCLA As-disposed Waste Volume Estimate less EMWMF Available Capacity	1,721,074	2,500,000

Appendix A provides further detail by year about the as-disposed waste volume estimate with 28% uncertainty allowance in future volumes.

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 Sect. 2.2.1) could delay EMWMF reaching maximum capacity and the operational start of a new facility by a number of years. A higher funding scenario could result in EMWMF reaching capacity sooner.

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 the 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 the EMWMF approximately represent the waste characteristics of future waste streams. Use of characterization data for waste disposed at the EMWMF is limited in the RI/FS to serving as a basis for the transportation risk and natural phenomena risk calculations.

The EMWMF waste characterization results were used to develop a derived data set of radionuclide contaminants as discussed in Sect. 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 D. 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 Sect. 2.3.2.

PWAC 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 PWAC evaluation is used to determine the following:

- Does the PWAC 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 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. 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:

1. Waste lots (WLs) for waste disposed at the EMWMF were identified using a Waste Transportation Management System[9] EMWMF Disposition Summary Report.
2. Radionuclide COPC concentration data for identified WLs were obtained from a Waste Acceptance Criteria Forecast Analysis Capability System[10] output report or waste profile data. The expected value concentrations of radionuclide COPCs reported in the individual waste WL data sets were identified.
3. Net weight data for identified WLs were collected.

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:

1. 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.

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[9] 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.

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

2. 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 2-6 forms the data set used for risk evaluation.

Table 2-6. Data Set for Natural Phenomena and Transportation Risk Evaluation

Isotope	Mass Weighted Average (pCi/g)
Ag-110m	4.76E-01
Am-241	9.18E+00
Am-243	5.77E-01
Bi-214	3.89E-01
C-14	2.91E+01
Cm-242	1.63E-01
Cm-243	6.69E+00
Cm-244	1.14E+04
Cm-245	1.39E-01
Cm-246	5.41E+00
Cm-247	9.55E-03
Co-57	1.48E-01
Co-60	5.05E+02
Cs-134	2.48E+04
Cs-137	5.83E+03
Eu-152	6.43E+03
Eu-154	4.85E+03
Eu-155	1.41E+03
F-59	1.49E+00
H-3	1.91E+02
I-129	1.79E+00
K-40	4.21E+00
Kr-85	1.04E+02
Mn-54	8.47E-01
Nb-94	7.93E-02
Ni-59	4.04E+01
Ni-63	1.05E+02

Isotope	Mass Weighted Average (pCi/g)
Np-237	2.91E-01
Pb-210	2.50E+00
Pb-214	4.02E-01
Pm-147	1.00E+01
Pu-238	5.69E+01
Pu-239	1.17E+01
Pu-240	1.74E+02
Pu-241	2.01E+02
Pu-242	3.79E-01
Pu-244	3.22E-02
Ra-226	9.10E-01
Ra-228	7.95E-01
Ru-106	6.27E+04
Sr-90	9.73E+03
Tc-99	3.67E+01
Th-228	4.27E-01
Th-229	4.00E-03
Th-230	1.55E+00
Th-232	1.69E+00
U-232	1.65E+00
U-233	8.13E+01
U-234	2.69E+02
U-235	1.63E+01
U-236	1.14E+01
U-238	1.60E+02
Zn-65	1.46E+00

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 in the 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 limited to information about contaminants anticipated to be present in future generated CERCLA waste.

For on-site disposal of waste, the administrative WAC for a potential disposal facility would require the RCRA hazardous waste that is disposed meet applicable land disposal restrictions (LDRs).[11] The analytic WAC identifies additional risk- and dose-based chemical limits for constituents which may be present in the waste disposed at the EMWMF (see Sect. 1.1 in Appendix F). Off-site waste shipments are required to meet the U.S. Department of Transportation (DOT) requirements.

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 2-7.

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[11] 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 groundwater and/or surface water. Specific constituent levels (i.e., treatment standards) must be achieved before the hazardous waste can be land disposed.

Table 2-7. Chemical Constituents

Chemical	CASN	Chemical	CASN
(1,1-Dimethylethyl)benzene	98-06-6	4-Chloro-3-Methylphenol	59-50-7
(1-Methylpropyl)benzene	135-98-8	4-Methyl-2-Pentanone (MIBK)	108-10-1
1,1,1-Trichloroethane	71-55-6	4-methylphenol (p-cresol)	106-44-5
1,1-Dichloroethane	75-34-3	Acenaphthene	83-32-9
1,1-Dichloroethene (Dichloroethylene)	75-35-4	Acenaphthylene	208-96-8
1,1,2-Trichloroethane	79-00-5	Acetone	67-64-1
1,1,2-Trichloro-1,2,2-Trifloroethane	76-13-1	Acetophenone	98-86-2
1,2,4-Trichlorobenzene	120-82-1	Aldrin	309-00-2
1,2,4-Trimethylbenzene	95-63-6	Alpha-BHC	319-84-6
1,2-Dichlorobenzene	95-50-1	alpha-Chlordane	5103-71-9
1,2-Dimethylbenzene	95-47-6	Aluminum	7429-90-5
1,2-Dichloroethane	107-06-2	Anthracene	120-12-7
1,2-Dichloroethene	156-59-2	Antimony	7440-36-0
1,3,5-Trimethylbenzene	108-67-8	Arsenic	7440-38-2
1,3-Dichlorobenzene	541-73-1	Asbestos	1332-21-4
1,4-Dichlorobenzene	106-46-7	Barium	7440-39-3
1-Methyl-4-(1-methylethyl)benzene	99-87-6	Benzo(a)anthracene	56-55-3
2,3,4,6-Tetrachlorophenol	58-90-2	Benzene	71-43-2
2,3,7,8-Tetrachlorodibenzo-p-dioxin	1746-01-6	Benzenemethanol	100-51-6
2,4-Dimethylphenol	105-67-9	Benzo(a)pyrene	50-32-8
2,4-Dinitrophenol	51-28-5	Benzo(b)fluranthene	205-99-2
2,4,5-Trichlorophenol	95-95-4	Benzo(g,h,i)perylene	191-24-2
2-Butanone (also known as Methyl Ethyl Ketone)	78-93-3	Benzo(k)fluoranthene	207-08-9
2-Chlorophenol	95-57-8	Benzoic Acid	65-85-0
2-Chloronaphthalene	91-58-7	Beryllium	7440-41-7
2-Hexanone	591-78-6	Beta-BHC	319-85-7
2-Methylnaphthalene	91-57-6	Bis(2-ethylhexyl)phthalate	117-81-7
2-methylphenol (o-cresol)	95-48-7	Boron	7440-42-8
3-3'-Dichlorobenzidine	91-94-1	Butylbenzylphthalate	85-68-7
3-methylphenol (m-cresol)	108-39-4	Cadmium	7440-43-9
2-Nitroaniline (O-Nitroaniline) IP-Nitroaniline)	88-74-4	Calcium	7440-70-2
4,4'-DDD	53-19-0	Carbazole	86-74-8
4,4'-DDE	72-55-9	Carbon disulfide	75-15-0
4,4'-DDT	50-29-3	Carbon tetrachloride	56-23-5
4,6-Dinitro-2-methylphenol	534-52-1	Chlordane	57-74-9

Table 2-7. Chemical Constituents (Continued)

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

3. EVALUATION OF BASELINE RISK

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 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 a 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. 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 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.[12]

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. Section 6.1 provides further discussion of the No Action Alternative.

Although this RI/FS does not present a typical evaluation of baseline risk of a contaminated site for the No Action Alternative, evaluations of transportation risk and natural phenomenon risk for the On-site Disposal Alternative and transportation risk for the Off-site Disposal Alternative are provided in Appendix D. Appendix F provides PWAC for the proposed on-site disposal facility based on contaminant pathway analysis modeling to meet risk and dose criteria. 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

[12] 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.

effectiveness, and long-term effectiveness use risk assessment information from Appendix D and Appendix F.

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

Site	Subproject	Risk Evaluation Document	Decision Document*	Project
ETTP	K-25/K-27 D&D	*Engineering Evaluation/Cost Analysis for the Decontamination and Decommissioning of the K-25 and K027 Buildings at the East Tennessee Technology Park, Oak Ridge, Tennessee (DOE/OR/01-1917&D3)*	*Action Memorandum for the Decontamination and Decommissioning of the K-25 and K-27 Buildings, East Tennessee Technology Park, Oak Ridge, Tennessee* (DOE/OR/01-1988&D2)	K-27 Area D&D
	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 D&D
				Centrifuge Facilities D&D
				ETTP Main Plant Area Facilities D&D
				K-29 Area Facilities D&D
				Poplar Creek Facilities D&D
				TSCA Incinerator D&D (Non BJC Scope)
	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 ROD	Experimental Gas Cooled Reactor D&D
				Health Physics Research Project Area D&D
				MV Liquid Gaseous Waste Operations D&D
				MV Homogeneous Reactor Experiment D&D
				MV Legacy Material Disposition
				TRU Waste Processing 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 Decisions for Interim Actions in Bethel Valley, Oak Ridge, Tennessee* (DOE/OR/01-1862&D4)	BV Chemical Development Lab Facilities D&D
				BV Isotope Area Facilities D&D
				BV Reactor Area Facilities D&D
				BV Tank Area Facilities D&D
				BV Remaining Slabs and Soils
				ORNL Non-hydrofracture (HF) Well plugging and abandonment (P&A)
				ORNL Remaining Non-HF Well P&A
				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
				3019 Ancillary Facilities D&D
				3019A D&D
				3525 Complex
				4501/4505 Building D&D
				5505 Building D&D
				6010 Building D&D
				Central Stack Hot Cell Facilities Complex
				Fire Station Complex
				Low-Level Liquid Waste Facilities D&D
				ORNL Small Facilities D&D

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)	Process Waste Facilities D&D
				Remaining East BV Facilities
				Southeast (SE) Contaminated Lab Complex
				SE Services Group Complex
				Sewage Treatment Plant Complex D&D
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 Legacy Material Disposition (LMD)
				9212 Complex
				9212 Complex LMD
				Alpha-2 Complex
				Alpha-2 Complex LMD
				Alpha-3 Complex
				Alpha-3 Complex LMD
				Alpha-4 D&D
				Alpha-5 Complex
				Beta-1 Complex
				Beta-1 Complex LMD
				Beta-3 Complex LMD
				Beta-4 Complex
				Beta-4 Complex LMD
				Biology Complex
				Deactivation Only Complex (Beta-3 and 9731)
				Transition Facility D&D
				Y-12 EM Facilities D&D

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

<table>
<tr><th>Site</th><th>Subproject</th><th>Risk Evaluation Document</th><th>Decision Document*</th><th>Project</th></tr>
<tr><td rowspan="6">Y-12 (cont)</td><td rowspan="4">Upper East Fork Poplar Creek</td><td rowspan="2">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)</td><td>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)</td><td>UEFPC Sediments-Streambed & Lake Reality</td></tr>
<tr><td>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)</td><td>UEFPC Soils 81-10 Area Remediation</td></tr>
<tr><td rowspan="2">Upper East Fork Poplar Creek Soil and Scrapyard Focused Feasibility Study (DOE/OR/01-2083&D2)</td><td rowspan="2">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)</td><td>UEFPC Remaining Slabs and Soils</td></tr>
<tr><td>UEFPC Soils Remediation</td></tr>
<tr><td rowspan="2">Bear Creek Valley</td><td>To Be Determined</td><td>Bear Creek Valley White Wing Scrap Yard Record of Decision</td><td>BCV White Wing Scrap Yard Remediation</td></tr>
<tr><td>Remedial Investigation of Bear Creek Valley at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee, Volume 1 (DOE/OR/01-1455/V1&D2)</td><td>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)</td><td>BCV S-3 Ponds</td></tr>
</table>

*Red Text Denotes a Future CERCLA Evaluation

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 and 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 from ORR and associated sites after EMWMF capacity is reached. Because the actions being evaluated are designed to provide for the disposition of various waste types derived from a wide range of sources and activities, establishing specific cleanup goals is not appropriate. Instead, remediation goals for site cleanup at the project-specific level have already been made in existing CERCLA decision documents or will be made in future CERCLA decision documents.

The four RAOs for alternatives evaluated in this RI/FS remain the same as those established for the alternatives evaluated in the EMWMF RI/FS. The first three RAOs are most directly applicable to evaluation of the protectiveness of a permanent waste disposal facility under the On-site Disposal Alternative:

1. Prevent exposure to future-generated CERCLA waste that exceeds a human health risk of 1×10^{-5} Excess Lifetime Cancer Risk (ELCR) or Hazard Index (HI) of 1.
2. Prevent ecological exposure to future-generated CERCLA waste.
3. Prevent releases of future-generated CERCLA waste, or waste constituents, that exceed a human health risk of 1×10^{-5} ELCR or an HI of 1, or ARARs for environmental media.

Appendix C provides a description of the siting option in EBCV evaluated in this RI/FS and siting options that were screened out from further evaluation. As shown in Figure C-1 in Appendix C, the proposed EMDF site is located in the BCV Watershed on the ORR in BCV Zone 3 area designated for future DOE controlled industrial use in the BCV Phase I ROD (DOE 2000). This site will remain under DOE control within DOE ORR boundaries for the foreseeable future.

As described in Chapter 3, under the No Action Alternative, no coordinated ORR effort would be implemented to manage waste generated by future CERCLA actions after EMWMF capacity is reached. The first three 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.

Under the Off-site Disposal Alternative, waste is shipped for permanent disposal at existing permitted off-site facilities. As a result, the first three RAOs are not directly applicable to the Off-site Disposal Alternative because the permits for each individual off-site facility specify requirements to protect human health and the environment and minimize exposure risk.

The fourth RAO is directly applicable to the On-site Disposal and Off-site Disposal Alternatives as well as the No Action Alternative:

4. Facilitate timely cleanup of ORR and associated facilities.

Evaluation of disposal alternatives for waste under the CERCLA process in this RI/FS will support DOE implementation of a recent Oak Ridge Site Specific Advisory Board (ORSSAB) recommendation (ORSSAB 2011), including the following recommended actions:

- Evaluate and propose disposal capacity necessary to support current EM scope and potential additional cleanup waste streams.

- Analyze and compare the lifecycle 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.

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).

5. TECHNOLOGY SCREENING AND ALTERNATIVES ASSEMBLY

Section 5.1 of this chapter identifies and screens technologies and process options and selects representative process options to support disposal of the candidate waste streams identified in Chapter 2. Section 5.2 assembles the representative process options into disposal alternatives and evaluates their ability to meet RAOs. Chapters 6 and 7, respectively, describe and evaluate the selected disposal alternatives.

5.1 IDENTIFICATION, SCREENING, AND SELECTION 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 is based on the general response actions, technology types, and process options that were presented in the EMWMF RI/FS. Applicable new information and lessons learned from construction and operation of the EMWMF are presented and applied throughout the screening process as well.

As specified in EPA RI/FS guidance (EPA 1988), steps are taken to logically reduce the number of technology types and process options to be considered for alternatives analysis. In the initial screening step, each process option is evaluated to determine its technical applicability to the remediation site(s). In the following step, 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. 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:

- No action
- On-site disposal
- Off-site disposal
- Waste packaging and transport
- Institutional controls

The process for developing and screening alternatives is presented in the EPA RI/FS guidance document (EPA 1988). Table 5-1 summarizes this process as it was applied and presented in the EMWMF RI/FS, where each process option was described and evaluated in detail. Process options that were screened from consideration as not being applicable to disposal of ORR CERCLA waste are shaded in Table 5-1. Applicable process options were then evaluated for effectiveness, implementability, and cost to select representative process options for each technology type within a general response action; results of the evaluation are summarized under the discussion heading in the table. Process options that were found to be applicable, but were not retained as representative for development of remedial alternatives in the EMWMF RI/FS due to effectiveness, implementability, and/or cost, are also shaded. In most cases, the analysis for this RI/FS is consistent with the EMWMF RI/FS; changes or updates to the analysis presented previously are noted in the discussion column in bold text. Following the table, Sect. 5.1.1 through 5.1.6 provide a discussion of the representative process options that were selected in the EMWMF RI/FS and retained for alternative development in this RI/FS as well.

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

General Response Action	Technology Type	Process Option[1,2]	Description	Discussion
No action	None	No actions	No additional actions	Retained as representative process option. 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.	Eliminated. Few if any single parcels on ORR with adequate depth to groundwater. Cost is high.
		Sanitary landfill	A sanitary or construction/demolition landfill similar to engineered disposal facility but with fewer isolation features incorporated into design.	Eliminated. Not applicable for candidate waste streams. Existing on-site capacity available for uncontaminated waste.
		Unlined trenches landfill	A trench or excavation with no bottom liner and a simple vegetative cover.	Eliminated. Unsuitable for LLW and mixed wastes.
		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.	Applicable. Not retained. No additional protection over engineered disposal cell. Larger land area needed. More costly.
		Engineered disposal facility	Facility that is partially below 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.	Applicable. Retained as representative process option based on equivalent effectiveness, superior implementability, and lower cost.
		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.	Applicable. Not retained. No additional protection over engineered disposal cell. Implementability somewhat more difficult. Moderate cost.
	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.	Not applicable for candidate LLW and mixed waste streams.
		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.	Not applicable for candidate LLW and mixed waste streams.
		Interim Waste Management Facility	Tumulus facility at SWSA 6 designed as a disposal facility for LLW generated at ORNL.	**Eliminated. Closed under the Melton Valley Closure Project and not available for waste disposal.**
		Long-term storage	Storage in containers in existing buildings until treatment or disposal capability is available.	Applicable for limited waste volumes. Retained as interim option for waste that may not meet disposal facility WAC, pending treatment and disposal options.
		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 mixed-waste disposal.**	**Applicable. Projected to be at capacity and unavailable.**

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

General Response Action	Technology Type	Process Option[1,2]	Description	Discussion
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 mixed wastes.	Eliminated. No known plan for a new facility. Adequately represented by existing permitted DOE and commercial facilities.
	Existing LLW and mixed-waste facilities	Chem Nuclear	Commercial LLW disposal facility in Barnwell, South Carolina.	Eliminated because present and future availability is uncertain (state equity issues).
		Energy*Solutions* (formerly Envirocare)	Commercial LLW/mixed waste facility in Clive, Utah.	**Applicable for non-classified LLW and mixed waste. Treatment of LLW/RCRA waste to meet LDRs is available at facility. Retained as representative off-site disposal option for non-classified LLW and mixed waste.**
		DOE NNSS (formerly Nevada Test Site)	DOE disposal facility near Las Vegas, Nevada.	**Applicable for classified and non-classified LLW and mixed waste that meets LDRs. Retained as representative off-site disposal option for classified and non-classified LLW and mixed waste that meets LDR treatment standards.**
		DOE Hanford Reservation	DOE storage/disposal facility near Richland Washington.	Applicable for LLW disposal; CERCLA ROD does not allow receipt of mixed waste from out-of-state. Not retained because of administrative concerns and lack of mixed waste disposal capability.
		US Ecology-Hanford	Commercial LLW waste facility near Richland Washington.	Applicable for LLW; however, not applicable for ORR waste streams.
		Waste Control Specialists	Commercial LLW/mixed waste facility in Andrews, Texas	Applicable for LLW and mixed waste, but not yet available to accept waste from Federal facilities. Not retained because unable to accept waste at this time.
	Existing RCRA/TSCA facilities	WMI-Emelle	Commercial RCRA-Hazardous and TSCA waste disposal facility in Emelle, Alabama.	**Eliminated because the facilities are no longer on approved active TSDRF list for ORR cleanup. Non-hazardous RCRA/TSCA waste is a portion of the small percentage of CERCLA waste generated each year that does not meet the EMWMF WAC. The waste is not a differentiator in the On-site and Off-site Disposal Alternatives and is not included in candidate waste streams for quantitative analysis (see Sect. 2.1.3).**
		US Ecology-Beatty	Commercial RCRA-Hazardous and TSCA waste disposal facility in Beatty, Nevada.	
		Rollins Environmental Services	Commercial RCRA-Hazardous and TSCA waste disposal facility in Deer Park, Texas.	
		Rollins Environmental Services	Commercial RCRA-Hazardous and TSCA waste disposal facility in Clive, Utah.	
		Other existing RCRA/TSCA facilities	**A list of approved active commercial facilities such as Clean Harbors' facilities in UT and TX is maintained for ORR cleanup.**	**Applicable for non-radioactive RCRA and TSCA waste. However, non-radioactive RCRA and TSCA waste is a portion of the small percentage of CERCLA waste generated each year that does not meet the EMWMF WAC. The waste is not a differentiator in the On-site and Off-site Disposal Alternatives and is not included in candidate waste streams for quantitative analysis (see Sect. 2.1.3).**

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

General Response Action	Technology Type	Process Option[1,2]	Description	Discussion
Waste packaging and transport	Packaging	Small containers	Small containers such as drums, B-25 boxes, or lab packs can be used to accumulate, store, or transport waste.	Applicable. Costs are relatively high, but effective and implementable for accumulating small waste streams generated over long periods. Not appropriate for containing large waste streams or bulk waste or debris. **Retained in EMWMF RI/FS, but not retained for this RI/FS. Large containers are retained in this RI/FS for all waste streams as representative for comparative analysis of alternatives.**
		Large containers	Large containers such as rolloff bins, sealand containers, and/or intermodal containers can contain bulk waste or small containers.	Applicable. **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.	Applicable. Not retained because their use is limited and they are adequately represented by large containers.
	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.	Eliminated. The Hanford Reservation is the only disposal facility able to receive barge shipments, and more direct transportation methods are available. Hanford is not selected as a representative process option.
		Truck	Transportation of bulk waste on-site in dump trucks, or packaged waste to on- and off-site disposal facilities by flatbed or other trucks.	Applicable for all on-site and off-site waste transportation. Retained as representative for all on-site transportation. **Retained for off-site transportation of classified waste and for rail to truck transfer to NNSS.**
		Train	Transportation of bulk or packaged waste to off-site disposal facilities by railroad.	Applicable for off-site waste transportation. Retained as representative for transport of LLW and mixed waste off-site to Energy*Solutions* **and NNSS. Truck to rail transfer is required at ETTP. Energy*Solutions* has direct rail service and NNSS can be accessed by using rail to truck transfer facility in Kingman, AZ. While waste must be transferred from truck to train, total costs are less than long-distance transport by truck.**
Institutional controls	Access and use restrictions	Physical barriers	Security fences, signs, buffer zones, and other barriers installed around potentially contaminated areas to limit access.	Applicable. Would be used with other actions. Readily implementable and low cost. All access and use restrictions are retained to enhance the reliability of on-site disposal actions.
		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.	
		Covenants and deed restrictions	Restrictions on land use by licensed agreements, regulatory permits, code, zoning, stipulations on property deeds.	

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

General Response Action	Technology Type	Process Option[1,2]	Description	Discussion
Institutional controls (continued)	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.	Applicable. Would improve reliability of on-site actions. Readily implementable and moderate cost. Maintenance and monitoring options retained to enhance the reliability of on-site disposal actions.
		Environmental monitoring	Use of results from sampling and characterization of media before, during, and after remediation to predict and verify effectiveness of remedial actions.	

[1]Process options that are NOT retained in the screening are shaded.
[2]BOLD TEXT indicates changes or updates to the analysis presented in the EMWMF RI/FS (DOE 1998).

5.1.1 No Action

The no action general response action is required by the NCP to serve as a baseline for comparison to action-based alternatives. The No Action Alternative is described further in Sect. 6.1.

5.1.2 On-site Disposal

On-site disposal technology types considered include new facilities and existing facilities. To be selected as a relevant process option through the initial screening step, the process must be able to accept candidate waste streams – non-classified or classified LLW and mixed solid waste types with RCRA and/or TSCA components. Additional screening (presented in the EMWMF RI/FS) considers effectiveness, implementability, and cost of the retained process options to narrow the selection(s) down to representative process option(s). Details of the analysis are available in the EMWMF RI/FS and summarized and updated in Table 5-1.

5.1.2.1 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 for on-site disposal, as concluded by the EMWMF RI/FS analysis and confirmed in this RI/FS, is the partially below grade engineered disposal facility. It was originally selected based on equivalent or superior effectiveness, relative ease of implementation, and reduced cost compared to other process options. The conclusion for this RI/FS remains the same.

5.1.2.2 Existing Facilities

With the exception of the EMWMF, no existing facilities on the ORR have a WAC that allows for disposal of projected candidate waste streams. Most of these options were eliminated in the EMWMF RI/FS analysis. This RI/FS eliminates all existing facility options and is based on the projection that the EMWMF will be at capacity and therefore unavailable.

As it was in the EMWMF RI/FS, long-term storage is retained in this RI/FS as an interim option for waste that may not meet disposal facility WAC, pending treatment and 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.

5.1.3.1 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. There is no such known plan for a new off-ORR engineered facility; therefore the option is eliminated in the initial screening as was the case in the EMWMF RI/FS.

5.1.3.2 Existing LLW and Mixed Waste Facilities

LLW and mixed waste disposal sites evaluated in the EMWMF RI/FS included Chem Nuclear in Barnwell, SC; Energy*Solutions* (formerly Envirocare) of Clive, UT; the DOE Nevada National Security Site (NNSS) facility near Las Vegas, NV (formerly the Nevada Test Site); the DOE Hanford Reservation near Richland, WA; and U.S. Ecology-Hanford. All these sites would be effective at isolating wastes that meet their respective WAC. ORR wastes are currently being shipped to the Energy*Solutions* and NNSS facilities, and shipment and disposal at these sites is readily implementable. All sites would incur high transportation/disposal costs as well as risk liabilities until waste reaches its destination. Energy*Solutions* accepts mixed waste for disposal, with mixed-waste disposal fees higher than LLW fees. Chem Nuclear, DOE Hanford, U.S. Ecology-Hanford, and a Waste Control Specialists (WCS) facility in Andrews, TX were eliminated from consideration as described in Table 5-1. Although not yet available to accept waste from Federal facilities, the WCS facility in Texas is discussed as a potential process modification to the Off-site Disposal Alternative (see Sect. 6.3.3.8.1).

Energy*Solutions* of Clive, UT was retained for disposal of LLW and mixed waste in the EMWMF RI/FS and remains a representative process option for this RI/FS for non-classified LLW and mixed waste. Treatment of LLW/RCRA waste to meet LDRs prior to disposal is available at the Energy*Solutions* facility. The DOE NNSS facility near Las Vegas, NV was retained in the EMWMF RI/FS for LLW disposal only as a process modification and not as a representative process option because of administrative concerns and lack of mixed waste disposal capacity. The NNSS facility is retained in this RI/FS for non-classified and classified LLW and mixed waste disposal in this RI/FS because of its expanded capabilities to accept mixed waste (LLW/TSCA waste as well as LLW/RCRA waste that meets LDR treatment standards). Treatment of LLW/RCRA waste prior to disposal is not available at NNSS.

5.1.4 Existing RCRA/TSCA Facilities

The Waste Management, Inc. (WMI)-Emelle (Emelle, AL), US Ecology-Beatty (Beatty, NV), Rollins Environmental Services (Deer Park, TX), and Rollins Environmental Services (Clive, UT) facilities were identified as existing RCRA/TSCA facilities in the EMWMF RI/FS and the WMI facility was retained for the EMWMF evaluation. All of the facilities are eliminated in this RI/FS because the facilities are no longer on the approved active treatment, storage, disposal, and recycling facilities (TSDRFs) list for ORR cleanup. Non-hazardous RCRA/TSCA waste is a portion of the small percentage of CERCLA waste generated each year that does not meet the EMWMF WAC and is not a differentiator in the On-site and Off-site Disposal Alternatives (would be shipped off-site in either alternative). Non-hazardous RCRA/TSCA waste and other waste that would not meet an on-site disposal facility WAC are not included in candidate waste streams for quantitative analysis (see Sect. 2.1.3).

There are other existing RCRA/TSCA facilities on the approved active TSDRF list for ORR cleanup such as Clean Harbors' facilities in Utah and Texas that are applicable for disposal of non-radioactive RCRA and TSCA waste. However, as stated above, non-radioactive RCRA and TSCA waste is a portion of the small percentage of CERCLA waste generated each year that does not meet the EMWMF WAC. The waste is not a differentiator in the On-site and Off-site Disposal Alternatives and is not included in candidate waste streams for quantitative analysis.

5.1.5 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.

5.1.5.1 Packaging

Small containers (e.g., lab packs, B-12 and B-25 boxes, drums, and overpacks) are effective and implementable for specific candidate waste streams. They are typically disposed of with the waste rather than emptied and reused. They can be placed in large containers for ease of shipment. Small containers are costly due to the need to replace, rather than reuse the containers. In the EMWMF RI/FS the small containers process option was retained, but is not retained for this RI/FS. Large containers are retained in this RI/FS for all waste streams as representative for the purpose of comparative analysis of On-site and Off-site Disposal Alternatives.

Use of large containers (e.g., rolloff bins, sealand containers, intermodal containers) for bulk waste and overpacks containing small containers are effective and implementable. Their use is commonly implemented on the ORR, and the variety of sizes and configurations provides for diverse loading and unloading scenarios. Large containers were retained in the EMWMF RI/FS and are retained in this RI/FS.

Bulk containers such as Supersacks 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. As determined previously in the EMWMF RI/FS, bulk containers are not retained in this RI/FS because their use is limited and they are adequately represented by large containers.

For this RI/FS, the large container packaging process option is retained as representative for the purpose of comparative analysis of alternatives.

5.1.5.2 Transport

Truck transport is applicable, effective, and implementable for both local and long-distance waste transport. Cost for long-distance transport is high. This process option is retained as representative, as it was in the EMWMF RI/FS.

Rail transport is viable for long-distance waste transport and is retained as it was previously. An existing transfer 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 mixed wastes. Transport by rail to NNSS in Nevada requires transfer of the waste from railcars to trucks at a transfer facility (Kingman, AZ assumed) for the last leg of the trip unless additional rail spurs are constructed to the disposal facility (outside of the scope of this RI/FS). The cost for rail transport, including the cost for transferring containers from truck to train, would be lower than truck transport for very large waste volumes.

5.1.6 Institutional Controls

As shown in Table 5-1, all institutional controls process options were retained in the EMWMF RI/FS and are also representative in this RI/FS to be used in conjunction with other actions to ensure adequate protectiveness.

5.2 ASSEMBLY OF ALTERNATIVES AND ABILITY TO MEET RAOS

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 three disposal alternatives: the No-Action Alternative, the On-site Disposal Alternative, and the Off-site Disposal Alternative. This section describes the ability of the alternatives to meet RAOs. The alternatives presented in Table 5-2 are described in detail in Chapter 6 and fully evaluated in Chapter 7.

As described in Chapter 4, the first three RAOs are most directly applicable to the On-site Disposal Alternative. The On-site Disposal Alternative is designed to meet the RAOs as follows:

1. Prevent exposure to future-generated CERCLA waste that exceeds a human health risk of 1×10^{-5} ELCR or HI of 1.

   On-site Disposal Alternative. Construction and operation of a new on-site disposal facility for CERCLA waste would meet this RAO for waste meeting the facility's WAC, by providing adequate capacity at an engineered facility that isolates waste with appropriate containment features to preclude human contact. Waste not meeting the on-site disposal facility WAC 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, including compliance with regulations 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 of the facility for an indefinite period. Such isolation would be 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., deed restrictions) on land and groundwater use, would ensure long-term protection of workers and the public.

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

General Response Action	Technology Type	Representative Process Option	No Action Alternative	On-site Disposal Alternative	Off-site Disposal Alternative	Comments
No action	None	No actions	X			Required by NCP. No Action Alternative.
On-site disposal	New facilities	Engineered disposal cell (partially below grade)		X		Representative process option applicable only to on-site disposal.
	Existing facilities	Long-term storage		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			X	Energy*Solutions* and NNSS are used for off-site LLW and mixed waste disposal. Both are applicable for the Off-site Disposal Alternative.
		DOE NNSS			X	
Waste packaging and transport	Packaging	Large containers		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	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 Disposal Alternative with rail to truck transfer for shipments to NNSS.
		Train			X	
Institutional controls	Access and use restrictions	Physical barriers		X	X	All institutional controls apply to both On-site and Off-site 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	
	Maintenance and monitoring	Surveillance and maintenance		X	X	
		Environmental monitoring		X	X	

2. Prevent ecological exposure to future-generated CERCLA waste.

   On-site Disposal Alternative. The isolation features of an on-site disposal facility would be designed to protect ecological receptors from contact with or exposure to the waste. Candidate wastes would be contained during transport, operations, and disposal to prevent exposure to ecological receptors. The On-site Disposal Alternative would meet this RAO.

3. Prevent releases of future-generated CERCLA waste, or waste constituents, that exceed a human health risk of 1×10^{-5} ELCR or an HI of 1, or ARARs for environmental media.

   On-site Disposal Alternative. This alternative would place most candidate wastes into an on-site engineered disposal cell, effectively isolating the wastes from the environment, minimizing release of contaminants, and reducing overall risk. By design, meeting the facility WAC would ensure that the ELCR from wastes disposed of at the facility would be $<1 \times 10^{-5}$, and the total noncarcinogenic risk would have an HI of <1 for future hypothetical residents living adjacent to the disposal facility. The On-site Disposal Alternative would meet this RAO.

The fourth RAO is directly applicable to the On-site Disposal and Off-site Disposal Alternatives as well as the No Action Alternative:

4. Facilitate timely cleanup of ORR and associated facilities.

   No-Action Alternative: This alternative does not ensure the RAO to facilitate timely cleanup of ORR sites is met. A centralized disposal facility on the ORR would not be constructed and there would be no coordinated ORR site-wide effort implemented to manage wastes generated by future CERCLA actions. Lack of a coordinated disposal option could result in increased management of waste in place and greater residual risk at individual sites.

   On-site Disposal Alternative: This alternative would meet this RAO by consolidating most candidate wastes from dispersed areas into a single on-site disposal facility. The availability of this disposal option could encourage waste removal at individual sites and facilitate timely cleanup of ORR. If a waste disposal option were not available, the need to procure disposal services on a project-by-project basis could increase the time and cost required to complete remedial actions at individual sites. Timely cleanup of the ORR is in keeping with the DOE and public goal of releasing portions of the ORR for beneficial uses by allowing unrestricted or less-restricted release of some currently contaminated areas.

   Off-site Disposal Alternative: This alternative would meet this RAO by providing coordinated off-site disposal of candidate wastes. Similar to the On-site Disposal Alternative, the availability of disposal at off-site disposal facilities could encourage timely remediation and release of portions of ORR for beneficial use.

6. ALTERNATE DESCRIPTIONS

This chapter provides detailed descriptions of the No Action Alternative and the On- and Off-site Disposal Alternatives for the candidate CERCLA waste streams identified in Chapter 2. The representative process options assembled in Chapter 5 have been used to develop conceptual designs and actions described in this chapter.

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 this RI/FS 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 ORR and associated waste generator sites after EMWMF capacity is reached would not be implemented.
- A centralized disposal facility would not be constructed on 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.

Unlike the No Action Alternative for a typical 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 no coordinated ORR effort would be implemented to manage wastes generated by future CERCLA actions after EMWMF capacity is reached. Otherwise, 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 sitewide disposal strategy or infrastructure. While protective remedies would be implemented, the lack of a coordinated disposal program has potential cost and protectiveness impacts relative to the On-site Disposal Alternative and Off-site Disposal Alternative as discussed in Sect. 7.2.1 and Sect. 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, partially below-grade, engineered waste disposal facility (i.e., landfill) on ORR, referred to herein as the EMDF. 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, TRU wastes, spent nuclear fuel, and sanitary wastes are not considered to be candidate waste streams for the EMDF. Uncontaminated or lightly contaminated waste generated during CERCLA remedial actions that can meet the WAC of existing Y-12 industrial or construction/demolition landfills are also not considered to be candidate waste streams for the EMDF. These wastes can be disposed of at the Y-12 Landfills regardless of the decision about on- or off-site disposal of CERCLA waste. Wastes not meeting the EMDF's WAC would be transported to off-site disposal facilities or placed in interim storage until treatment or disposal capacity becomes available.

This alternative only addresses disposition of CERCLA waste. It includes designing and constructing the landfill, support facilities, and roadways; receiving waste that meets the facility's WAC; unloading and placing the 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 location of the EMDF (Sect. 6.2.1), design of the facility's waste containment features (Sect. 6.2.2), characteristics of the waste placed in the EMDF (Sect. 6.2.3), facility construction, operations, and monitoring (Sect. 6.2.4 through 6.2.6), management of waste exceeding WAC (Sect. 6.2.7), and facility closure and post-closure care, including institutional controls (see Sect. 6.2.8 and 6.2.9).

6.2.1 EMDF Site

A proposed site in EBCV near EMWMF is evaluated in this RI/FS as part of the On-site Disposal Alternative for development of the EMDF. Figure 6-1 shows the location of the EMDF site relative to the ORR; the site plan for the EMDF 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 of sharing existing infrastructure (see Sect. 6.2.2.5).

The EMDF site in EBCV is located in the Zone 3 area designated for future DOE controlled industrial use in the BCV Phase I ROD (DOE 2000) as shown in Figure C-1 in Appendix C. Appendix C describes the screening process and selection of the EMDF site which will remain under DOE control within DOE ORR boundaries for the foreseeable future. The nearest residence to the proposed EMDF site is 0.84 mi. north, and is separated from the site by Pine Ridge.

Construction of a disposal facility at the EMDF site would 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 or upon Y-12. In order to revise this boundary, DOE would publish a notice of revision in the Federal Register.

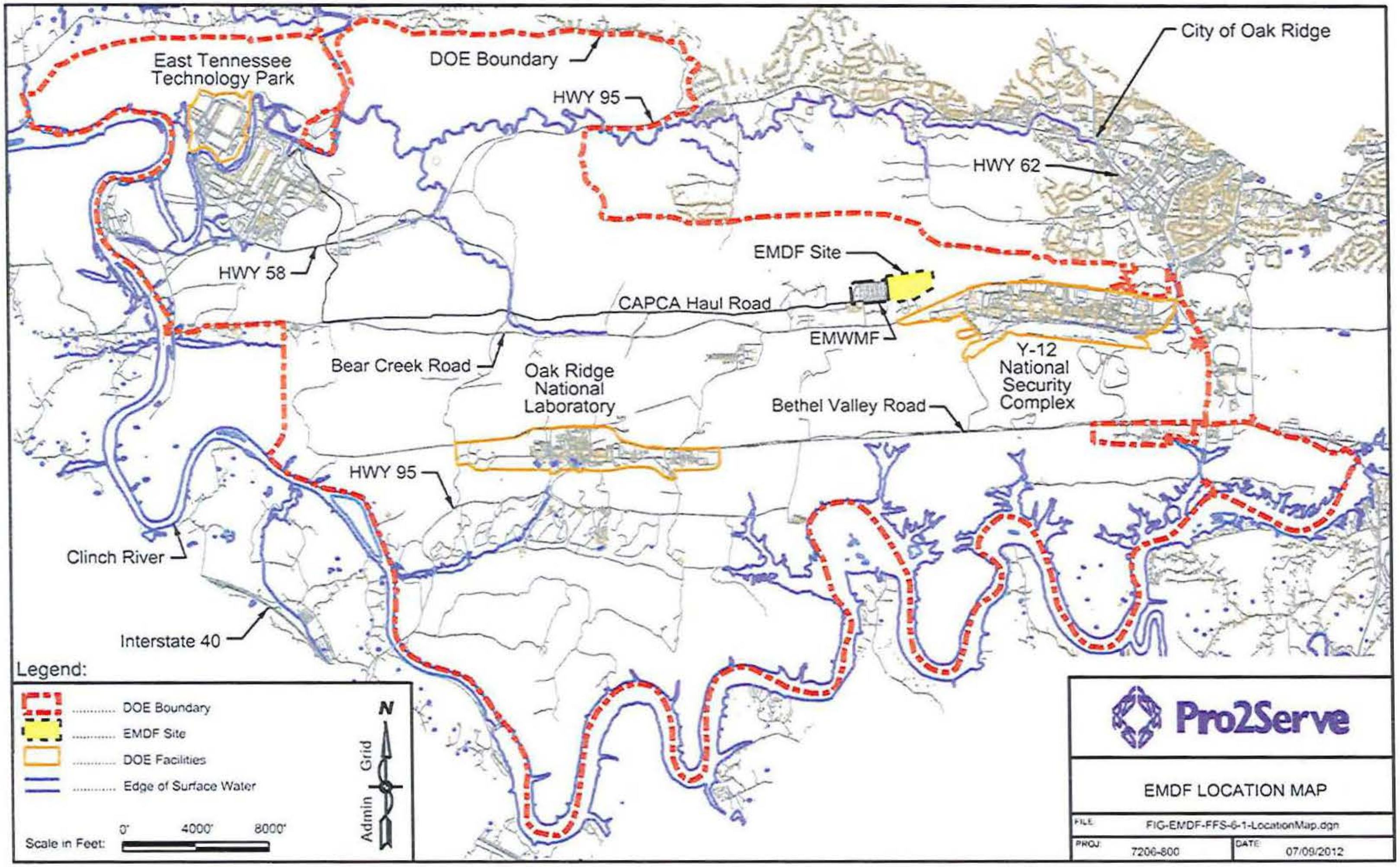

Figure 6-1. EMDF Location Map

6.2.1.1 EMDF Site Characteristics

The approximately 70-acre EMDF site is situated along the southern flank of Pine Ridge on undeveloped land immediately east of EMWMF. Based on process knowledge and a review of historical maps, the site is believed to be uncontaminated. The site is north of Bear Creek and is bounded by the Haul Road to the south, a rerouted location for Northern Tributary (NT-3) to the west (the proposed landfill would be constructed over a portion of NT-3), the steep upper slope of Pine Ridge to the north, and NT-2 to the east. The site is heavily wooded; most of the trees are deciduous. The topography varies from moderate in the southern part to very steep along the northern portion where it meets Pine Ridge. The site is dissected by tributaries to Bear Creek and contains several deep ravines oriented in a generally north-south direction. The main channel of NT-3 crosses the central and western portions of the site in a southwesterly direction, and two small draws/ravines join the main channel just north of the Haul Road. Much of the flow in NT-3 and in the draws that drain into NT-3 is supported by springs and seeps. Two draws located in the southeastern portion of the site direct surface water to NT-2 in a southerly direction. The streams form a trellis drainage pattern typical of the Valley and Ridge Province of Tennessee. The site topography and geology are further described and illustrated in Appendix C.

From south to north, the EMDF site is underlain by bedrock of the Maryville Limestone, Rogersville Shale, Rutledge Limestone, Pumpkin Valley Shale, and Rome Formations of Cambrian age. The landfill footprint is underlain primarily by bedrock of the Maryville Limestone, Rogersville Shale, Rutledge Limestone, and Pumpkin Valley Shale Formations. The lower units of the Maryville Limestone form a series of knolls south of and parallel to Pine Ridge. The EMDF site soils are dominated by a thin mantle of alluvial and colluvial deposits and pedogenic soil underlain by saprolite and shales/siltstones of the previously mentioned formations. Pedogenic soil is formed in place by weathering and pedogenic alteration of the parent materials. Alluvial soil is soil that has been transported to its present location by running water. Shallow alluvial soil, generally less than 5-ft thick, but ranging up to about 10-ft thick near Bear Creek, may be present within the drainageways and along tributaries. Colluvial soil is soil that has been transported to its present location by gravity and includes slope wash at the base of slopes. Colluvium may be several feet thick at the base of some slopes. Typically, the depth to competent bedrock (i.e., as defined by auger refusal) varies from about 10 to 50 ft below ground surface and increases from south to north. Also, the depth to weathered rock is typically shallower in the incised drainageways and deep ravines than in the adjacent higher ground.

Groundwater exists under the site in matrix pores, fractures, and cavities. Flow occurs mainly in the fractures and cavities, and the overall direction of flow is south with the slope of the groundwater table. Based on the results of groundwater measurements made immediately east and west of the site in a similar topographic and geologic setting, the depth to groundwater varies from less than 3 ft below ground surface in the low areas along the tributaries in the southern portion of the site to more than 45 ft deep along the higher elevations of Pine Ridge. In the southern portion of the site groundwater has an upward gradient and discharges to the tributaries. The tributaries and draws that drain to the tributaries are natural discharge areas for both shallow perched (stormflow zone) groundwater and groundwater upwelling from bedrock. Shallow perched groundwater moves laterally down slope where it discharges as "wet weather" seeps along the base of Pine Ridge. Numerous seeps and springs have been mapped within the site, including three seeps and springs which "daylight" near the contact of the Rome and Pumpkin Valley Shale Formations, forming the headwaters of NT-2 and NT-3.

Several wetland areas occur along NT-2 and NT-3 within and bordering the EMDF site (see Figure C-17 in Appendix C). A biologically sensitive wetland area designated as Reference Area (RA)-5 encompasses wetlands, known as the Temporary Quillwort Pond, on NT-3 immediately north of the Haul Road. There are no known federal- or state-listed threatened or endangered species in this area. The Tennessee Dace is a fish that is listed by Tennessee as being in-need-of-management. There are no known archeological or historical resources in or near the proposed EMDF site (DOE 1999; DuVall 1996; Fielder, et al. 1977).

Soil and groundwater contamination is present in several areas south of the site, including along NT-3 south of the Haul Road. Contaminants originated from contaminated waste disposed at the Oil Landfarm, Boneyard/Burnyard (BY/BY), Sanitary Landfill I, and Hazardous Chemical Disposal Area (HCDA) (B&W 2011; DOE 1997). Soils at these sites have been removed or isolated, but groundwater has not been remediated.

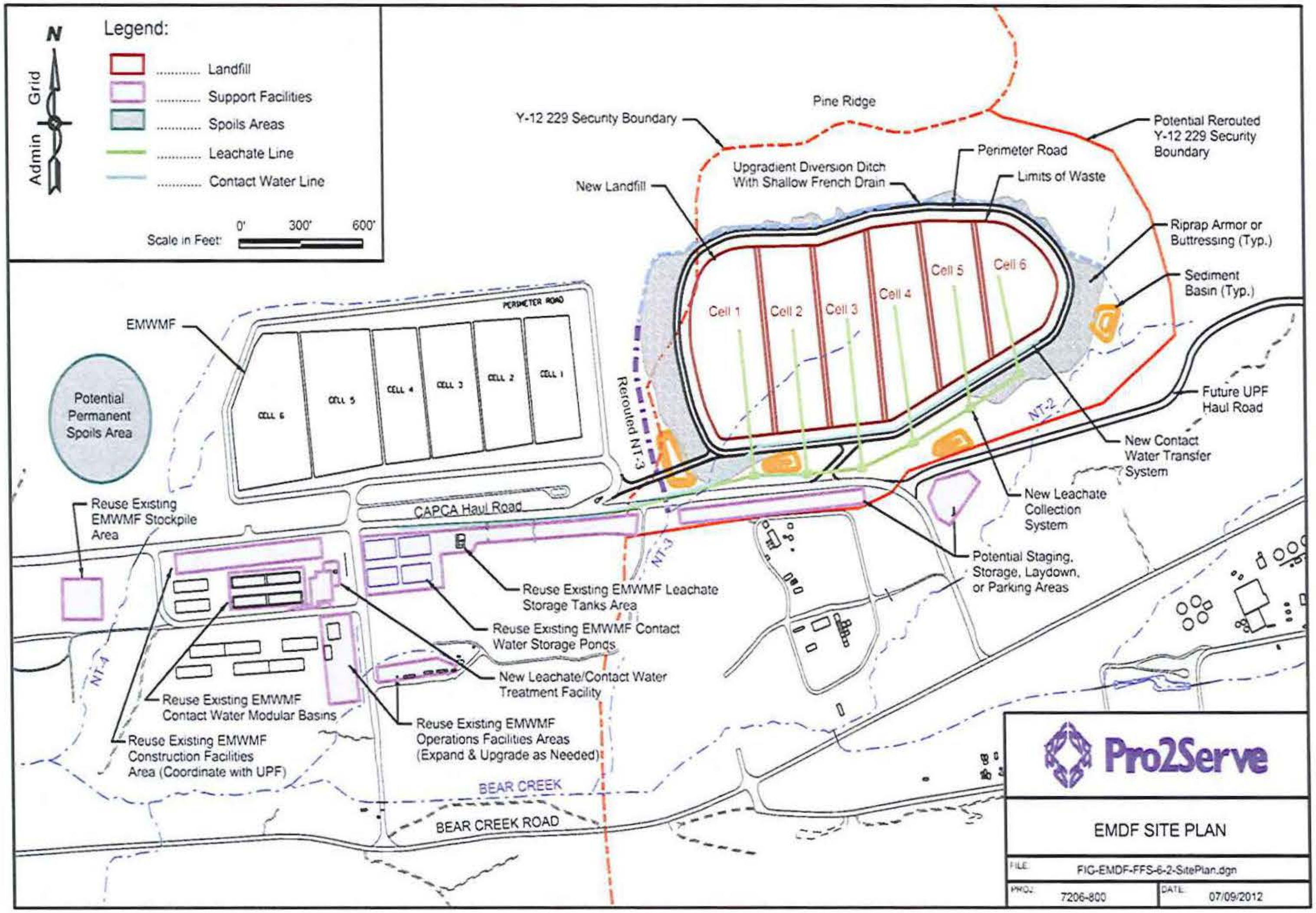

Figure 6-2. EMDF Site Plan

6.2.2 EMDF Conceptual Design

This section describes the conceptual design for an on-site EMDF. Note that this feasibility-level, conceptual design is used to provide a comparative analysis of the On-site Disposal Alternative siting option. If the On-site Disposal Alternative is the selected remedy in the ROD, the final design for the selected site may differ from this conceptual design and would require approval by regulatory agencies. This conceptual design is based 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. With the exception of two hydrologic condition ARARs for which a waiver would be requested (see Sect. 3 in Appendix E), the design complies 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 design.

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
- Leachate/contact water treatment facility
- Process modifications

6.2.2.1 Remedial Design

Remedial design would include preparation of RDRs, remedial design work plans, 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 the regulators.

6.2.2.2 Early Actions

Certain remedial design activities would be performed early in the remedial design process. These activities are referred to as early actions and include: a baseline site topographic survey, wetlands delineation, field surveys to identify and map wetlands and threatened and endangered species, hydrogeological and geotechnical investigations, construction and upgrade of groundwater monitoring wells, and baseline groundwater monitoring.

Baseline Site Topographic Survey: The EMDF site topography and surface features would be mapped using civil land surveying techniques. This information would be used to perform hydrogeological/geotechnical investigations, establish locations, elevations, and depths for new groundwater monitoring wells, map wetlands (in concert with a qualified wetlands delineator), and conduct landfill site design.

Wetlands Delineation: A field wetlands delineation survey would be conducted by a qualified wetlands delineation specialist along streams and other low-lying portions of the landfill site and other areas, such as existing roadways where construction would take place to determine the areal extent of wetlands.

Wetland boundaries would be mapped using civil land surveying techniques. Potential wetland impacts during early actions (e.g., hydrogeological and geotechnical investigations), construction, operations, and/or closure of the landfill would be evaluated. Wetland protection considerations would be incorporated into planning and implementation, including mitigation of adverse impacts.

Field Surveys for Threatened and Endangered Species: Field surveys would be performed by qualified biologists as necessary to identify threatened and endangered species within areas of potential site disturbance prior to performing intrusive site activities such as clearing access for drilling equipment to perform hydrogeological and geotechnical investigations and construction clearing.

Hydrogeological and Geotechnical Investigations: The EMDF footprint and surrounding land would be investigated to determine surface hydrological, hydrogeological and geotechnical conditions. Also, samples of soil, surface water, and groundwater would be collected and analyzed for potential contamination to establish baseline conditions. Geotechnical, surface hydrological, and hydrogeological data/information would be used to develop the facility structural design and develop the groundwater and surface water monitoring program. The geotechnical investigation would encompass landfill support facilities, roadways, and on-site spoil/borrow areas. Off-site borrow areas may also be explored and characterized. No previous hydrogeological or geotechnical explorations are known to have been performed within the EMDF footprint. The hydrogeological and geotechnical investigations may be performed concurrently or in multiple phases.

Construct New Groundwater Monitoring Wells and Surface Water Weirs: As part of the hydrogeological investigation, new groundwater monitoring wells and surface water weirs would be constructed around and within the landfill footprint to determine baseline groundwater and surface water conditions, support WAC modeling efforts, and monitor groundwater levels and surface water flow during construction, operations, monitor post-closure of the landfill, and if necessary, be used in remedial treatment programs. Existing groundwater monitoring wells down gradient of the EMDF site would be used, where possible, and additional groundwater monitoring wells would be installed as needed. Boring and well logs, geophysical data, hydraulic conductivity data, and groundwater flow data would be collected.

Baseline Groundwater and Surface Water Monitoring: Groundwater levels would be monitored for one year, and surface water and groundwater quality parameters (specific conductivity, pH, dissolved oxygen) and contaminants (radionuclides, metals, volatile organic compounds, and polychlorinated biphenyls (PCBs) would be monitored quarterly for one year. Groundwater flow would be determined by down-hole measurements. Surface water flow volume/rate would be monitored 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 the performance assessment and WAC finalization.

6.2.2.3 Site Development

The following development actions 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 measures installed. Standard erosion and sediment controls would be installed per best management practices (BMPs) as construction proceeds.
- Clearing and grubbing for site development activities.
- Constructing access roads to the landfill site.
- Extending power lines, water lines, phone lines, and other utilities to the landfill site from existing infrastructure used for EMWMF (see Sect. 6.2.2.5).

- Preparing additional parking, laydown, and staging areas.
- Preparing on-site spoil/borrow areas for future construction activities.
  - A temporary spoils area would be prepared near the landfill for temporary 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 restoring 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 disposable 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, graded, and the area would be restored for appropriate future uses after landfill closure.
- Creating/expanding wetlands, as required, to mitigate impacts of the new proposed facility construction.
- Relocating the Y-12 229 security boundary and installing new guard stations.
- Upgrading and installing a new weigh scale.
- Setting up construction trailers.

6.2.2.4 Disposal Facility

Key elements of the disposal facility 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 groundwater, geologic buffer, and multilayer cover to reduce infiltration and isolate the waste from human and environmental receptors, and landfill gas collection and venting system. The engineered disposal facility design basis incorporates the following:

- Attainment of RCRA, TSCA, and LLW regulatory design criteria.
- Effective protection of human health and the environment through waste isolation for up to 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years (DOE O 458.1).
- Protection against animal and plant intrusion, and minimization of the potential for human intrusion.
- 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 the disposal facility are described in the following paragraphs. Cross-sections and details of the conceptual design for the EMDF are provided in Figures 6-3 through 6-9.

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 6-3). The clean-fill dike would also protect against erosion, biointrusion, and inadvertent intrusion by humans or animals. The clean-fill dike would be constructed of suitable earthen materials. 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 typical side slopes of three horizontal to one vertical (3:1) or flatter, as determined by slope stability and erosion analyses. 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 thick rock buttress for added stability and erosion resistance (see Figure 6-4). The viability of steepening the side slopes of the clean-fill dike to 2:1 would be further evaluated during the remedial design. Final design slopes for the clean-fill dike and details for rock buttressing would depend on the results of slope stability and erosion analyses.

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 to intercept and divert upgradient storm water and shallow groundwater away from the landfill (Figure 6-5). The geomembrane liner would prevent surface water infiltration and recharge of groundwater 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 10 ft below the ground surface and would be comprised of durable gravel wrapped with a geotextile filter fabric. The French drain would collect uncontaminated groundwater which could be discharged to the ground surface along the down gradient side of the landfill. This would help lower the water table and minimize underflow towards the liner system.

Liner System: The purpose of this system is to prevent leachate from migrating out of the disposal unit and impacting groundwater. 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.

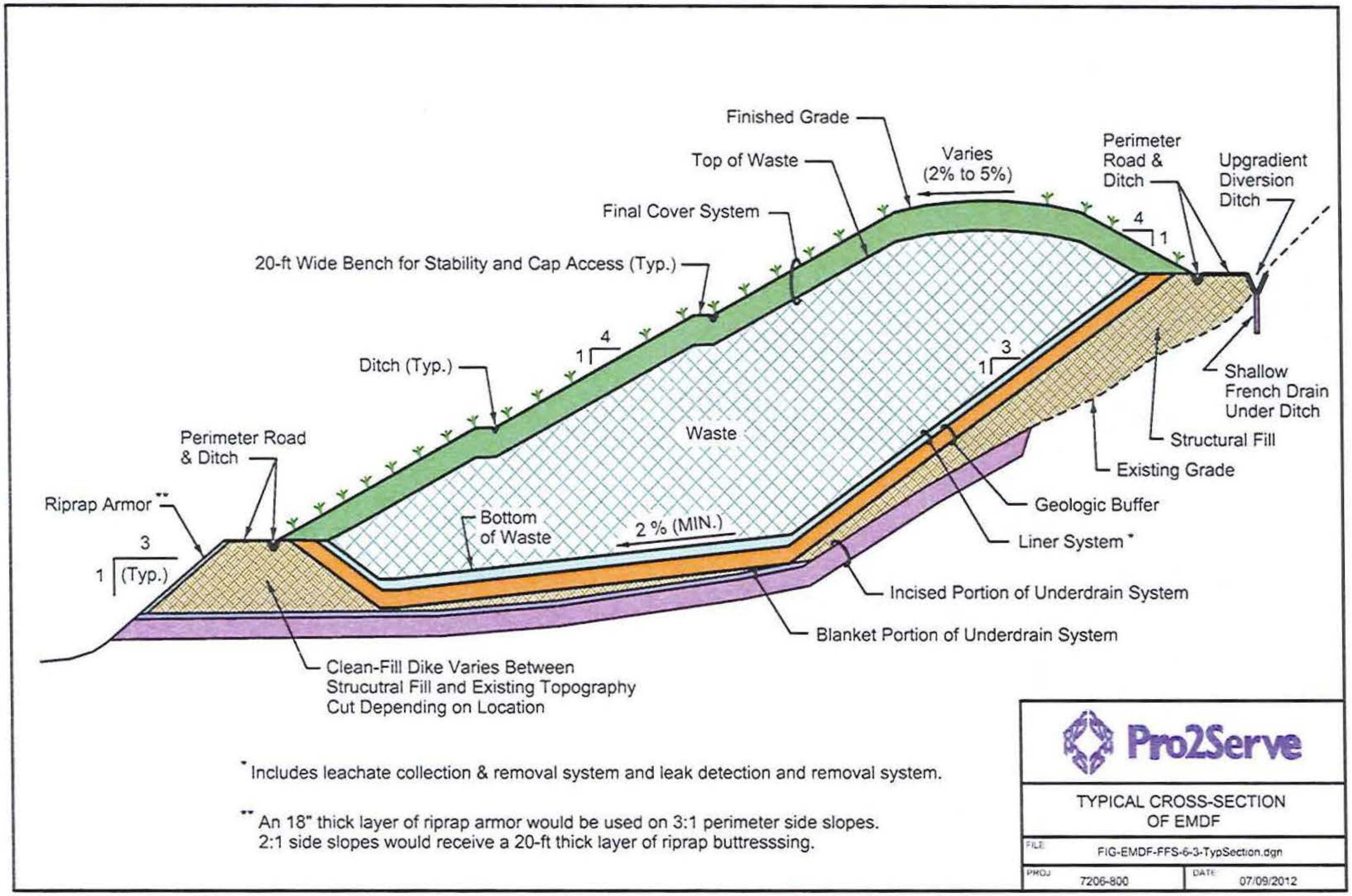

Figure 6-3. Typical Cross-section of EMDF

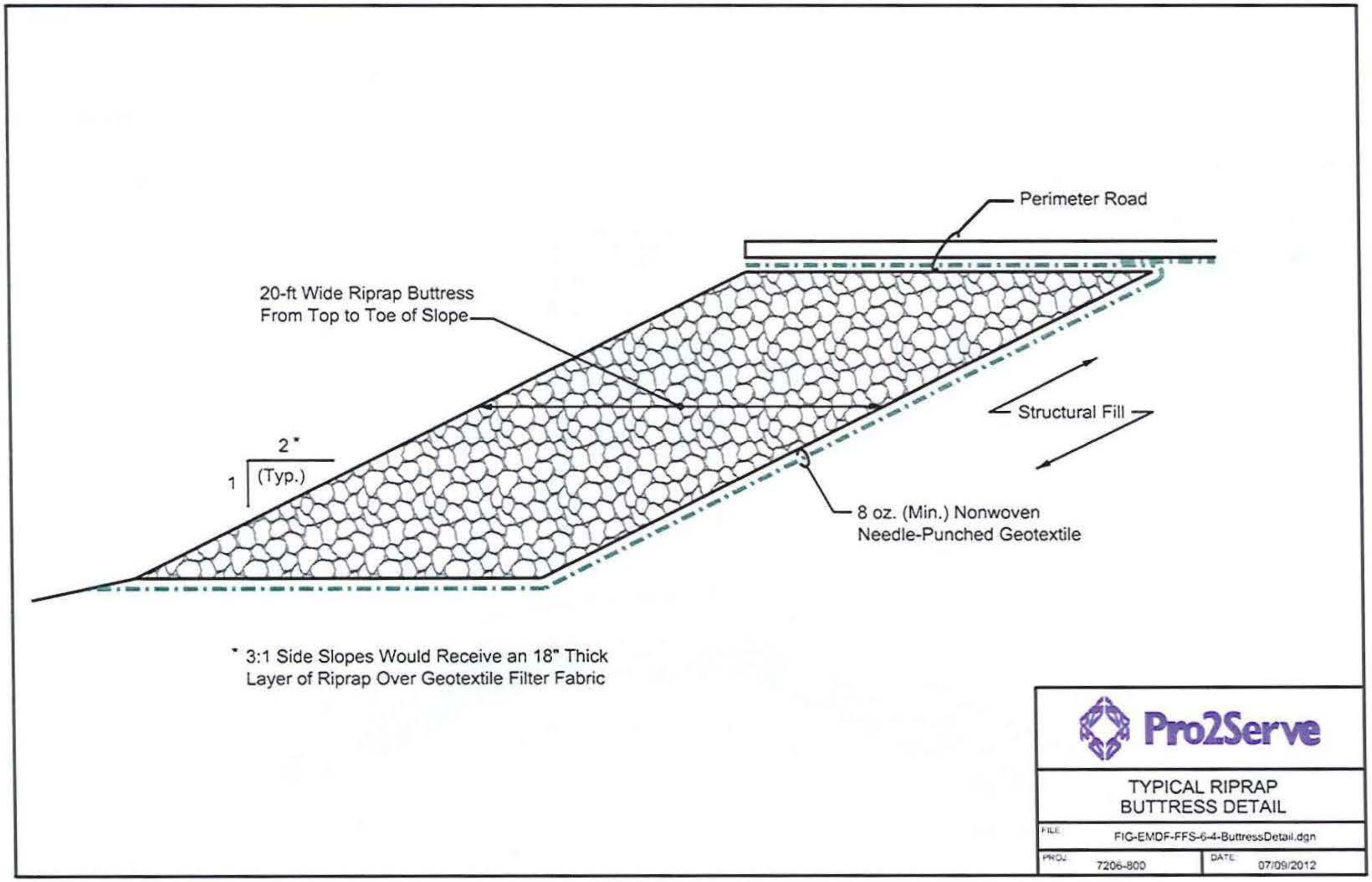

Figure 6-4. Typical Riprap Buttress Detail

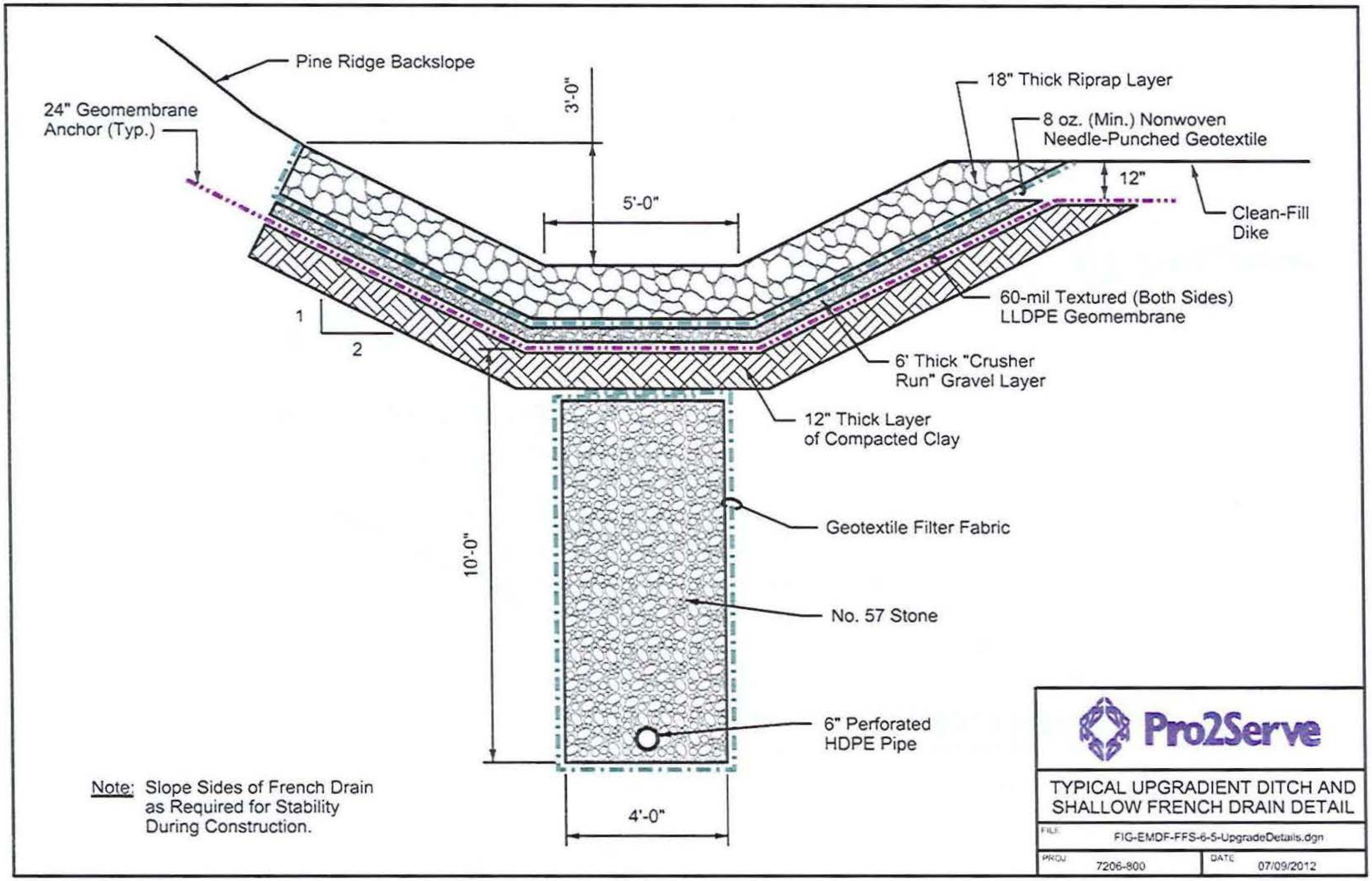

Figure 6-5. Typical Upgradient Ditch and Shallow French Drain Detail

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. The layers of the liner system are depicted in Figures 6-6 and 6-7. 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 Soil 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 and for the life of the landfill. In addition, use of a protective soil layer with hydraulic conductivity less than the leachate collection and removal system layer is desirable, since this allows contact water to pond temporarily above the leachate collection and removal system layer and be pumped off during landfill operations as it drains downward and into the leachate collection and removal system layer. 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.
- Leachate Collection and Removal System – In order to enhance slope stability and constructability, the design components of the leachate collection and removal system 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 eight oz per yd^2, used as a separator between the protective soil layer and leachate collection drainage stone.
    - Leachate Collection Drainage Layer – 12-in. thick (minimum) layer of hard, durable, inert (non-limestone) 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) pipes (i.e., leachate collection piping) would be installed in this layer to provide additional flow capacity. 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.

  <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 – 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.
- Leak Detection and Removal System – 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 for 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 pipes (i.e., leak detection piping).

This layer would be used to detect and remove any leachate that may leak through the primary geomembrane liner. Little or no leachate would be expected to be captured by this system during the operation or post-closure periods.

- Secondary Geomembrane Liner – 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 would direct leachate into 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.

Geologic Buffer Layer: As discussed in Sect. 3 of Appendix E, it is anticipated that the depth to the historical high water table would be less than 50 ft below the bottom of the landfill liner system. Therefore, a waiver from the TSCA 50-ft geologic buffer requirement (40 CFR 761.75[b][3]) would be requested from the regulators based on "equivalent protectiveness".

The EMDF conceptual design includes at least a 10-ft thick geologic buffer between the landfill liner and groundwater table[13]. 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, bedrock, or combinations of these geologic materials, depending on measured in situ hydraulic conductivity and layer thickness.

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.

Facility Underdrain: 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 construction is that a landfill can be successfully constructed over a tributary in BCV. An underdrain is necessary within the tributary channel to provide a flow path for groundwater immediately below the landfill and prevent upwelling, since tributaries are natural discharge areas for groundwater.

[13] The EMWMF design complies with the TDEC solid waste requirement for a 10-ft geologic buffer (TDEC 1200-1-7-.04[4][a][2]) per a TDEC request. Consistent with this agreement, the conceptual design for the proposed EMDF includes a 10 ft geologic buffer.

An extensive underdrain system would be required beneath the landfill within the portion of NT-3 to be filled and beneath the landfill where there are located other draws/ravines containing springs and seeps. The intent of this underdrain system would be to intercept potentially upwelling groundwater and prevent it from rising up into the geologic buffer and liner system. The conceptual layout plan for the underdrain is shown in Figure 6-8. The underdrain system would extend from the spring and seep areas along the northern, upgradient side of the landfill to the perimeter of the clean-fill dike on the southern, down-gradient side of the landfill. In addition, underdrains would be constructed similarly within wet draws/ravines that drain to NT-2 and NT-3. Figure 6-9 shows a typical detail of an underdrain cross-section that could be used. 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 where the underdrain section is located on the site. It is anticipated the underdrain would consist of permeable layers of durable, inert, siliceous crushed stone or river gravel and sand wrapped with filter fabric along the base of the landfill. These backfilled existing channels would behave hydraulically as underdrains to allow shallow groundwater discharge preferably to surface water on the downgradient side of the landfill. The underdrain system would be designed to prevent clogging and would be sized to accommodate the flow rates of the intercepted groundwater, based on field measurements and groundwater modeling.

The underdrain would be installed down into the native residual soil/weathered bedrock and would provide a lower pathway for groundwater movement than currently exists. The upgradient shallow French drain would intercept and divert shallow, perched groundwater (which flows down slope during storm events) around the landfill. Construction of the landfill would eliminate groundwater recharge within the footprint of the landfill. Consequently, these measures would collectively lower groundwater levels and reduce groundwater fluctuations beneath the landfill.

The facility underdrain ensures the water table would not rise above the underdrain and into the geologic buffer. However, the underdrain system would act as a preferred migration pathway for contaminant movement under some conditions if a failure in the liner system occurred. While contaminant leachate could percolate into the groundwater system and migrate downgradient in the aquifer zone, some leachate would be captured in the underdrain system and discharge into surface water. Modeling results of long-term facility conditions show the proposed conceptual design, including the underdrain system, would be protective for a hypothetical receptor near the facility (see Appendix F).

With groundwater monitoring at the discharge points for the underdrain, the underdrain could function as a tertiary leak detection and removal system. Thus, if a leak in the liner system occurred, collection and treatment of contaminated groundwater would be simplified.

Leachate Collection and Transfer System: As previously stated, the perforated leachate collection and detection piping (see Figure 6-7) would collect leachate draining from the waste. The perforated collection pipes would connect to solid double wall pipes that extend through the clean-fill perimeter dike. As was done for the EMWMF (DOE 2001a), redundant perforated collection pipes would be installed at slightly higher levels than the primary collection pipes to provide added factor of safety against clogging. The solid pipes would penetrate the liner, and would be sealed to the geosynthetic layers to prevent leakage through the penetration. Other features (e.g., antiseep collars, plastic waterstops in the dike sealed to the solid pipe) would be installed to further reduce the potential for leakage along the outside of the pipe. The solid double wall pipes from the collection system and detection system in each cell would connect to manifolds that flow to temporary leachate storage tanks in route to the leachate/contact water treatment facility located adjacent to the landfill and described in Sect. 6.2.2.7. If necessary, lift stations and pumps would be used to assist in transferring leachate to the temporary storage tanks and treatment facility. Flow meters would be installed to measure the leachate volume from each collection and detection pipe during disposal activities, cap construction, and the long-term maintenance period following capping and closure. Leachate generated from the landfill would be properly treated and disposed.

Cover System: After support facilities 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 Sect. 6.2.5. After waste disposal is complete, an approximately 13-ft thick multilayer cover system (or cap) would be installed to prevent infiltration of precipitation into the waste. Note that some of the layers may be installed as an interim cover system to reduce the volume of leachate and contact water needing treatment.

Interim Cover System: An interim cover system, also referred to as an interim cap (see Figure 6-6), 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 infiltration into the waste and, thus, the volume of leachate requiring treatment 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.
- Granular Contour/Vent Layer – 1-ft thick (minimum) layer of No. 57 stone which serves 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.
- 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 include gas vent flaps (i.e., small diameter openings in the geomembrane with cover flaps) for venting landfill gas that accumulates within the underlying granular contour/vent layer.

It is anticipated 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.
- Accommodate settling and subsidence to maintain the cover's 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 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 ratio of four horizontal to one vertical (4:1) or flatter. 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 13-ft thick, multilayer final cover system would be comprised of the following layers from the top of waste upward:

- Compacted Clay Layer – 1-ft thick (minimum) layer of unamended, 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 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 $\leq 1 \times 10^{-7}$ cm per sec) unamended 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 1×10^{-9} 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 1×10^{-9} cm per second.
- Geomembrane Layer – 40-mil thick linear low-density polyethylene 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., size No. 57 crushed limestone gravel) with sufficient transmissivity to drain the cover system and satisfy the requirements of the infiltration analysis.
- Biointrusion Layer – 3-ft thick layer of free-draining, 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 – 5-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, 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 would 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. If unvented, the accumulation of these gases beneath the landfill cover could reduce the stability of the cover system and create a potentially explosive environment. Thus, as a minimum, the landfill cover would include a passive gas collection and venting system to collect and remove gases that accumulate beneath the landfill cover. 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. In the conceptual design, this layer is referred to as the granular contour/vent layer. It serves the dual purpose of providing a contouring fill and gas vent layer. The contouring fill establishes uniform contours upon which to construct the overlying layers of the cover system.

6.2.2.5 Support Facilities

A brief description of support facilities for the EMDF is provided below. Site layouts depicting proposed locations of the primary support facilities relative to the landfill footprint and surrounding existing and future facilities are shown in Figures 6-2 and 6-10. Locating the EMDF immediately east of EMWMF offers advantages relative to sharing existing infrastructure for the EMWMF and being in close-proximity to existing utilities. For the conceptual design, it is assumed the EMDF would utilize and upgrade, as necessary, the following support facilities and structures that are being used by the EMWMF:

- Operations/support trailers, staging/laydown areas, stockpile area, and parking areas
- Leachate storage tanks
- Contact water tanks and basins
- Haul road
- Electrical, water, and communication utilities
- Weigh scale
- Guard shacks

The following new support facilities would be constructed:

- Parking areas
- Laydown/storage/staging areas
- Material stockpile area
- Spoils areas (temporary and permanent)
- Guard shacks

Land suitable for development of new support facilities is very limited near the EMDF site (see Figure 6-10). The EMWMF landfill occupies the land to the west of NT-3. The slopes north of the 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 EDF is occupied by former waste disposal areas, existing EMWMF support facilities, and land planned for use by the Y-12 Uranium Processing Facility (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 the sites.

The planned haul road extension under the UPF project will impact wetland areas. In kind, in place mitigation of this loss is planned through expansion and/or creation of wetland acreage at several locations within the Bear Creek watershed (B&W 2010). The southern part of the proposed EMDF footprint will potentially impact three of these planned wetland expansion areas identified in the Aquatic Resources Alteration Permit (ARAP) issued in June 2010 (TDEC 2010). If the On-site Disposal Alternative is selected, coordination of EMDF activities with planned UPF project activities, including a modification to the ARAP, would be required.

Earthwork spoil materials that can be reused in future landfill construction would be stored on-site, since construction of the landfill would be phased. Existing potable water/fire water, electrical, and communication lines used by EMWMF are in close proximity to the proposed landfill footprint and could be extended as needed for the new facility or brought on-site 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.

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 washed or packaged for disposal. It is anticipated water from the clothes washers would drain to a storage tank for temporary storage prior to treatment at a wastewater treatment 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 properly treated at a wastewater treatment facility, 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.

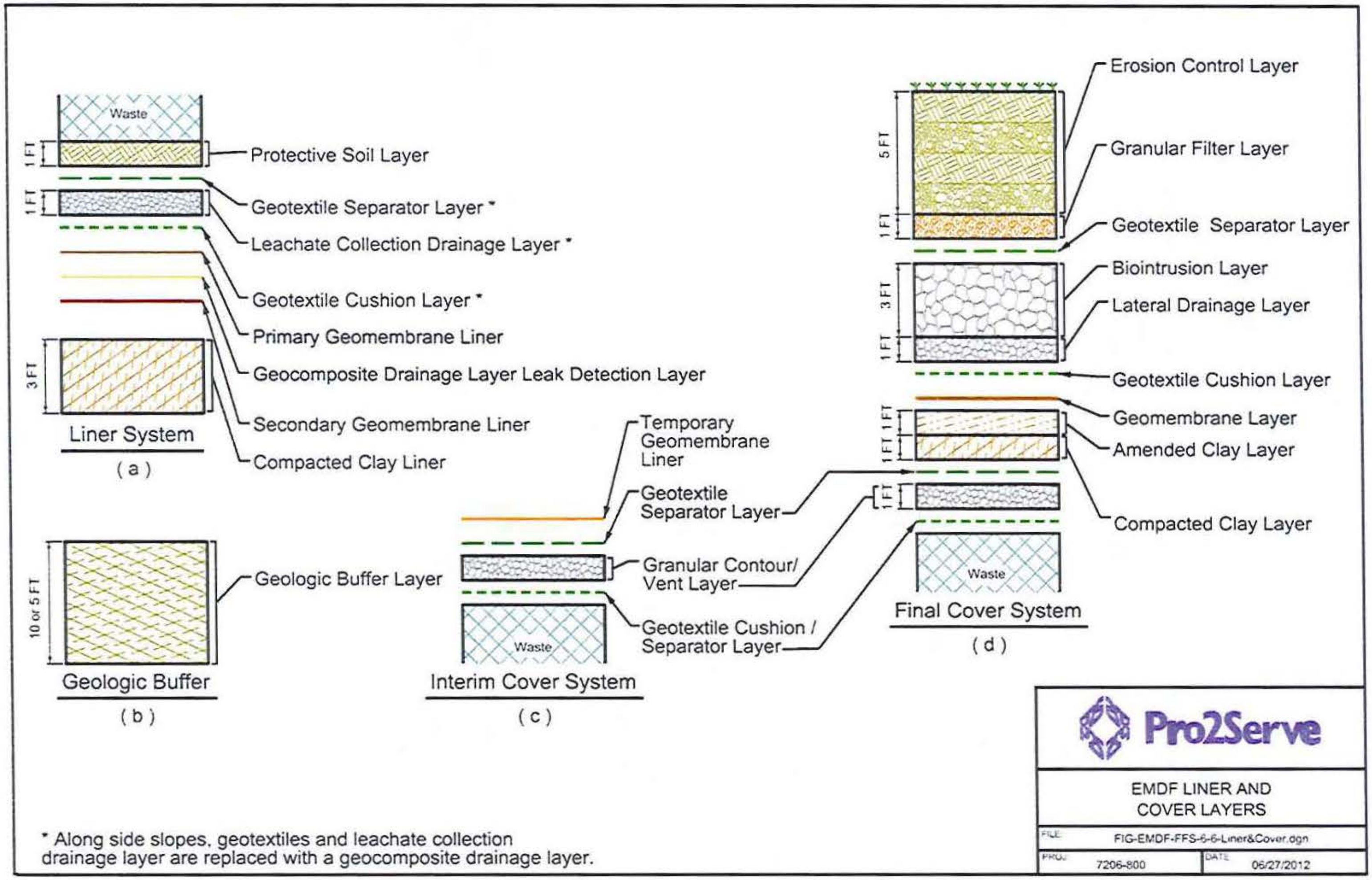

Figure 6-6. EMDF Liner and Cover Layers

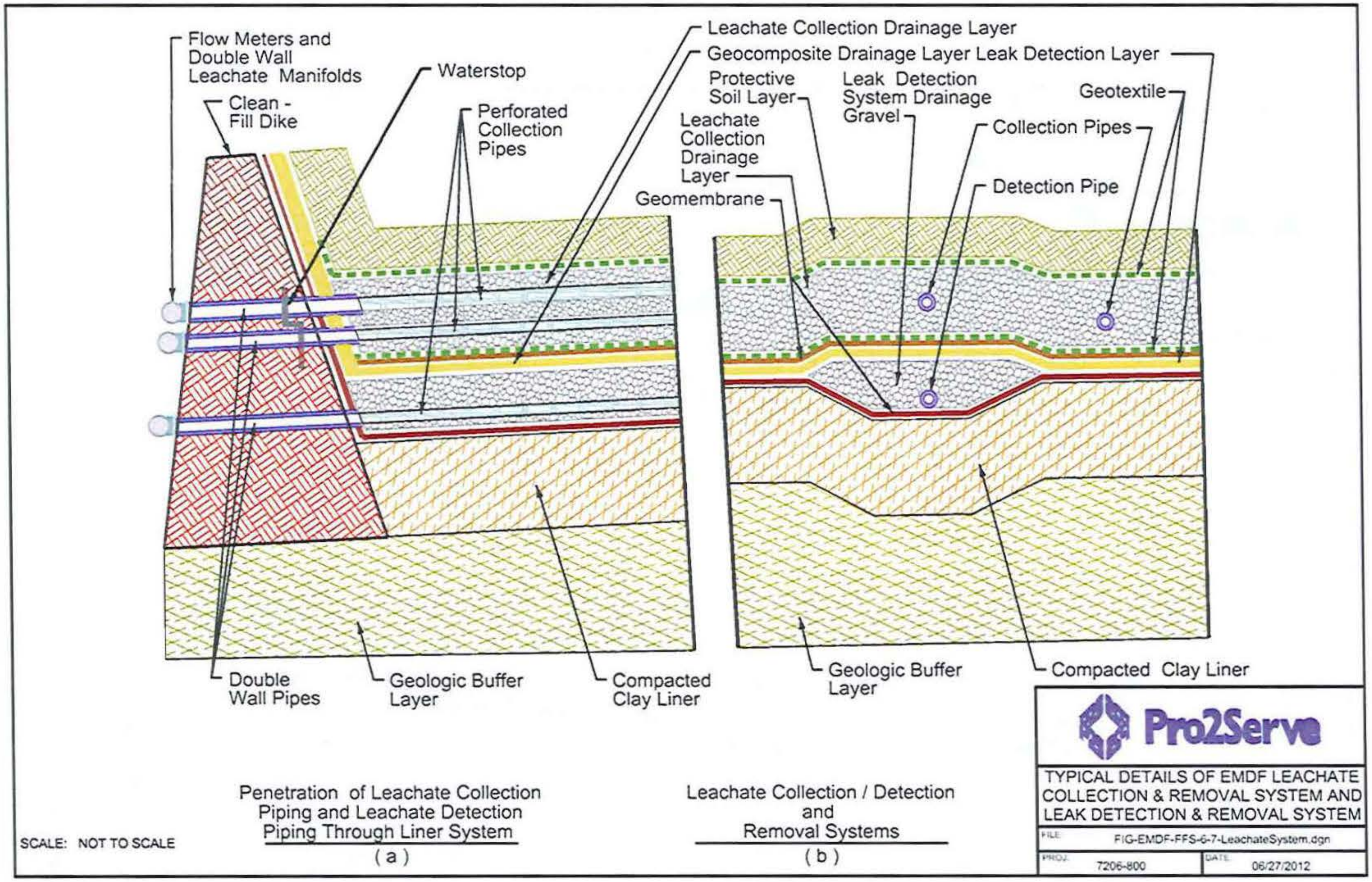

Figure 6-7. Typical Details of EMDF Leachate Collection and Removal System and Leak Detection and Removal System

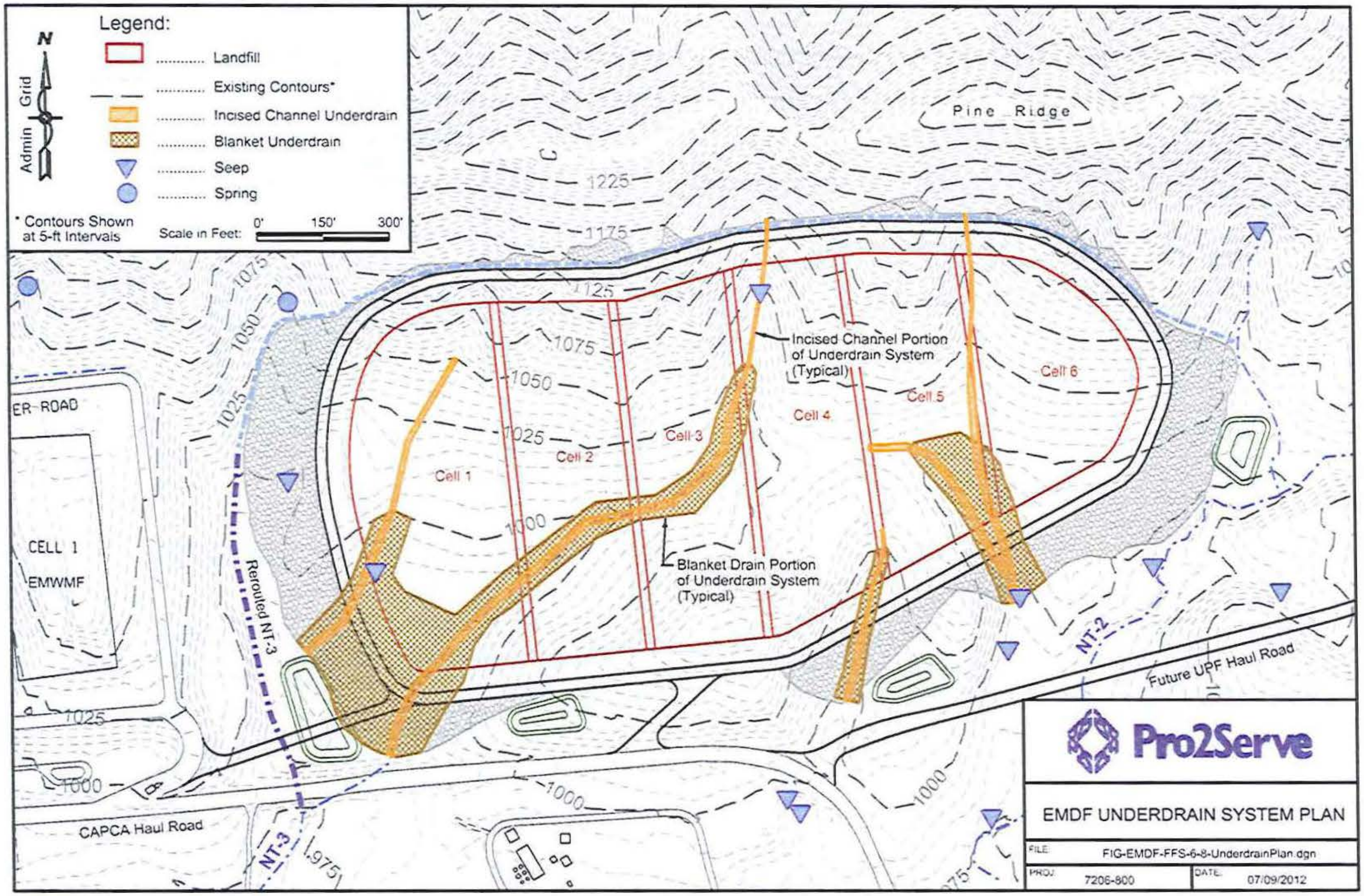

Figure 6-8. EMDF Underdrain System Plan

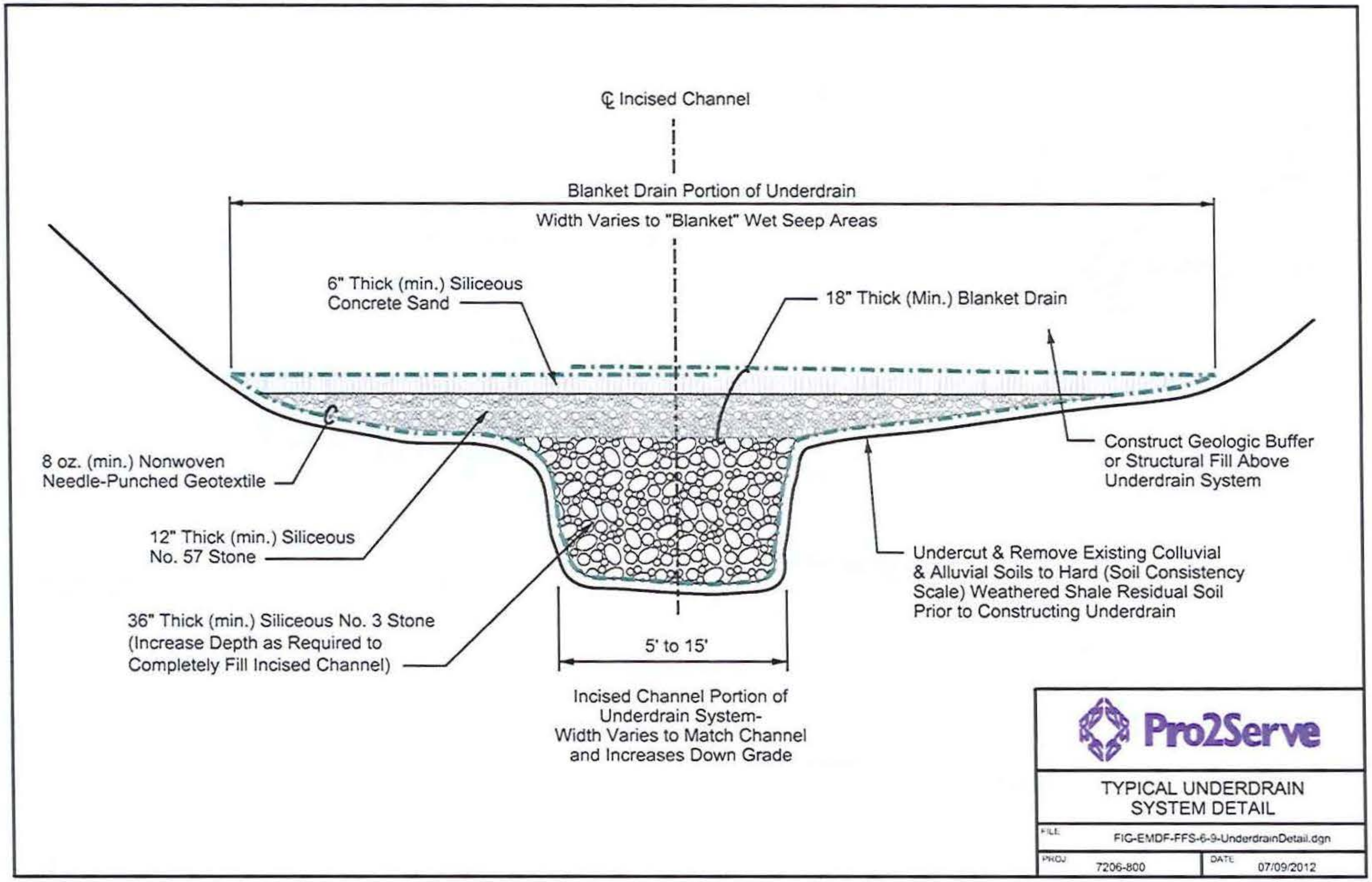

Figure 6-9. Typical Underdrain System Detail

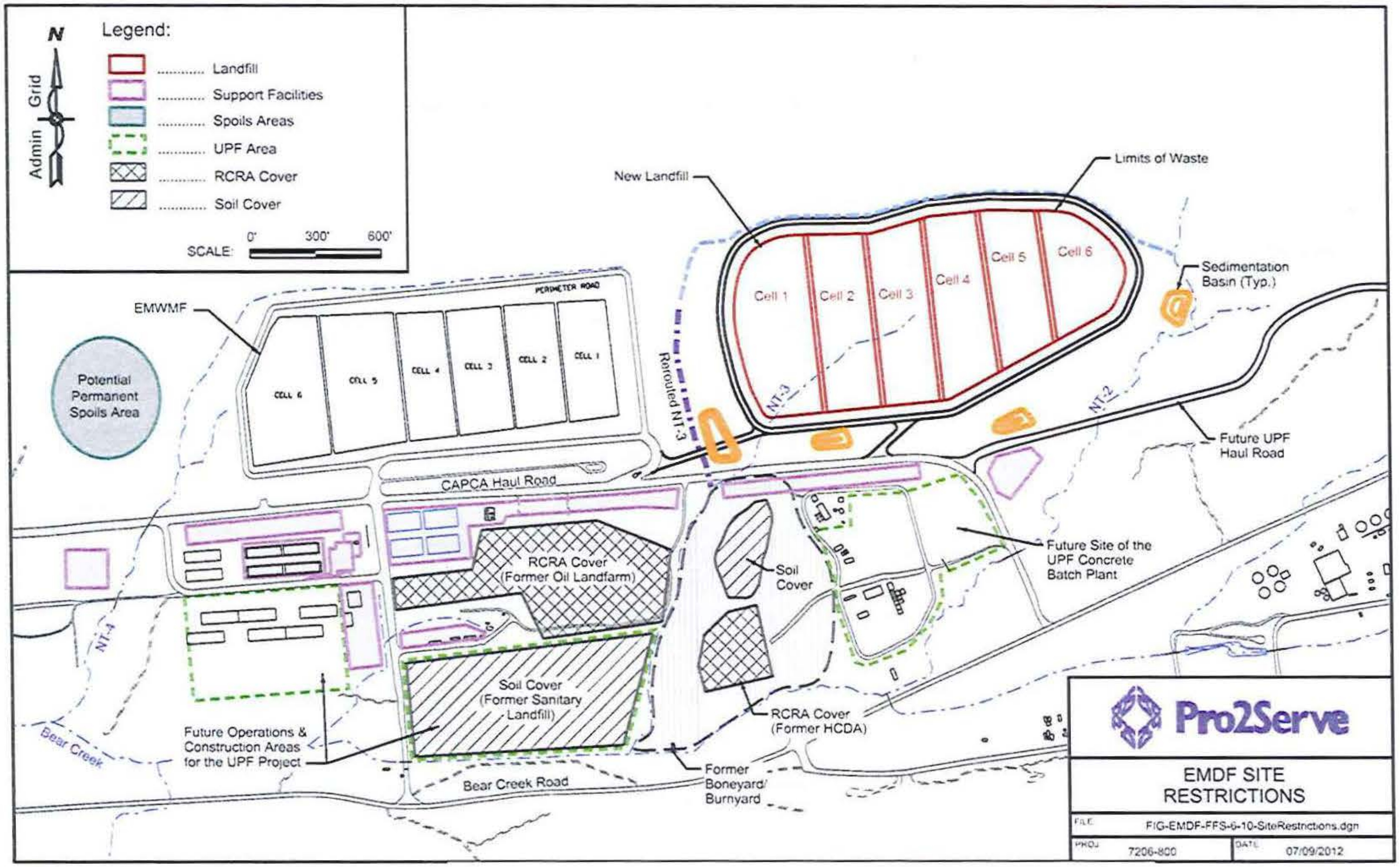

Figure 6-10. EMDF Site and Surrounding Facilities

6.2.2.6 EMDF Conceptual Design Approach

A conceptual final cover grading plan for the EMDF landfill in EBCV is shown in Figure 6-11; landfill cross-sections are depicted in Figure 6-12. The conceptual design for the EMDF would provide a disposal capacity[14] of approximately 2.5M yd^3. With this layout, the approximately 48-acre landfill footprint (computed to outside edge of grading for perimeter clean-fill dike) would be oriented in a roughly east-west direction. The landfill would be somewhat rounded in shape to enhance geomorphic stability and more closely model the natural topography. The approximate total area of development, including temporary construction activities, existing and new support facilities and spoils areas would be approximately 92 acres, of which approximately 60 to 70 acres would remain permanently committed (see Figures 6-2 and 6-10). The total area of disturbance at any point in time would be reduced by phased construction, reuse of construction spoil, implementation of BMPs, and other detailed design considerations. A new larger culvert would be constructed to carry NT-3 and runoff from the EMDF beneath the haul road. Sediment basins would be constructed in phases along the southern side of the landfill. Depending on the outcome of detailed storm water calculations preformed 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 the EMDF would be provided from the existing haul road. The landfill would share the existing access road and guard shack for the EMWMF, located southwest of the EMDF. A secondary access road would be constructed along the southern side of the EMDF to better accommodate concurrent construction and operations activities. As shown in Figure 6-2 and discussed in Sect. 6.2.2.5, existing and new support facilities would be located south of the existing haul road and south/southwest of the EMDF.

Layout Approach: A number of factors were considered when selecting and laying out the conceptual design of the EMDF landfill, including its location in a historical waste management (brownfield) area, proximity to EMWMF, and the area available to feasibly construct a facility (see Appendix C). The proposed EMDF footprint would be constructed over a portion of NT-3. The approach used to set the extents of the landfill waste and perimeter features was based on maximizing the 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.
- The southern constraint was set by the existing Haul Road and avoiding any impact to that road and associated overhead high-voltage power line. Keeping the landfill footprint north of the existing haul road avoids shallower groundwater, 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 Figures 6-2 and 6-10).
- 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 tied into existing grade along the north side of the landfill. Using a flatter backslope was undesirable since it would create an excessively high cut slope that would not "daylight"

[14] The assumed allowance of 28% uncertainty applied to waste volume estimates described in Chapter 2 corresponds to a projected disposal capacity need of approximately 2.5M yd^3.

until intersecting 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 unreasonably steep. A maximum roadway grade of 8% was set to control this and also controlled how far up Pine Ridge the northern edge of the landfill could be positioned.

Phased Construction Approach: The EMDF conceptual design allows the ability to construct the landfill in phases. The landfill would have six cells and construction of the landfill would be constructed from west to east. This approach promotes using gravity drainage for piping systems and keeps brownfield areas consolidated if it is decided in the future that later phases of the landfill construction are not needed.

It is anticipated each construction phase would build two cells of the landfill. 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 1 and part of the rough grading that would be required for Cells 3 & 4 (Phase 2) would be completed in Phase 1 to direct surface water runoff away from the newly constructed Cells 1 & 2 and towards the NT-2 drainage area.

Predicting Seasonal High Groundwater Elevations: Since existing groundwater data for the new site is limited, a reasonable but conservative estimate for the seasonal groundwater level was developed in order to set the bottom of the proposed landfill. The EMDF landfill bottom was established to leave a 10-ft clearance between the bottom of the liner system and the estimated seasonal high groundwater elevations.

The conceptual design of the bottom of the EMDF landfill is conservatively based on a potentiometric surface estimated from data obtained from *The Y-12 Groundwater Protection Program Location Information Database* (B&W 2012). There are no known wells or boring data within the proposed EMDF footprint; however, there are wells and groundwater data in adjacent areas east and west of the site. Seasonal high groundwater 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 maximum groundwater elevations from *The Y-12 Groundwater Protection Program Location Information Database* were plotted for the area around the proposed site. The locations of the existing drainageways within the proposed EMDF site were then noted and assumed to be where the groundwater table would either surface or be very shallow during seasonal high conditions. For the higher elevations of the proposed site, the seasonal high groundwater elevations were predicted by assuming they would be similar to nearby wells at the same ground surface elevation and in the same geologic formation.

As described in Sect. 6.2.2.4, construction of the landfill with facility underdrains, an upgradient geomembrane-lined diversion ditch, and upgradient shallow French drain would cause the groundwater table to drop beneath the landfill. The conceptual design conservatively takes no credit for lowering of the water table after construction of the landfill. Thus, it is anticipated it may be possible to lower the bottom of the landfill after additional site-specific groundwater information is gathered and analyzed.

Data Gaps and Uncertainties: As previously stated, there are no known wells or boring data within the proposed EMDF footprint. However, the areas immediately adjacent to the site have been well characterized. The conceptual design for the EMDF is based on groundwater, geologic, and geotechnical data obtained immediately east and west of the EMDF site and in other locations in BCV in similar geology. These data are deemed sufficient for formulating a conceptual design for the EMDF and assessing the feasibility of constructing a CERCLA disposal facility at the EMDF site. If the On-site Disposal Alternative is selected for implementation, site-specific characterization data would be gathered as an early action in support of detailed design.

6.2.2.7 Leachate/Contact Water Treatment Facility

A water treatment facility is assumed to be constructed near the new landfill for treatment of leachate and contact water generated by the EMDF (see Figure 6-2). 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. Collection and transfer of leachate is described in Sect. 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. After capping and closure of the landfill, leachate volumes would gradually decline because infiltration of precipitation into the waste would be virtually eliminated. Leachate stored within the waste would drain into the leachate collection system over time and be collected for treatment at a much lower rate.

The portion of precipitation that falls within an open, active cell potentially coming in contact with the waste materials and collecting on the floor of the cell (referred to as "contact water") would be pumped out of the active cells and stored temporarily in lined basins located near the landfill. While in the basin, the contact water would be sampled and tested to determine whether it is contaminated. If the results of the analytical tests indicate the contact water is free of contamination, it would be released to the storm water detention basin. If contaminated, the contact water could not be released as storm water and would be transferred to the treatment facility via a dedicated piping system. The treatment facility would be sized based on estimated generation rates of leachate and contact water for the EMDF, considering experience gained from the EMWMF and similar waste disposal facilities. 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 and discharged without treatment.

Treatment Facility Conceptual Design: For conceptual design of the treatment facility, leachate characteristics were assumed to be similar to wastewater generated at EMWMF which contains low concentrations of metals such as copper, silver, and zinc; organic constituents such as PCBs; and radiological constituents such as uranium and strontium.

Requirements for effluent water release must be maintained as low as reasonably achievable (ALARA) per TDEC 1200-02-11-.16 (see Table E-1 in Appendix E). Additionally, there is an effective dose equivalent limit to a public individual of 100 mrem per year, from which Derived Concentration Standard limits (DOE 2011d) for radionuclide concentrations in water are determined. In the case of multiple contaminants, the sum of fractions must not exceed 1.0.

The conceptual design for the treatment facility includes unit operations for collection, chemical precipitation, clarification/filtration, ion exchange, and carbon adsorption. Chemical precipitation would include a series of tanks; a small flash mix tank for combining wastewater with chemical additives such as sodium hydroxide and other possible metal complexing agents; a flocculation tank for mixing the chemically treated water with coagulants and flocculating agents; a clarifier for allowing the flocculated precipitates to settle by gravity; and a sludge holding tank for holding and concentrating the sludge, and providing feed to a dewatering system such as a filter press. The clarified wastewater would pass through filter units prior to ion-exchange treatment. The ion-exchange system may include several flow-through columns for removing strontium, uranium, or other radionuclides from the wastewater. Treated wastewater would be collected in a final effluent holding tank for final pH adjustment prior to discharge at a surface water outfall in accordance with ARARs.

It is assumed that secondary solid waste would be disposed of on-site at the EMDF until closure. After closure, secondary waste disposal is assumed to be at NNSS. Secondary wastes would include dewatered sludge from chemical precipitation and suspended solids removal used to treat metals; contaminant-loaded zeolite and strong-base anion and strong-acid cation ion-exchange media used to treat radionuclides, and spent granular activated carbon used to treat organic constituents.

After wastewater volumes are reduced to the extent that it is no longer cost effective to operate and maintain the treatment facility, the treatment facility would be demolished (assumed to be during year 11 after closure). Waste from D&D of the treatment plant that fails to meet the acceptance criteria for one of the on-site ORR Landfills would be disposed at an off-site disposal facility. Remaining leachate collected would be trucked by tanker to an appropriate facility on the ORR.

6.2.2.8 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 the EMDF.

Process modifications that may be considered for the EMDF include geochemical immobilization technologies designed to retard movement of contaminants, in-cell solid waste treatment, disposal of RCRA-listed waste, modification of the leachate/contact water treatment facility to allow treatment of additional contaminated water from a future Bear Creek Burial Grounds (BCBG) action, and volume reduction processing. 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.

Geochemical Immobilization: PWAC are presented in this RI/FS based on conceptual facility design and assumed receptor exposure conditions (see Appendix F). For calculating the PWAC, wastes are assumed conservatively to be disposed of throughout the waste layer without segregation. However, geochemical immobilization of soluble waste radiological constituents with long half lives or other 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 in the waste disposal layer.
- Placing pulverized concrete in the waste layer to maintain a higher pH and promote geochemical stability of uranium minerals.

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.

In-cell Waste Treatment: For some waste streams, it may be more efficient for treatment to meet LDRs or other WAC to be implemented at the on-site disposal facility. In the case of waste treated by grouting, weight and feasibility limitations are a consideration for moving treated waste from the generator site to the disposal facility. Treatability studies and other quality assurance steps could be implemented to ensure effective waste treatment.

Disposal of RCRA-Listed Waste: Contact water basins are provided to collect precipitation that falls within an open, active cell potentially coming in contact with the waste materials. This water is expected to be clean enough to discharge without treatment in most cases, and contamination is not expected to approach levels that would be considered hazardous under RCRA. If, however, RCRA listed waste is disposed at the EMDF, several design modifications would be required. These modifications would include double-walled contact water piping. The piping would be similar to piping proposed for transporting leachate. Also, the design of contact water storage would need to be modified to meet RCRA requirements for secondary containment and leak detection. The existing contact water ponds and above-grade basins have single geomembrane liners.

Modification of the Leachate/Contact Water Treatment Facility: Potential interim actions that could be implemented to reduce migration of contaminants from BCBG located west of the EMWMF are being considered, such as enhanced leachate collection, a component of the preferred alternative presented in the BCBG Proposed Plan (DOE 2008c).

Given the proximity of the proposed EMDF to BCBG, the design, construction, and operation of a leachate/contact water treatment facility for the EMDF could potentially be modified to allow treatment of contaminated water from a future BCBG action. Potential modifications would include addition of lift stations and piping to transfer contaminated water from the BCBG to the leachate/contact water treatment facility, resizing the treatment facility components if necessary to accommodate additional flow, and modifying treatment facility unit operations to accommodate BCBG contaminants that the EMDF facility is not designed to remove.

Volume Reduction Processing: This modification involves the use of volume reduction (VR) equipment and other efforts such as recycling, additional waste segregation, and project sequencing to conserve EMDF disposal capacity. A study of potential VR options in Appendix B indicates a potential for significant disposal capacity and cost savings for the EMDF through VR.

Table 6-1 summarizes the potential benefits of VR activities for on-site disposal. Performing size-reduction of debris would significantly reduce the quantity of clean fill necessary for placing the some types of debris, and would allow debris such as masonry and concrete to be used to replace clean fill. Volume reduction equipment such as heavy duty mobile shredders, concrete crushers, and shearing machines (like a supercompactor used previously at ETTP) could be deployed for on-site processing of waste materials. Cost estimates in Appendix B indicate a cost of about $38M to deploy the equipment with possible savings in EMDF construction, operations, and transportation of up to $71.7M and a potential reduction in disposal capacity needs by up to two disposal cells (over 800,000 yd^3 disposal capacity). It was also estimated that recycling of metals from heavy equipment and structural steel could result in millions in cost savings and conserving over 71,000 yd^3 of EMDF disposal capacity. As described further in Appendix B, the recycling of demolition materials from radiological facilities remains a complex issue.

Project sequencing involves the scheduling of building D&D efforts with contaminated soil removal projects such that the waste soil can be used as fill material during placement of waste debris at the EMDF. Waste soil would replace clean fill and conserve a substantial fraction of EMDF capacity. The projected volume of waste soil to be used to replace clean fill is equivalent to more than an entire disposal cell and equivalent to an avoided cost of about $65.4M. The planning of EMDF disposal capacity assumes that this effective sequencing of projects will occur.

Waste segregation involves the separation of contaminated and uncontaminated D&D materials to ensure proper disposal. There are typically clean areas associated with contaminated facilities that could possibly be demolished in a manner that avoids comingling with materials from potentially contaminated zones, thus creating an opportunity for disposing of additional quantities of uncontaminated D&D materials at the ORR Landfill. Segregation of additional wastes to the ORR Landfill is beneficial due to the lower construction costs associated with the liner and final cover systems. Additional efforts to segregate and selectively remove non-contaminated materials during D&D activities along with revision of the current authorized limits to allow disposal of wastes containing additional radionuclides at the ORR Landfill could conserve EMDF capacity and reduce disposal costs significantly.

Table 6-1. Summary of Volume Reduction Benefits

Parameter	Activity			
	Size Reduction	Recycling	Sequencing	Segregation
Basis	Shredding, crushing, and shearing operations are deployed at multiple sites as a programmatic effort.	Recycling of 25% of metal debris (44,761 tons)	RI/FS waste volume estimate assumes virtually all waste soil is used to replace clean fill (492,836 yd^3 as-disposed)	Debris is segregated and diverted to the ORR Landfill.
Cost of Method	$38M	$5M for characterization and transportation	Negligible	The cost of additional facility characterization and field surveys
Cost Savings	Scenario A:$27.4M Scenario B: $71.7M	$9.7M from sale and EMDF clean fill savings	$65.4M (cost avoided through assumed sequencing)	Reduced landfill construction and operations costs.
EMDF Capacity Gained	Scenario A: 504,973 yd^3 Scenario B: 820,582 yd^3	71,673 yd^3	492,836 yd^3	To be determined
Additional Potential Benefits	Increased landfill density with additional capacity gain of 69,438 yd^3; lower equipment maintenance costs			
Additional Notes		Assumes commercial value of $0.15/lb for metals	RI/FS waste volume estimate soil demand is based on successful sequencing.	ORR Landfill construction costs are significantly lower than for EMDF.

The largest cost savings and capacity gain could be achieved with deployment of size reduction equipment on a multiple project or programmatic basis; however, uncertainty factors such as funding, project sequencing, and contracting could impact the ability to implement this approach. The EMDF conceptual design allows the ability to construct the landfill in phases such that cells could be built as needed.

6.2.3 Waste Acceptance Criteria

The characteristics of future CERCLA waste generated are anticipated to be similar to CERCLA waste generated since EMWMF began operating in FY 2002. Appendix F describes modeling and calculations performed to develop a PWAC for the EMDF that meets applicable risk and dose criteria.

6.2.4 Construction Activities and Schedule

Figure 6-9 shows the conceptual sequence of design, construction, operations, and closure actions. In practice, alternative construction sequencing could be implemented by the construction and operations contractor(s).

The on-site disposal facility construction elements include those described in Sect. 6.2.2. Groundwater monitoring wells and surface water weirs would be installed as part of the early actions to support remedial design. Also, 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; relocating the Y-12 229 security boundary 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. Construction of the new on-site leachate/contact water treatment facility would be started during the same time period as the site development activities and would be completed prior to completion of the first phase of landfill cell construction.

Subsequent to site development, the disposal cells would be constructed in phases consistent with waste generation schedules. 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; 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, leachate collection and detection systems and piping, and contact water piping. 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. Interim caps over the Phase I cells would be installed during Phase II when Phase I disposal activities are completed. Phase III would include additional site preparation, construction of Cells 5 and 6, interim capping of Phase II cells, and interim capping of Cells 5 and 6 after the cells are filled.

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. Due to the conservative estimate of the seasonal high groundwater table, the conceptual design indicates that a large volume of structural fill will also be required from a borrow area. This is necessary to raise the bottom of the waste to maintain the appropriate buffer between the waste and the groundwater table. 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 onsite and reused as structural fill. For estimating purposes it was assumed that all structural fill would be purchased from an offsite source, however, as part of the final design process, it would be appropriate to evaluate onsite borrow source areas.

After completion of the three phases of construction 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 and Waste Placement

For the On-site Disposal Alternative, operations, including some personnel and equipment, would likely transition from the existing operations contractor to the new EMDF operations contractor. Disposal operations would include waste receipt, inspection, 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 leachate and contact water; storm water management, etc. Facility maintenance would include providing daily cover over the emplaced waste, as required; maintaining roadways, buildings, equipment, utilities, and other facilities; and leachate and contact water collection and treatment. Waste disposal operations would be similar to those at the EMWMF.

Leachate would be transferred to temporary storage tanks and contact water would be transferred to lined basins as previously described. Filled or partially filled tanks and basins would be sampled to determine contaminant concentrations. This would allow modifying flow through the treatment train; for example, the chemical precipitation system could be bypassed if no metals are present, reducing the use of acidic and caustic chemical additives and the volume of secondary waste generated.

Wastewater treatment operations would include managing flow from leachate storage tanks and contact water basins into the treatment facility; operating and monitoring the treatment system; sampling and analyzing the effluent; disposing of spent treatment media (e.g., zeolite, ion exchange resins, granular activated carbon); and replacement of spent media as needed.

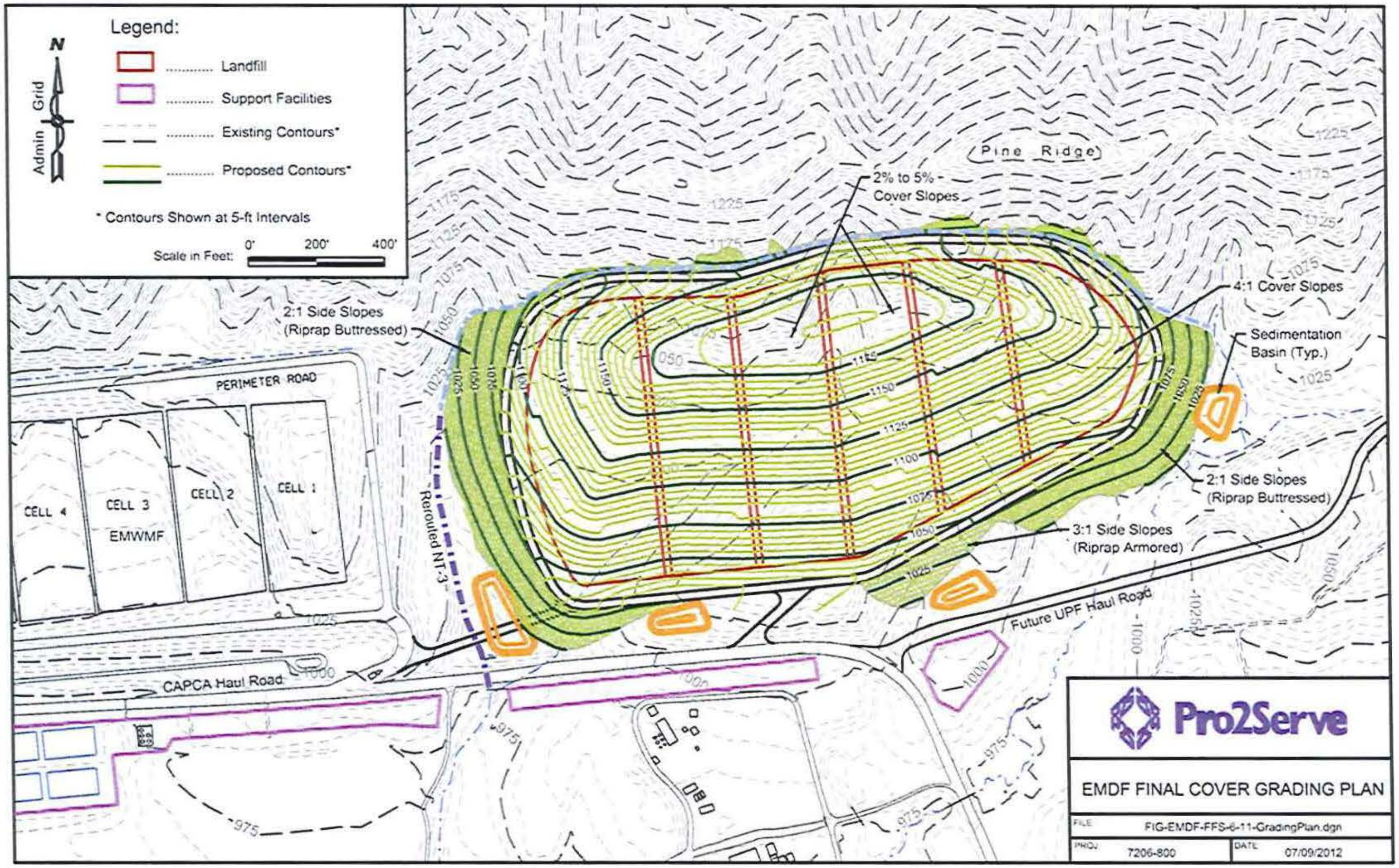

Figure 6-11. EMDF Final Cover Grading Plan

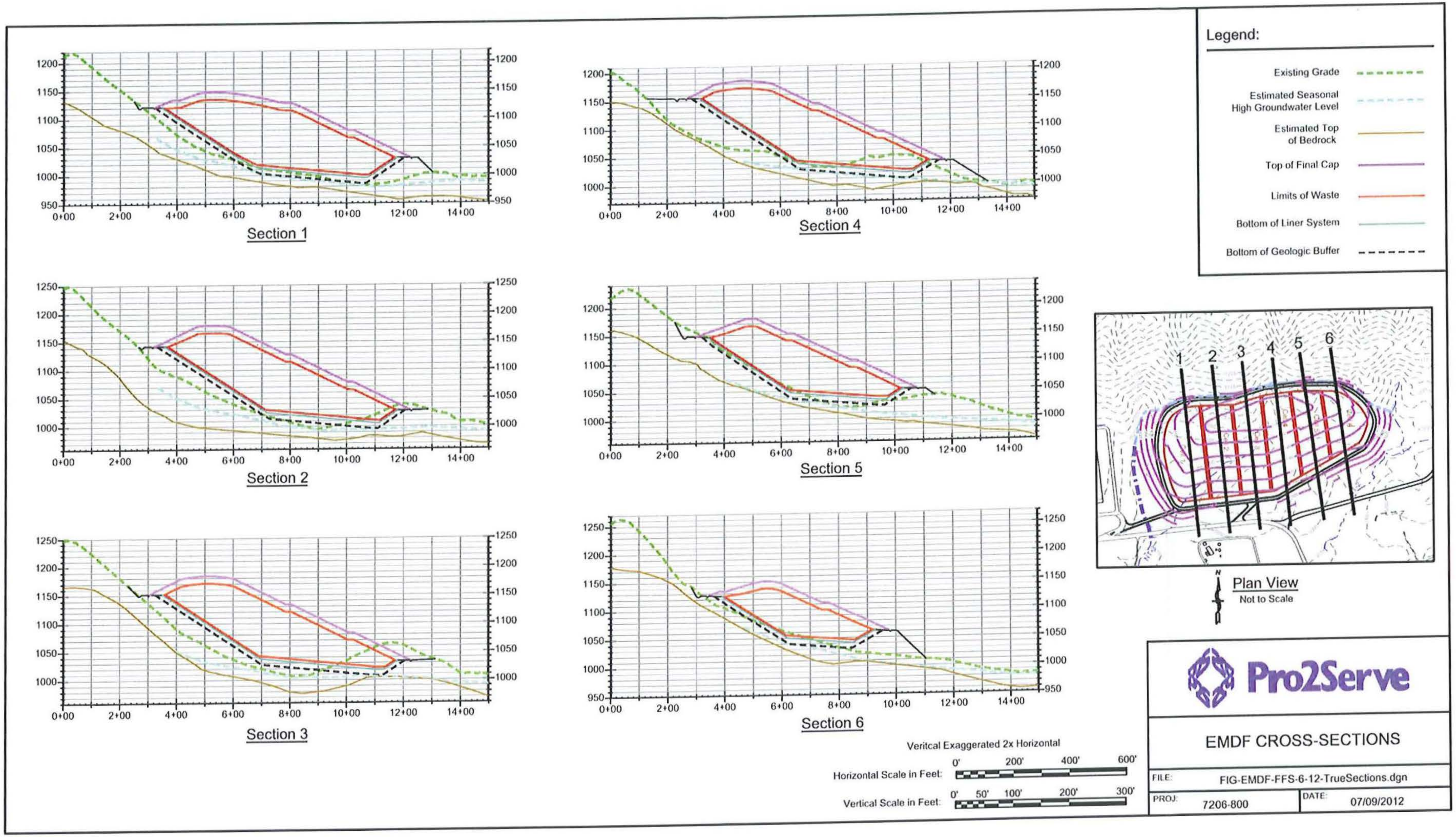

Figure 6-12. EMDF Cross-sections

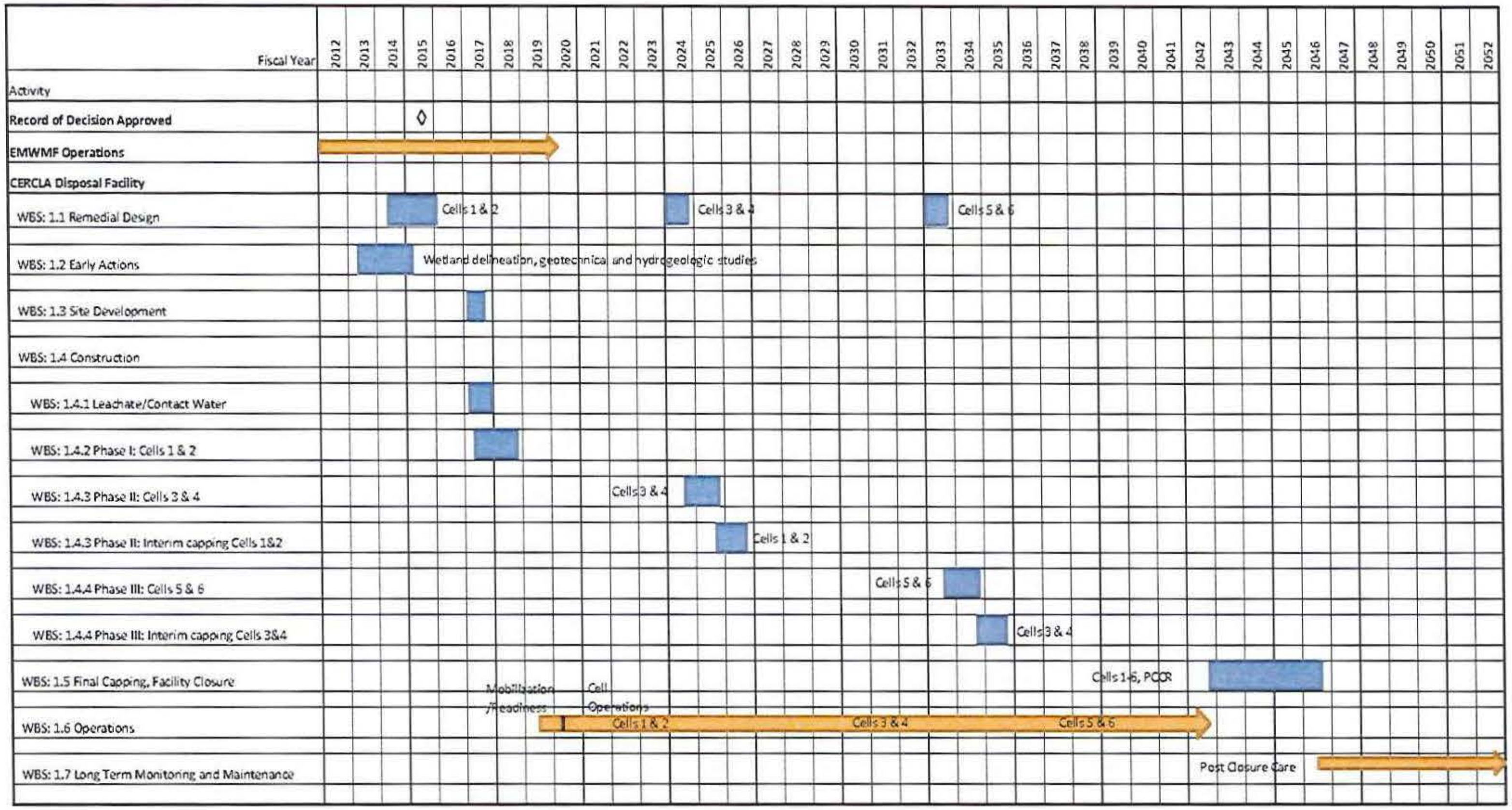

Figure 6-13. On-site Disposal Alternative Schedule

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 the on-site disposal facility to minimize the potential for adverse effects. It is assumed the EMDF would be constructed and operated similarly to the EMWMF.

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

- Preparing and implementing worker protection 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 design and during construction, and restoring habitat, as needed, in consultation with appropriate state and federal agencies.
- Limiting the number of active working face 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 groundwater monitoring before, during, and after facility construction and operation and implementing appropriate contingency plans if any adverse effects were detected.
- For on- or off-site disposal, transporting waste in closed 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, revegetating, and restoring disturbed areas.
- Preparing and implementing long-term monitoring and maintenance plans and, treatment facility operating plans, and contingency plans.

Similar measures would be in place at off-site disposal facilities, and costs are assumed to be included in disposal fees.

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. 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.

6.2.8 Closure

After completion of waste disposal, closure activities would include final capping (i.e., construction of the final cover system). 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. Leachate tanks would be removed over time, and the leachate/contact water treatment facility would be decommissioned after rates of leachate generation diminish. The site would be restored to maximize beneficial reuse of the property in accordance with the designated land use.

Deed restrictions would prohibit residential use of the property, construction of any facility that could damage the final cover system, or installation of groundwater 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 the EMDF and would be attached to the deed description and filed with the appropriate local governmental authority.

6.2.9 Post-Closure Care and Monitoring

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 would be performed for an indefinite period after facility closure.

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 system, 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. Long-term S&M would also include maintenance of monitoring wells, fences, signs, access roads, survey benchmarks; and leachate collection, storage, and transfer facilities, including treatment and disposal of leachate.

The leachate/contact water treatment facility would be operated in accordance with an operations and maintenance plan prepared by the construction/installation contractor(s) and equipment manufacturers. Effluent would be monitored as needed to ensure compliance with discharge requirements. After wastewater volumes are reduced to the extent that it is no longer cost effective to operate and maintain the treatment facility, it would be demolished and closed.

6.2.9.2 Monitoring

Landfill performance monitoring could be accomplished by (1) monitoring leachate from leachate collection and removal systems, (2) monitoring surface water in NT-2 and NT-3 at weirs on the upstream side of the Haul Road, (3) monitoring seepage emanating from the facility underdrain, and (4) groundwater monitoring. Details about operational and post-closure monitoring would be specified in future post-ROD CERCLA documents that require regulator approval. Available methodologies and technologies, such as real-time downhole sensors and well purging options for groundwater 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 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 seepage emanating from the facility underdrain and surface water in

NT-2 and NT-3 would serve as an early indication of liner system failure. If a failure in the liner system occurred, while contaminant leachate could percolate into the groundwater system and migrate downgradient in the aquifer zone, some leachate would be captured in the underdrain system and discharge into surface water. Also, natural groundwater flow paths are toward the tributaries, so that contaminants reaching shallow groundwater would enter the streams as base flow.

Groundwater monitoring would take advantage of the bedrock joint systems believed to underlie NT-2 and NT-3. As discussed in Appendix C, these joints help to direct groundwater flowing parallel to strike downgradient and across stratigraphic boundaries towards the Maynardville Limestone drainage system. Wells placed near the tributaries and screened in fractured rock could detect contaminants in the event of liner failure. Additionally, a well cluster placed at about the midpoint and on the downgradient side of the EMDF and screened in water-bearing fractures would act to monitor flow not captured by the tributaries and tributary joint system. One or two wells placed upgradient would provide background water data. Wells would be monitored for water level and indicator parameters, such as specific conductivity or radioactivity. This arrangement of three wells placed downgradient of the EMDF, when combined with one or two up gradient wells, and with indicator parameter monitoring, would meet the substantive RCRA monitoring requirements of 40 CFR 264.97 and 40 CFR 264.98.

Groundwater and surface water monitoring results during facility operation and after facility closure would be statistically compared to baseline conditions established before disposal operations, to long-term trends, and to satisfy regulatory criteria. Decisions regarding the placement of monitoring wells would be made with consideration of contributions of contaminants from sources outside of the EMDF, such as the BY/BY, former Oil Landfarm, and S-3 Ponds. Use of low-flow well purging techniques for sampling could reduce the likelihood of inducing contaminant flow from neighboring areas. If baseline monitoring identifies contaminants in the EMDF area, these data would be used to identify contributions of contaminants from sources outside of the EMDF during operational and post-closure care.

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 treatment required to meet the 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 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. For CERCLA actions that transfer wastes off-site, permits are required at 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:

- 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.

These procedures require confirmation by the regional EPA office with jurisdiction over the chosen disposal facility that 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 6-2 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 2020 through FY 2042 with approximately 28% uncertainty applied.

Table 6-2. Candidate Waste Stream As-generated Volumes by Waste Type, Material Type, and Disposal Facility for Off-Site Disposal Alternative with 28% Uncertainty

Off-site Disposal Facility	Waste Type	Material Type	Volume (yd^3)
NNSS (Non-Classified)	LLW	Debris	1,500,618
	LLW and LLW/TSCA	Soil	638,472
		NNSS (Non-Classified) TOTAL	**2,139,090**
NNSS (Classified)	LLW	Debris	7,612
NNSS (Classified, Mixed)	LLW	Debris	705
		NNSS (Classified) TOTAL	**8,317**
Energy*Solutions*	LLW/RCRA	Debris	27,616
		Soil	15,326
		Energy*Solutions* TOTAL	**42,942**
		TOTAL	**2,190,349**

6.3.2 Description of Representative Disposal Facilities

As shown in Table 6-2, non-classified LLW and LLW/TSCA waste and classified LLW waste would be shipped to NNSS in Nye County, NV. LLW/RCRA (mixed) waste would be shipped for treatment and disposal at Energy*Solutions*, Clive, UT. The disposal facilities are described in the subsections that follow.

6.3.2.1 Energy*Solutions*, Clive

Energy*Solutions* is located in Clive, UT, approximately 75 mi 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
- PCB radioactive waste
- Asbestos contaminated waste
- Mixed waste
- 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 mi^2 hazardous waste zone established by the state of Utah. The nearest population center is approximately 40 mi away. Energy*Solutions* offers a variety of mixed waste treatment processing 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 3/4-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 degrees Celsius 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 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 hazardous 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 (VTD) of Organic Constituents – For the thermal segregation of organic constituents from wastes including wastes with PCBs. Waste containing PCB liquids is also acceptable for VTD 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 (HMR). 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, sealands, 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

EnergySolutions is capable of receiving both truck and rail shipments. The existing rail spur at the ETTP truck-to-rail 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 (SNM) exemption – radiological information to evaluate waste containing SNM
- PCB certification – information about the type of PCB waste included

For waste streams requiring treatment (other than macroencapsulation) or solidification, a preshipment 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, NV, approximately 65 mi northwest of Las Vegas, NV. The facility is licensed and permitted to receive the following waste types for disposal:

- LLW
- TRU waste
- 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 solely 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 HMR. 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, AZ and then transferred to trucks for final delivery to NNSS. The existing rail spur at the ETTP is available for use 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 Order 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 Off-site Disposal Description

Figures 6-14 and 6-15, respectively, show the off-site disposal activities and responsible entities for waste shipments to Energy*Solutions* 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, AZ. All classified waste LLW shipments to NNSS would be by truck transport. LLW/RCRA (mixed) waste would be shipped by rail for treatment and disposal at Energy*Solutions*, Clive, UT. Appendix G contains the cost estimate and additional assumptions for the Off-site Disposal Alternative.

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; local waste transport; and interim storage, as required, for waste not meeting disposal facility WAC.

6.3.3.1 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 provides detailed information related to the required analyses for waste streams.

6.3.3.2 Packaging

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.

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 LLW/RCRA waste being treated and disposed at Energy*Solutions* or classified LLW waste disposal at NNSS. Intermodals used for LLW/RCRA waste treatment and disposal at Energy*Solutions* would be disposed of with the treated waste. Classified waste shipped to NNSS would also be disposed in non-returnable containers.

6.3.3.3 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 truck-to-rail transfer facility at the 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 before placement on the trucks. LLW/RCRA waste would be transported to the truck-rail transfer facility at ETTP for rail shipments to Energy*Solutions*. Non-classified LLW and LLW/TSCA waste would be transported to the truck-to-rail transfer facility at ETTP for rail shipment to Kingman, AZ and subsequent transfer to trucks for transport to NNSS.

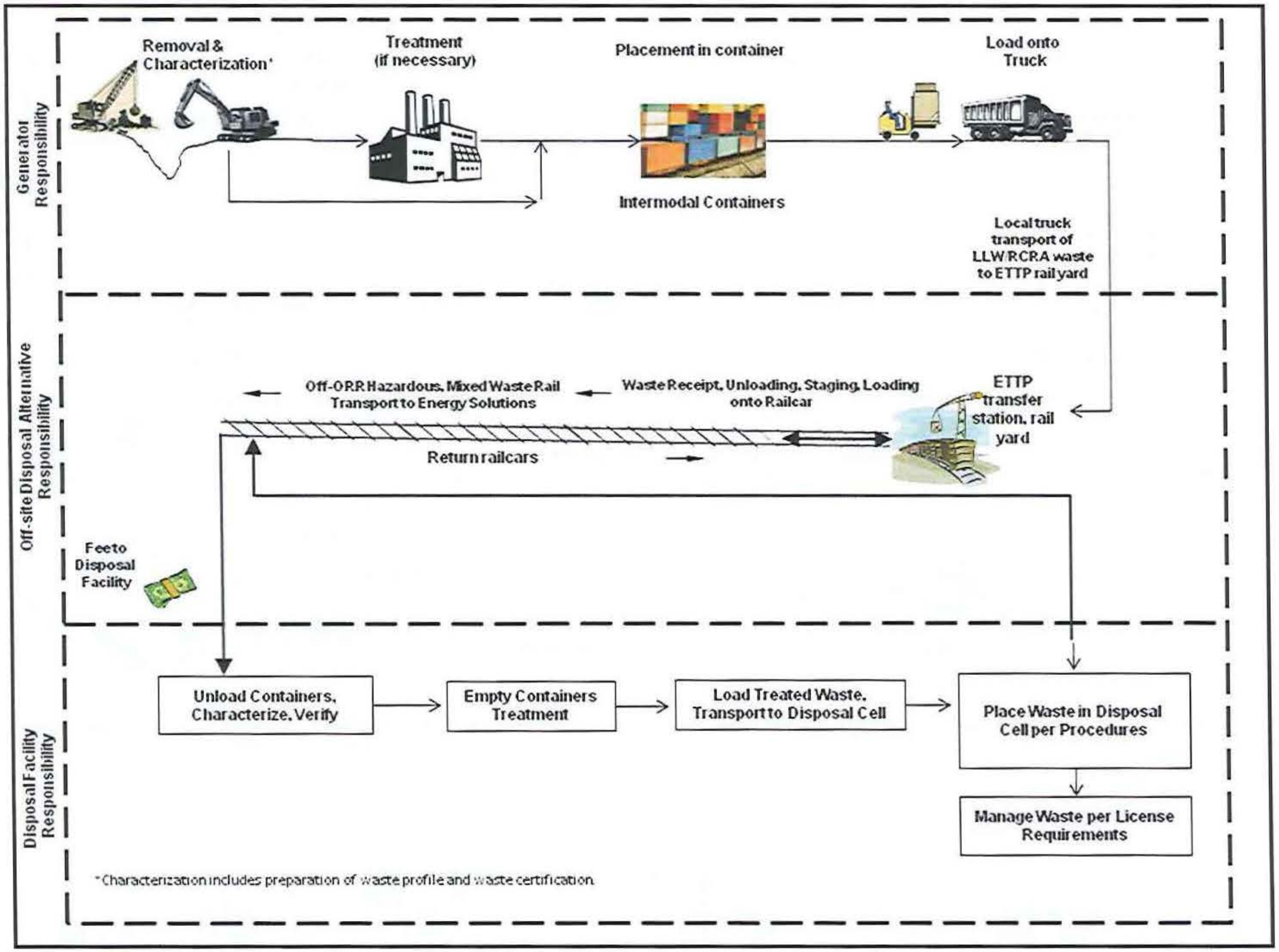

Figure 6-14. Schematic of Responsibilities for Waste Shipments to EnergySolutions for Off-site Disposal Alternative

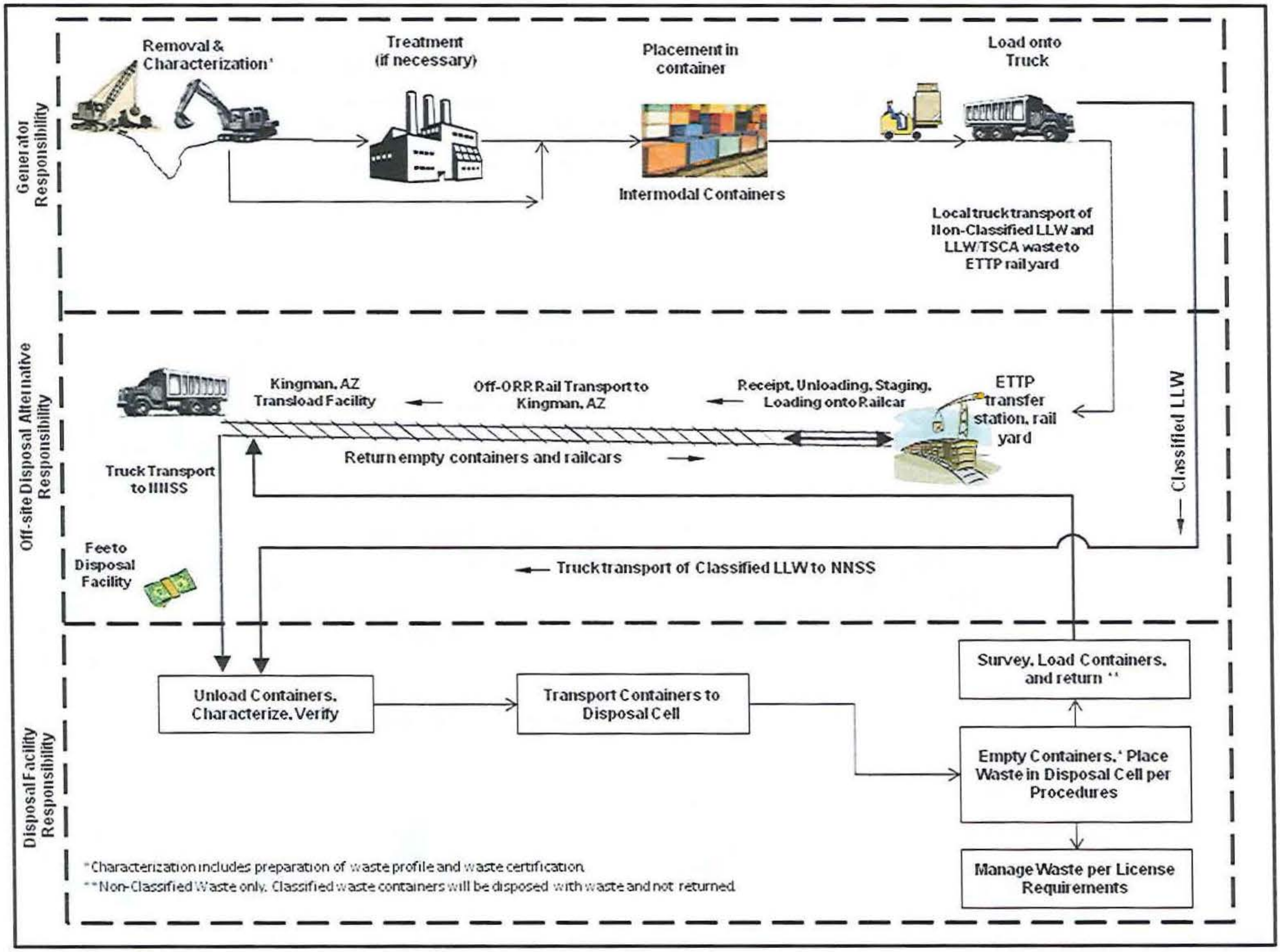

Figure 6-15. Schematic of Responsibilities for Waste Shipments to NNSS for Off-site Disposal Alternative

6.3.3.4 Truck-to-rail transfer facility at ETTP

Rail transportation of waste is assumed for all non-classified waste being shipped for off-site disposal. The existing truck-to-rail waste transfer facility at ETTP would facilitate the transfer and staging of waste containers from trucks to railcars. No capital improvements would be required at ETTP to handle loaded intermodal containers. Wastes in intermodal containers delivered by truck from generator sites would be staged at an existing docking area and loaded onto ABC railcars on the rail spur next to the docking area 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.

Approximately 182,670 intermodal containers would be transported from the individual remedial sites to the rail transfer facility at ETTP. Each railcar would carry either six or eight intermodal containers resulting in 486 railcar loads to Energy*Solutions* in Clive, UT and 24,168 railcar loads to Kingman, AZ for truck transfer to NNSS.

It is assumed that DOE would lease dedicated railcars. 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.

6.3.3.5 Off-ORR transportation

All LLW/RCRA (mixed) waste would be transported in intermodal containers by rail and disposed at the Energy*Solutions* facility in Clive, UT. The assumed rail route to Energy*Solutions* (see Figures 6-16 and 6-17) involves three major railroads (CSX, Indiana Harbor Belt [IHB] Railroad, and Burlington Northern Santa Fe [BNSF] Railway) and is approximately 2,290 mi (3,686 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 north into Corbin, KY, through southern Ohio, north through Indiana, and into Illinois near Chicago. Here the cargo transfers to the IHB rail line for 16 mi and then transfers to the BNSF line at La Grange, IL. The route continues west through Illinois and crosses into Iowa at Burlington. The route continues through Lincoln, NE; Denver, CO; and Grand Junction, CO before arriving in Clive, UT. Based on 486 railcar loads to Energy*Solutions*, approximately 1.1M railcar mi (1.8M railcar km) would be traveled between Oak Ridge, TN and Clive, UT. The total number of actual train loads would depend on the number of railcars per train.

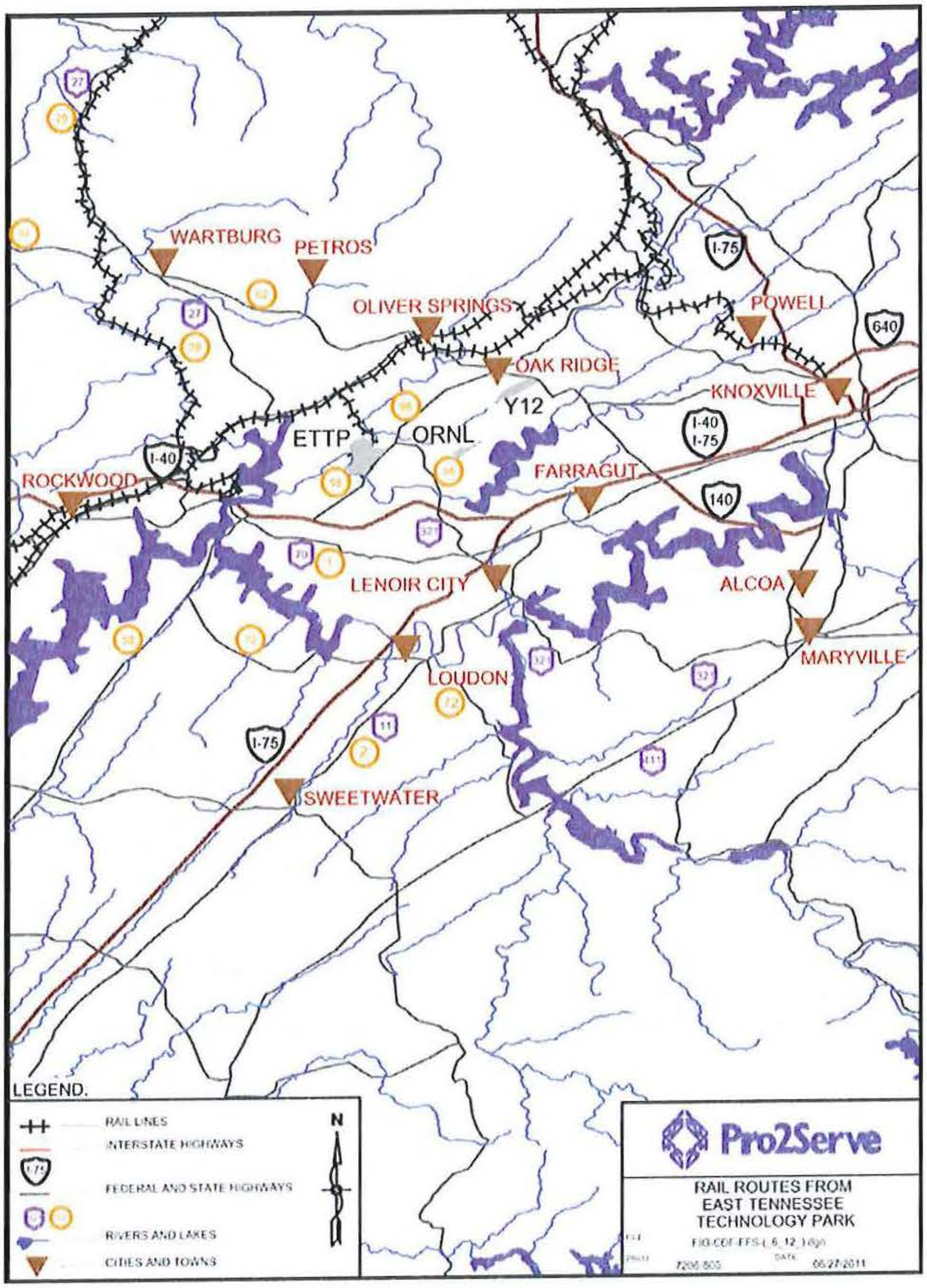

Figure 6-16. Rail Routes from ETTP

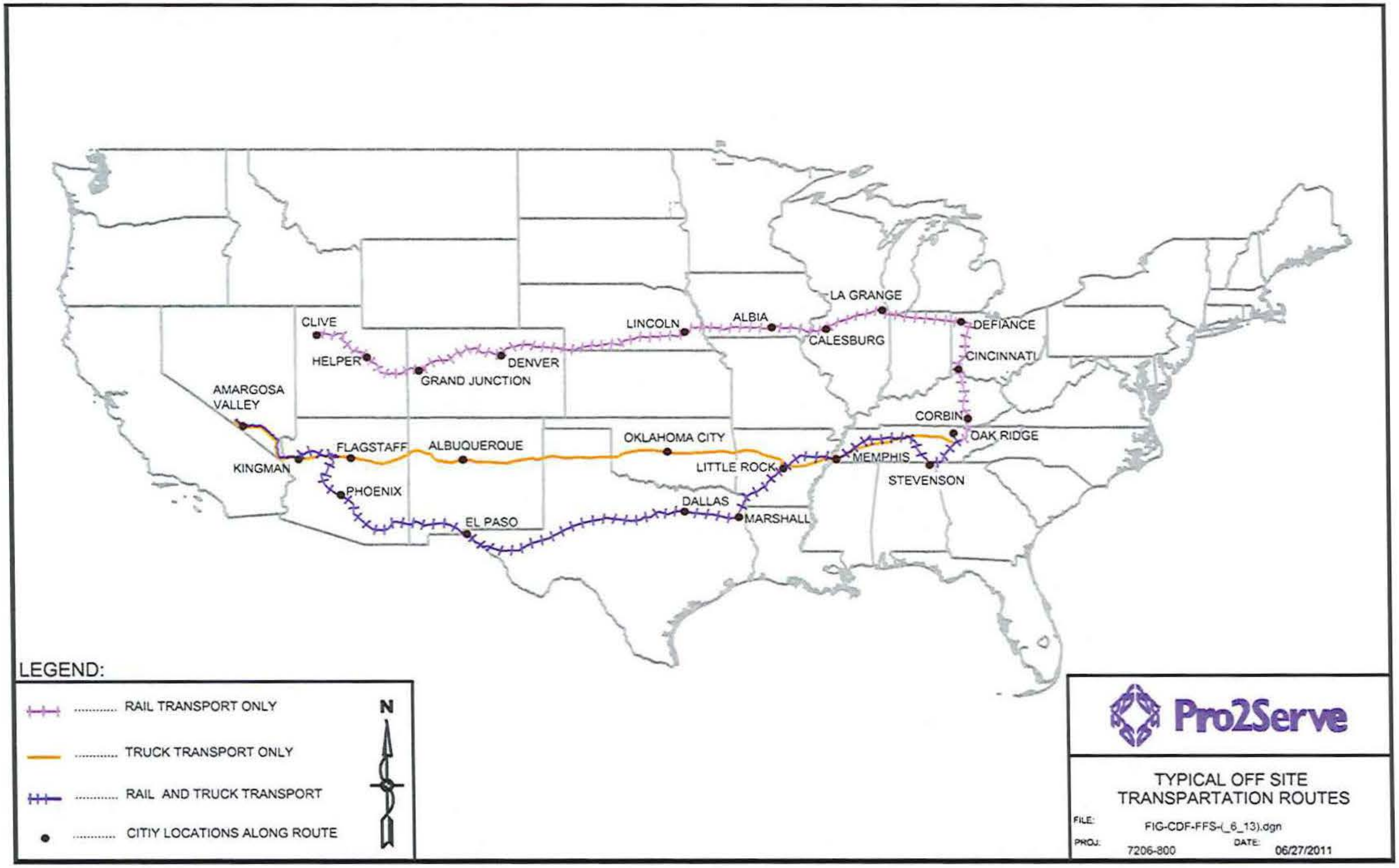

Figure 6-17. Typical Off-site Transportation Routes

For non-classified LLW and LLW/TSCA waste, this RI/FS assumes rail shipment to a transfer facility at Kingman, AZ. The assumed rail route to Kingman, AZ (see Figures 6-16 and 6-17) involves three major railroads (CSX, Union Pacific, and BNSF) and is approximately 2,402 mi (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, AR, Dallas, TX, El Paso, TX, and Phoenix, AZ. In Phoenix the cargo transfers to the BNSF line and continues north through Flagstaff, AZ before arriving in Kingman, AZ. Based on 24,168 railcar loads to Kingman, AZ, approximately 58M railcar mi (93.5M railcar km) would be traveled between Oak Ridge, TN and Kingman, AZ. The total number of actual train loads would depend on the number of railcars per train.

At Kingman, AZ, intermodals would be transferred from railcars to trucks for the trip to NNSS in Nye County, NV. The assumed truck route from Kingman, AZ to NNSS (see Figure 6-17) is approximately 214 mi (343 km) long. Based on 110,880 truckloads, approximately 23,728,320 truck mi (38,202,595 truck km) would be traveled between Kingman, AZ and NNSS. On the return trip, trucks would carry empty intermodals back to Kingman, AZ for transfer to railcars and the return trip to Oak Ridge, TN.

A 40-day round trip is assumed for rail transportation to Clive, UT or Kingman, AZ. The lease fee would be paid monthly. The number of railcars leased would change as the rate of waste generation changed.

For classified LLW waste, truck transportation is assumed for the trip from Oak Ridge, TN to NNSS. There are various approved routes for shipments of classified waste. A representative route approximately 2,056 mi (3,309 km) long was used for purposes of the RI/FS analysis. Based on 378 truckloads, approximately 777,168 truck mi (1,251,240 truck km) would be traveled between Oak Ridge, TN and NNSS.

From Oak Ridge, TN the intermodals would be loaded onto trucks and the trucks routed to Nashville, TN. From Nashville the truck would proceed thru West Memphis, AR, and Oklahoma City, OK. After passing thru Oklahoma City the truck would pass thru Vega, TX, Kingman, AZ and then arrive at Amargosa Valley, NV.

6.3.3.6 Disposal

Both the Energy*Solutions* 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 NNSS 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* for treatment/disposal as well as classified LLW shipped to NNSS for disposal would be packaged in purchased (non-returnable) intermodal containers.

Table 6-2 provides the estimated volumes that would be disposed at Energy*Solutions* 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 yd^3 for estimating purposes (NNSA 2008). In general, disposal fees at Energy*Solutions* depend on the classification of the waste (e.g., LLW or mixed waste), the type of the waste (e.g., soil, debris, etc.) and packaging. Mixed LLW/RCRA waste is assumed to undergo treatment to meet LDRs at Energy*Solutions* prior to disposal. Mixed waste treatment by macroencapsulaton is assumed for purposes of the RI/FS.

6.3.3.7 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 Sect. 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.

6.3.3.8 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, volume reduction prior to off-site shipment for disposal, and transportation by truck. If deemed beneficial and feasible, these process modifications could be incorporated into the Off-site Disposal Alternative.

6.3.3.8.1 Disposal at WCS

WCS is a waste processing and disposal company that operates a permitted 1,338-acre treatment, storage and disposal facility near Andrews, TX. WCS offers management of radioactive waste, hazardous waste, and mixed waste. Evaluation of WCS disposal alternatives utilizing a disposal fee that is comparable to Energy*Solutions* indicates highway transportation by truck could be a lower cost option than rail transport to NNSS. This assumes that the Federal disposal site at WCS is opened and bulk transport of debris and soil is allowed with non-containerized disposal. Non-containerized disposal at WCS is currently not allowed and will require approval of a license amendment.

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. Operation of the FWD facility is expected to begin in 2012.

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 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-gal 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 FWF.
  - 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 ORO to Andrews, TX is approximately 1,177 miles compared to about 1,862 for Energy*Solutions* and about 2,085 to NNSS. Consequently, transportation costs are expected to be lower for WCS. Disposal fee information is not yet available for the WCS Federal waste shipments. If disposal rates are comparable to Energy*Solutions*, WCS overall off-site disposal costs would be competitive with other off-site facilities.

6.3.3.8.2 Transportation by gondola

Currently not feasible, but possible with infrastructure upgrades, the lowest cost form of transportation of CERCLA waste to off-site disposal facilities is likely to be by rail using gondola carriers. Standard gondolas have a volume capacity of about 100 yd^3 and supergondolas have a volume capacity of about 230 yd^3. This form of transportation would require construction of a transload station at the ETTP capable of loading gondolas from dump trucks. NNSS is not accessible by rail and transload stations near NNSS are not equipped for unloading loose debris or soil from gondolas to highway transport containers. WCS can also receive waste by rail, but currently does not have the capability to unload gondolas. 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 for both is about 110 tons.

6.3.3.8.3 Volume reduction prior to off-site disposal

VR of demolition materials through the use of size reduction equipment would substantially increase bulk density of the waste and reduce the number of off-site shipments. The cost effectiveness of size reduction would depend upon the type of material, quantity of material, and contamination levels, as well as the ability to deploy VR equipment on a programmatic basis.

As-generated materials that have a relatively high bulk density such as concrete and masonry may not be cost effective to crush further because the truckload quantity would be limited by weight rather than volume. However, larger quantities of low-density materials could be shipped per truckload by size-reducing, increasing the bulk density, and increasing the quantity and weight shipped per truckload.

Heavy duty shredders, crushers, and shears are available and can be mobilized to the demolition site for VR processing of demolition debris of all kinds. For very heavy equipment and structural steel, shearing machines such as a supercompactor could be deployed although large machines such as this are stationary. Mobile shears are available, but typically not as effective for heavy steel.

If contamination levels are low enough to justify open-air processing, VR could be performed without the need of costly airborne containment systems. The cost of VR increases significantly when enclosure facilities, ventilation systems, administrative controls, and PPE are necessary for radiation safety.

VR machinery is expensive to own and to operate, therefore, cost effectiveness is increased when larger volumes of materials are available for processing. VR machines, therefore, are more likely to be deployed for larger buildings that have a significant fraction of light voluminous debris or large equipment with a high void fraction to process. For smaller buildings, VR efforts would be limited to what can be performed using excavator supplementary tools such as shears and crushers.

Appendix B describes a plan that would limit the deployment of VR equipment to large demolition projects located at ORNL, ETTP, and Y-12. Deployment of this equipment is estimated to cost about $38M to allow VR processing for about 936,736 yd^3 of material. This assumes that VR is deployed on a programmatic basis such that the same machines or facilities are used for multiple demolition projects. Uncertainty factors such as funding, project sequencing, and contracting could impact the ability to implement this approach.

Materials that would benefit the most from VR include those with lower bulk densities that would allow transportation and disposal of additional mass per truck or railcar. These materials include equipment with large void fraction, large diameter ductwork and pipe, structural steel, light framing, siding, small tanks, asphalt shingles and other roofing materials, containers, furniture, trash, and wood. Decreasing the void fraction of these materials could reduce the number of shipments required for a given mass by a large margin. The avoided shipping volume would be expected to be more than 318,439 yd^3 which is equivalent to an avoided cost of $252M in 2012 dollars. The unit cost for off-site disposal decreases from

\$909.50 to \$640.84 per yd^3 when VR processing is deployed on a programmatic basis. See Appendix B for additional information about the feasibility and cost effectiveness of deploying VR equipment for off-site disposal.

6.3.3.8.4 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 EnergySolutions 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.

7. DETAILED ANALYSIS OF ALTERNATIVES

This chapter provides detailed analysis of the No Action Alternative and the On- and Off-site Disposal Alternatives 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 requirements and community acceptance) are not addressed in the detailed analysis because these criteria rely on stakeholder participation and feedback to 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 the alternatives. This approach involves nine evaluation criteria to facilitate a comparison of the relative performance of the alternatives and provide 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, and 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 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 2010b). 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 Sect. 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 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 E presents a listing of ARARs and to be considered (TBC) guidance for the actions that would be taken to implement the On-site and Off-site 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. Substantive requirements of DOE Orders serve as TBC requirements that, when specifically incorporated in a CERCLA ROD, become enforceable.

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 groundwater 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, groundwater resources, threatened and endangered species, historical and cultural resources, noise, visual impacts, and duration of the alternative.

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 analysis 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 G. 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

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 G.

Operations costs include (1) long-distance transportation costs and fees paid to off-site disposal facilities and (2) waste handling and placement, facility maintenance, and monitoring during On-site Disposal Operations, as well as (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 2.0% according to the Office of Management and Budget (OMB) Circular No. A-94 (OMB 2012). The present worth costs are based on discounting costs given in 2012 dollars over the period of activity as determined by the project schedule.

7.1.8 State acceptance

State acceptance of alternatives will be evaluated in the proposed plan issued for public comment. 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.

7.1.9 Community acceptance

Community acceptance of alternatives will be evaluated in the proposed plan issued for public comment. 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.

7.1.10 NEPA Considerations

DOE policy (DOE 1994 and DOE 2010c) directs that CERCLA documents will incorporate NEPA values, such as analysis of cumulative, ecological, and socioeconomic impacts, to the extent practicable. This process provides decision makers with 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 that follows highlights 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 because of 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 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. Short-term effectiveness would be determined in CERCLA actions at individual sites.

7.2.1.5 Reduction of Contaminant Toxicity, Mobility, and 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 a lower overall degree of reduction in toxicity, mobility, and 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 implement a comprehensive waste disposal strategy. NEPA considerations would be determined in CERCLA actions at individual sites without the benefit of a coordinated disposal capacity. This could indirectly result in more wastes being managed in place, limited reuse of some land, 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, partially below-grade, engineered waste disposal facility (i.e., landfill) on 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. Sect. 6.2 gives a detailed description of this alternative. The On-site Disposal Alternative evaluates a proposed EMDF site in EBCV adjacent to the existing EMWMF.

7.2.2.1 Overall Protection of Human Health and the Environment (On-site)

The On-site Disposal Alternative 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 waste to meet the EMDF WAC. Placement of wastes into the EMDF would result in an overall net reduction of risks associated with environmental contamination at ORR and associated sites.

A new on-site waste disposal facility would be designed to control releases to groundwater, 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 postclosure 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, groundwater use restrictions, monitoring, and maintenance) and permanent restrictions on land use (e.g., deed restrictions).

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 the EMDF site would result from clearing, grading, construction, and operations conducted within the area designated as an Oak Ridge Environmental Research Park (ORERP). The ORERP is on 20,000 acres and encompasses the majority of the ORR (see Sect. 1.2.1 of Appendix C). Approximately half of the proposed EMDF site is located within the ORERP. Flora and fauna would be impacted by the permanent commitment of land to the disposal facility.

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.

Human-health and environmental risks from transport of waste, disposal activities, and storage would be maintained 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 Sect. 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 would comply with chemical-, location-, and action-specific ARARs and pertinent TBC guidance, including DOE Orders, with the exception of two hydrologic conditions ARARs for which a waiver would be requested (see Sect. 7.2.2.2.3 below and Sect. 3 in Appendix E). Waste treatment is not included as part of this alternative. 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 and TBC guidance provide health- or risk-based concentration or discharge limitations in various environmental media (i.e., surface water, groundwater, 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 and TBC guidance 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 environment are presented in Appendix E. The EMDF would meet these standards through control measures detailed in Sect. 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 requirements for how activities will be conducted 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. Construction of the EMDF would require modification of NT-3 (i.e., construction over a portion of NT-3 and rerouting a portion of the stream), site improvements, and potential construction of new bridges or culverts that would impact existing wetlands. Actual design considerations would determine whether and to what extent aquatic impacts would occur. In addition, 10 CFR 1022 requires that the effects of any actions taken in wetlands or a floodplain be considered and avoided wherever possible. 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 and results would be incorporated into planning and implementation, including mitigation of adverse impacts. There are currently no identified federal- or state-listed species in the proposed EMDF site area. Should any of these species be identified in the area, 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 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 onsite 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, 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, TDEC, and Nuclear Regulatory Commission (NRC) regulations.

Facility design would also incorporate TSCA requirements for a chemical landfill to accommodate wastes containing polychlorinated biphenyls at concentrations $\geq$ 50 ppm. Most TSCA requirements parallel those of RCRA. However, TSCA has a hydrogeologic requirement that the bottom of the landfill liner system be located 50 ft above the historical high water table (40 CFR 761.75[B][3]) for which a waiver would be requested. Implementation of more stringent RCRA requirements would meet or exceed the protectiveness of the TSCA requirement.

A waiver would also be requested from the TDEC requirement that restricts building a LLW disposal unit over any point where groundwater discharges to the ground surface (TDEC 1200-2-11-.17[1][h]). The conceptual design includes an extensive underdrain system, shallow upgradient French drain, and upgradient geomembrane-lined diversion ditch, and a landfill liner composed of multiple impermeable layers, which are designed to mitigate the hydrologic conditions at the site.

Waivers from the TSCA and TDEC hydrologic conditions requirements would be requested on the basis of demonstrated equivalent or superior protectiveness of the design. The EPA Region IV administrator and other representatives of the FFA parties would be consulted with respect to these requests.

Other action-specific ARARs address management of stormwater runoff, fugitive dust emissions, wastewater treatment facility operation and discharge, waste management, facility closure, and postclosure maintenance and monitoring. These requirements would all be met. Appendix E contains a more detailed discussion of ARARs for this alternative.

7.2.2.3 Long-term Effectiveness and Permanence (On-site)

For the On-site Disposal Alternative, 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 2046. 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, noncandidate waste streams, or any treatment residuals from on-ORR processing of waste to meet WAC.

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, representing an overall collective decrease in residual risk. 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 noncarcinogenic risk HI value would be less than one to a hypothetical future resident receptor living adjacent to the facility (see Appendix F) for a 1,000 year compliance period. Waste not meeting the EMDF WAC would be either shipped to off-site disposal facilities or stored by the generator pending availability of treatment or disposal options. The magnitude of residual risk for off-site disposal facilities is further addressed in Sect. 7.2.3.3.

The On-site Disposal Alternative 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 controls would be built into the EMDF and support facilities to prevent exposure to contaminants and to prevent, detect, and mitigate contaminant releases. The geomembrane liners of the landfill liner system would control releases of leachate to groundwater for their design life, which is at least 200 years. 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 secondary liner and geologic buffer would provide control of leachate release; these controls would last at least for their design live and probably for several thousand years. The long-term rate of leachate release is controlled by the infiltration rate of the robust final cover system. The landfill final cover system would prevent airborne releases and direct contact with or exposure to the waste. The thickness of the final cover system (approximately 13 ft) and the presence of the biointrusion layer would discourage inadvertent penetration by humans and would prevent or minimize damage from burrowing animals and tree roots for hundreds of years. 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 expected environmental conditions, including possible erosion and earthquakes, for the foreseeable future. Because sinkhole development presents challenges to long-term landfill integrity, site-selection criteria preclude construction of the EMDF over a rock unit susceptible to extensive karst development and collapse. 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 the EMDF and use of local groundwater. Active institutional controls would continue for an indefinite period and land use (e.g., deed) restrictions would be permanent. 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 are those impacts that may occur following closure of the EMDF. Cleared land over the 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 revegetated 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 would probably 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 growth of deep-rooted trees, but would not prevent their establishment over the long-term. Plant uptake of contaminants could become an exposure pathway if roots penetrate the cap, but these contaminants would be unlikely to impact biotic resources. The cap integrity could be degraded by uprooting of trees, possibly exposing waste that might impact fauna through contaminant release.

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 EMDF candidate site, primarily the upper reaches of NT-3 and at least one draw/ravine that flows into NT-2, would be permanent and irreversible because the landfill would be constructed over them. Neither of these areas of water flow 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 would significantly decrease following closure of the EMDF, and long-term effects are not expected to be significant. 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 the 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. The landfill is designed to resist erosion with minimal maintenance, and only extensive erosion would breach containment. The area is geomorphically stable, and extensive erosion so severe that it would breach the containment systems is unlikely. Contaminant releases to groundwater from leachate migrating from the EMDF in the long-term could also eventually impact surface water quality (see Appendix F for modeling results).

Groundwater Resource Impacts: Design, construction, and maintenance of the EMDF would prevent or minimize contaminant releases to groundwater. These control elements include a multilayer cap to minimize infiltration and biointrusion; a liner that includes synthetic and clay barriers, and a geologic buffer; and institutional controls that would include monitoring and groundwater 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 groundwater resulting from contaminants migrating from the EMDF are provided in Appendix F. PWAC analysis indicates that exposures would be acceptable at the hypothetical receptor location downgradient of the proposed EMDF site.

7.2.2.4 Short-term Effectiveness (On-site)

For the On-site Disposal Alternative, the short-term period is considered to include pre-construction investigations, construction, operation and closure of the EMDF. Operation of the on-site EMDF is expected to continue approximately 23 years through FY 2042 with closure activities completed in FY 2046. 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 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, 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 accidents. High-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 the 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 D.

A single route transportation analysis was completed for the On-site Disposal Alternative. Individual receptors (maximum exposed individuals [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 5.61×10^{-4} to 1.22×10^{-2}; 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 2.93×10^{-8} to 1.44×10^{-1}. Even though it is assumed that the majority of on-site travel will occur on a dedicated Haul Road, there would be people living and working within the zone of consideration for the risk model and thus off-link was considered in the on-site analysis. Vehicular risk (risk associated with travel/vehicles) due to emissions and accidents, resulted in an estimated 0.93 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, the 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 D 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 the 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 102 and 144 $\mu g/m^3$ for all activities. See Appendix D 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 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 (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 D provides detailed information for this assessment.

The primary risks to workers for the On-site Disposal Alternative 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 DOT and 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. Short-term effects for off-site disposal or storage of candidate waste not meeting disposal facility WAC would be as discussed for the Off-site Disposal Alternative in Sect. 7.2.3.4.

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 D).

Wetland and Aquatic Resource Impacts: A number of areas on the ORR have been identified as Natural Areas (NAs), Aquatic NAs (ANA), RAs, Aquatic RAs, Special Management Zones, Conservation Easement Areas, Cooperative Management Areas, Habitat Areas (HAs), and Potential HAs. As shown in Figure C-17 in Appendix C, the largest wetlands in or near the candidate site are on NT-3 and are included in RA-5 (Baranski 2009). 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. RA-5, the Quillwort Temporary Pond, encompasses the largest wetlands on NT-3 and two of its draws/ravines north of the Haul Road (Baranski 2009). The Quillwort Temporary Pond is so named for the occurrence of a species of quillwort (*Isoetes caroliniana*). This species is not currently a federal- or state-listed sensitive species. Wetlands along draws/ravines that feed into NT-3, including much of RA-5, and a short draw/ravine west of NT-2 would be impacted by construction. A small emergent wetland occurs farther upstream on NT-3 from RA-5. Rosensteel and Trettin (1993) classified this wetland, but did not document the presence of any sensitive species.

Bear Creek is designated as ANA-2. The ANA designation is given to aquatic areas that contain listed species, in this case the Tennessee dace (*Phoxinus tennessensis)*, listed by the state as being in need of management. The eastern reaches of Bear Creek (ANA-2) were found by Southworth, et al. (1992) to be highly impacted by contaminants from the various waste management facilities in the area, and that aquatic species diversity and populations in the area were considerably reduced as compared to the lower reaches of Bear Creek.

Appropriate runoff and siltation controls would be implemented at the EMDF site to minimize impacts to wetlands or streams outside the construction area during construction and operation. Prior to the start of the on-site action, a field wetlands delineation survey would be conducted as necessary along streams and other low-lying portions of the landfill site and adjacent areas, such as existing roadways and work support areas where construction would take place, to determine the areal extent of wetlands. Wetland boundaries would be mapped using civil land surveying techniques, the results of which would be incorporated in planning and implementation, including mitigation of adverse impacts.

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 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 bridges or 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 NT-3 and, to a lesser extent, NT-2 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. The 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 the 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 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.

Potentially contaminated runoff from the EMDF, water used for decontamination, water from the leachate detection/collection system, and other wastewater generated during the operational period would be collected and treated at the wastewater treatment facility to be constructed at the EMDF or transported to the appropriate treatment facility, as required. The potential for impact to surface water resources from the migration of contaminants from the EMDF in groundwater would be exceedingly low because of engineered and active controls, as discussed previously in Sect. 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.

Groundwater Resource Impacts: Groundwater 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 the EMDF or treatment facility. 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 groundwater resources that could result from contaminant migration from the EMDF.

Localized, small-scale reduction in average water table elevation may occur as a result of decreased infiltration caused by more rapid run-off, which could in turn lead to an increase in the number and duration of zero-flow periods in nearby streams. This impact may be mitigated by groundwater inflow from surrounding areas, as well as the release of waters collected in retention basins. Implementation of this alternative would result in few or no overall short-term impacts to groundwater resources.

Threatened and Endangered Species Impacts: Tennessee Wildlife Resources Commission Proclamation 94-16 prohibits destruction of the habitat of a state-listed species. There are currently no identified federal- or state-listed species in the proposed EMDF construction area. A field survey of the

EMDF construction site would be performed as necessary to identify threatened and endangered species within areas of potential site disturbance before construction begins. If these species were found, plans to mitigate adverse impacts would be developed and implemented in compliance with endangered, threatened, or rare species ARARs listed in Table E-2 of Appendix E.

Construction of the EMDF would impact wetlands on a draw/ravine to the west of NT-2 and along the main channel and a western draw/ravine of NT-3. These wetlands are not currently known to harbor any federal- or state-listed threatened and endangered species, or sensitive species listed as in need of management by the state. 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 NT-2 and NT-3 during the wet season. Impacts to the Tennessee dace from stream alterations would likely be small because the fish could migrate to unaffected areas in Bear Creek.

Historical and Cultural Resource Impacts: There are no known significant historical or archaeological resources within, or in the vicinity of, the conceptual design footprint of the EMDF or its support facilities. Two home sites once occupied areas adjacent to the junction of NT-3 with Bear Creek, well away from the proposed EMDF site. Little or nothing remains of these home sites except for scattered bricks and dimension stone and no relocation or salvage is anticipated to be needed. No impacts to cultural resources would be expected from construction and operation of the proposed EMDF, and mitigative actions are not expected to be necessary.

Noise Impacts: There would be a short-term increase in noise levels during construction, operation, and closure of the EMDF from sources such as earth-moving equipment, material handling equipment, waste transport vehicles, commuter traffic, and general human activity. Earth-moving and material handling equipment include bulldozers, scrapers, hydraulic excavators, and front-end loaders. Trucks used to transport wastes to the EMDF from ORR would use a dedicated haul road and avoid publicly accessible routes. The increase in noise at the 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 would be visible from BCV Road, western parts of the Y-12 plant, Chestnut Ridge, and Pine Ridge. Because BCV 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 6-13 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 2013 and FY 2014, respectively, followed by facility construction. Waste disposal operations are estimated to begin in FY 2020 for approximately 23 years until FY 2042 when facility closure activities would begin. Facility closure activities would end in FY 2046. The post-closure period after FY 2046 is addressed in the long-term effectiveness evaluation in Sect. 7.2.2.3.

7.2.2.5 Reduction of Contaminant Toxicity, Mobility, and 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; 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 would reduce the mobility of contaminants through isolation of waste in the EMDF.

7.2.2.6 Implementability (On-site)

Implementation of the 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. 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 an on-site wastewater treatment facility and other support facilities, would involve no unusual or unprecedented conditions or technologies.

While administratively feasible, implementation of the On-site Disposal Alternative would present administrative challenges. Two areas of uncertainty relative to administrative feasibility are:

- Agreement among FFA parties to select the alternative and site a new disposal facility on the ORR.
- Availability of sufficient funds for both construction of the on-site EMDF and environmental remediation of ORR and associated CERCLA sites anticipated to generate waste.

The FFA provides a specific framework for discussion and resolution of CERCLA issues among DOE, TDEC, and EPA. This forum supports long-term coordination among FFA parties.

DOE O 435.1 (formerly DOE O 5820.2A) requires that a performance assessment be used to demonstrate the performance objectives in the Order for disposal of radioactive wastes are met. For CERCLA sites, it is DOE policy to use the CERCLA process to demonstrate attainment of these human health and environmental protection performance objectives.

Construction of a disposal facility at the EMDF site would require moving the 229 security boundary for Y-12. The proposed location of the EMDF 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.

The southern part of the proposed EMDF 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 is selected, coordination of EMDF activities with planned UPF project activities, including a modification to the ARAP, would be required and are implementable.

All construction related activities would be conducted on-site and would not require permits; however, any substantive provisions of any permits (e.g., ARAP) that would be required would be considered ARARs. The EMDF would be designed to meet all substantive requirements for a RCRA hazardous waste landfill and a TSCA chemical waste landfill (except for the 50-ft buffer requirement for which a waiver would be requested as described in Appendix E). NRC licensing would not be required because DOE is exempt from NRC licensing requirements; however the EMDF would be designed to meet substantive NRC LLW landfill requirements per TDEC implementing regulations at Rules of the TDEC 1200-2-11 et seq. that are identified as ARARs with one exception. A waiver from the requirement that the hydrogeologic unit used for disposal shall not discharge groundwater to the surface within the disposal site would be requested as described in Appendix E.

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. The administrative feasibility of off-site disposal, including the issue of state equity, is discussed in greater detail in Sect. 7.2.3.6.

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 the EMWMF, have been constructed and are operating today, demonstrating their viability. Construction and operation of the EMDF would involve no unusual or unprecedented conditions or technologies.

Future remedial actions at the EMDF should not be required because of waste treatment by generators as necessary to meet the disposal facility WAC, the protectiveness provided by implementation of the disposal facility WAC (see Appendix F), and the high level of isolation 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 leachate to groundwater or erosion of the cap and exposure of the waste to the environment.

All release pathways at the EMDF would be monitored through leachate collection, leachate detection monitoring, surface water and groundwater monitoring, and physical inspection of external EMDF conditions. Should releases to groundwater go undetected, groundwater in the immediate vicinity of the EMDF could be contaminated and minor releases to Bear Creek could occur. The actual risk of exposure from such a release would be low.

Services and materials required for EMDF construction, off-site disposal, treatment, storage, and supporting operations would be available for implementation of this alternative. The 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 bids could be expected for procurements necessary to develop the 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 Sect. 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. 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 cost for the On-site Disposal Alternative at the proposed EMDF site in EBCV is \$708M (2012 dollars) and \$499M (present worth). The cost estimate is based on a conceptual design that yields an approximate landfill waste disposal capacity (i.e., air space volume) of 2.5M[15] yd^3.

The estimated total project cost of \$708M in 2012 dollars correlates to:

[15] The EMDF conceptual design of 2.5M yd^3 includes approximately 28% uncertainty (see Chapter 2 and Appendix A).

- An estimated cost of $283 per unit volume of waste disposal capacity for the EMDF in 2012 dollars ($708M divided by 2.5M yd^3 disposal capacity = $283 per yd^3 disposal capacity).
- An estimated cost of $323 per unit volume of as-generated waste for the EMDF in 2012 dollars ($708M divided by 2.19M[16] yd^3 as-generated waste = $323 per yd^3 as-generated waste).

The cost estimates were prepared using the methodology described in Sect. 7.1.7 and the technical scope and assumptions for the proposed EMDF site are described in Chapter 6. Appendix G provides further description of the total project costs and assumptions for the candidate site.

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 the 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 the 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.

There would be no long-term socioeconomic impacts associated with the On-site Disposal Alternative since the small workforce required to construct, operate and close the 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 candidate site lies partially within the ORERP, which includes industrial areas, NAs, ANAs, RAs, field research areas, and other areas designated for their unique natural attributes. Construction and operation of the EMDF would require clearing land within the ORERP that could result in short-term effects on ANA-2 and adjacent activities such as research, and would impact most of RA-5 which is situated on NT-3. 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 the 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, while forested and undeveloped, is adjacent to a brownfield area 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 its co-location with a brownfield area, other advantages for the proposed EMDF site include the lack of public access and visibility and the presence of existing infrastructure. Location of the EMDF at this site maintains the waste disposal facilities in an area that is already monitored.

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 C-1 in Appendix C). The EBCV site is located in Zone 3, with an agreed upon future land use goal of "controlled industrial use" stated in the BCV Phase I ROD. Construction of a disposal facility at the EBCV site 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 site would remain under DOE control within DOE ORR boundaries for the foreseeable future.

[16] The as-generated waste volume includes approximately 28% uncertainty (see Chapter 2 and Appendix A).

The approximate areas impacted by the EMDF at the proposed site and corresponding conceptual design capacity are summarized in Table 7-1. 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.). 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.

Table 7-1. EMDF Area of Impact and Permanent Committed Area for the EBCV Site

Description	EBCV
Approximate total area impacted during construction, operations, and final closure	92 acres
Approximate area permanently committed after closure	60 to 70 acres
Approximate landfill disposal capacity	2.5M yd^3

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 and 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 kept permanently cleared of trees, representing long-term impact on the direct use of that land.

Environmental Justice Impacts: No environmental justice impacts have been identified 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.

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 7-1). Additionally, 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. Transportation, construction, operation, closure, and long-term institutional controls for the 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 the EMDF would not result in any significant cumulative impacts to the environment if BMPs, including engineering and administrative controls, are used. Incremental impacts to air quality, traffic, and noise levels from construction and operation of the 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. Groundwater would not be used for construction or operation of the 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 EBCV and result in a net loss of forested area. The EMWMF as well as old waste disposal facilities are located in EBCV, adjacent to the proposed EMDF site. Environmental impacts from the old 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 EBCV 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 would result from the commitment of land within the permanent institutional control boundary, 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. Removal of contamination and waste from these sites may result in positive long-term environmental effects by reducing the potential for exposure to and migration of contaminants, although 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 LLW-mixed 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 long-term monitoring and maintenance over the long term. However, the co-location of the EMDF with the EMWMF and former waste management sites (i.e., BCBG, BY/BY, Oil Landfarm, etc.) in one area aggregates the post-closure care and monitoring efforts.

The potential for long-term cumulative impacts at the off-site disposal facilities from the presence of ORR wastes that cannot meet the EMDF WAC are expected to be minimal. These wastes would represent a 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.

7.2.3 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 Sect. 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* and NNSS facilities are located in isolated, arid environments with few 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. The considerable transportation distances required for off-site disposal would result in an increased potential for accidents that could result in injuries, fatalities, or contaminant releases. Transportation risks from both vehicular accidents and exposure to contaminants are detailed in Sect. 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 E). 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. 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), Rules of the TDEC 1200-1-11-.03 and .04, and DOE Orders 435.1 and 460.1C. DOE requirements to characterize and certify wastes before transport off-site would be triggered. Because DOE Order 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.

The off-site facilities used for this alternative would be 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 nonsubstantive 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.

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, noncandidate waste streams, or any treatment residuals from waste processing required to meet 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,* the facility has waste treatment capabilities and the WAC allows for receipt of untreated waste. It is assumed for the On-site Disposal Alternative that the Energy*Solutions* 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 and NNSS are both located in an arid environment, isolated from population centers. Low long-term risk to human health results from their remote location, very low precipitation, and greater depth to groundwater. The Energy*Solutions* and NNSS facilities use conventional, durable designs and materials to effectively isolate the waste. The arid climate at both 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. Accordingly, reliance on specialized or unproven designs or procedures is not necessary to protect human health and the environment over the long term. 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 Sect. 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 D.

For the transportation risk analysis, several routes were evaluated: a route for classified waste that travels by truck to the 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, UT for disposal. And a third route 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, AZ where it would be transferred to truck to make the final travel to the NNSS for disposal. 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 1.06×10^{-3} to 7.53×10^{-2}; 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 1.58×10^{-4} to 3.01×10^{-1}. Vehicular risk (risk associated with travel/vehicles) due to emissions and accidents, resulted in an estimate of 25.3 total incidents of illness, trauma, or death. 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 the 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 D 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, AZ 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 D.

Duration of the Off-site Disposal Alternative: For the Off-site Disposal Alternative, waste disposal operations are estimated to begin in FY 2020 after EMWMF reaches maximum capacity and continue through FY 2042, a duration of approximately 23 years.

7.2.3.5 Reduction of Contaminant Toxicity, Mobility, and Volume by Treatment (Off-site)

Although the Off-site Disposal 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 could 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,* the facility has waste treatment capabilities and the WAC allows for receipt of untreated waste. It is assumed for the Off-site Disposal Alternative that the Energy*Solutions* receiving facility would provide treatment of the waste prior to disposal to reduce the potential for contaminant mobility. Transportation and disposal actions considered in this alternative would have no effect on toxicity or mobility through treatment.

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.

Review of state and federal regulations (addressed in Sect. 7.2.3.2 and Appendix E) indicates that there are no provisions that would prohibit shipment of waste derived from ORR sites to the receiving 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 Order 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, Hoover Dam, 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; however, the likelihood is considered minimal.

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 2008).

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* 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 23 years at both facilities. 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 cost for the Off-site Disposal Alternative is \$1.992 billion (B) (2012 dollars) and \$1.408B (present worth). The cost estimate is based on the estimating methodology described in Sect. 7.1.7 and the technical scope and assumptions described in Chapter 6.

The estimated total project cost of \$1.992B in 2012 dollars correlates to an estimated cost of \$910 per unit volume of as-generated waste in 2012 dollars (\$1.992B/2.19M[17] yd^3 as-generated waste = \$910 per yd^3 as-generated waste).

Fuel surcharges that may be incurred during transportation of the waste to off-site disposal facilities are not included in the estimate. Also, 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).

Appendix G provides a detailed description of the total project cost 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. Outside contractors rather than local manpower would likely transport wastes to off-site disposal facilities. 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.

[17] The as-generated waste volume includes approximately 28% uncertainty (see Chapter 2 and Appendix A).

Environmental Justice Impacts: No environmental justice impacts have been identified 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 off-site disposal of waste.

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 nonrenewable energy resources at the disposal sites; 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 shipment to NNSS and LLW/RCRA waste shipment to Energy*Solutions* 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.

7.3 COMPARATIVE ANALYSIS OF ALTERNATIVES

This comparative analysis evaluates the relative ability of the three alternatives to accommodate disposal of future generated CERCLA waste with respect to the evaluation criteria described in Sect. 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 tradeoffs to be made in selecting the preferred alternative.

Table 7-2 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 less costly than either of the action alternatives. The On-site Disposal Alternative would be less costly than the Off-site Disposal Alternative, but an additional area of 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 due to the arid climate, but long-distance waste transportation in the short-term could result in more accidents, causing injuries or fatalities.

Table 7-2. Comparative Analysis Summary for Disposal of ORR CERCLA Waste

Evaluation criterion	No Action Alternative	On-site Disposal Alternative	Off-site Disposal Alternative
Overall protection of human health and the environment	If more wastes were managed in place, protection would depend on long-term institutional controls at multiple sites.	Protective because of waste being disposed in a landfill designed for site-specific conditions. More protective in the short term because of decreased transportation risks.	Protective because of waste being disposed in a landfill designed for site-specific conditions. More protective than the On-site Disposal Alternative in preventing releases on the ORR because waste is permanently removed. Less protective in the short term because of increased transportation risks.
Compliance with ARARs	No action; therefore, no ARARs apply. ARARs for remedial actions at individual sites are specified in separate CERCLA documents. The potential exists for increased interim waste storage at individual waste sites.	Would comply with all but two ARARs and pertinent TBC guidance. CERCLA waivers would be requested for two hydrologic condition ARARs on the basis of equivalent protectiveness provided by landfill design.	Would comply with all ARARs and pertinent TBC guidance. Facility compliance with licenses and permits would be determined prior to transport.
Long-term effectiveness and permanence	May not meet the RAO to facilitate timely cleanup of ORR and associated facilities.	Provides effective long-term protectiveness. Waste disposed must meet receiving facility WAC developed based on risk criteria. Protectiveness at the EMDF could potentially diminish more rapidly than for off-site disposal at Energy*Solutions* or NNSS, both of which are located in areas with more arid climates and lower water tables than the ORR. Permanent loss of wildlife habitat or future land use at the EMDF location may be at least partially offset by the cleanup and release of individual ORR remediation sites.	Provides highly effective long-term protection for waste meeting the facility WAC. Land use at Energy*Solutions* and NNSS is already dedicated to waste disposal. ORR waste volume represents a relatively small portion of the total waste inventory. The off-site facility locations in an arid environment reduces the likelihood of contaminant migration and fewer receptors exist in the vicinity of Energy Solutions and NNSS than near the ORR.

Table 7-2. Comparative Analysis Summary for Disposal of ORR CERCLA Waste (Continued)

Evaluation criterion	No Action Alternative	On-site Disposal Alternative	Off-site Disposal Alternative
Short-term effectiveness	If more wastes were managed in place because no coordinated disposal option is available, less aggressive actions at remediation sites would cause fewer adverse short-term effects. May not meet the RAO to facilitate timely cleanup of ORR and associated facilities.	Risks to workers and the public at remediation sites and disposal facilities would be similar for the On- or Off-site Disposal Alternative. Some adverse environmental effects would result from construction and operation of the EMDF but would be controlled or mitigated per regulatory requirements and engineering practice. Environmental impacts and permanent loss of forest habitat and wetland would result from siting the EMDF at EBCV.	Risks to workers and the public at remediation sites and disposal facilities would be similar for the On- or Off-site Disposal Alternative. Transportation risks would be greater than for the On-site Disposal Alternative. Only minor, incremental environmental effects would occur at the existing off-site facilities.
Reduction of toxicity, mobility, or volume through treatment	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.	Mobility of contaminants would be reduced through isolation of waste in the EMDF. Any ex situ treatment to meet the facility WAC could reduce toxicity, mobility, or volume.	Mobility of contaminants would be reduced through isolation of waste at the off-site disposal facilities. Any ex situ treatment to meet the disposal facility WAC could reduce toxicity, mobility, or volume.
Implementability	No implementation required.	Administrative requirements would be extensive but are considered achievable. 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.	Administrative and technical requirements are implementable. 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 are not likely, but could challenge implementation of the alternative. The On-site Disposal Alternative provides a greater level of certainty than the Off-site Disposal Alternative that long-term disposal capacity would be available.

Table 7-2. Comparative Analysis Summary for Disposal of ORR CERCLA Waste (Continued)

Evaluation criterion	No Action Alternative	On-site Disposal Alternative	Off-site Disposal Alternative
Cost	No direct cost; however, efficiencies of consolidation and economies of scale would not be realized.	Estimated total project cost is $708M (2012 dollars) and $499M (present worth). Cost per yd^3 as-generated waste is $323 (2012 dollars)	Estimated total project cost is $1.992B (2012 dollars) and $1.408B (present worth). Cost per yd^3 as-generated waste is $910 (2012 dollars)
NEPA Considerations	If more wastes were managed in place because no coordinated disposal option is available, limited reuse of some land and greater residual risk at individual sites could result.	Cleanup of remediation sites and disposal in an on-site facility could result in a cumulative net benefit. While there are short-term environmental impacts associated with construction and operation of the EMDF, benefits, especially socioeconomic benefits, could be greater than for the Off-site Disposal or No Action Alternatives if the On-site Disposal Alternative encouraged more aggressive remediation at individual sites.	Cleanup of remediation sites could have a cumulative benefit on the ORR. Potential socioeconomic benefits from job creation, cleanup and reuse could be greater than for no action but would be less than for the On-site Disposal Alternative. Incremental environmental impacts due to waste transport would be minimal. Disposal of ORO waste at off-site facilities would have minor or no adverse cumulative effects at the disposal sites since those sites already exist, receive waste from other facilities, and would not require expansion.

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.

Selection of either the On- or Off-site Disposal Alternative 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 Disposal Alternative would be more effective in preventing potential future releases on the ORR because most of the CERCLA waste would be disposed of in off-site permitted facilities.

Both the On-site and Off-site Disposal Alternatives would be protective of human health and the environment. The On-site 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 would be protective through compliance with the WAC for each of the off-site existing permitted facilities.

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 would increase for the Off-site Disposal Alternative.

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. On- and Off-site Disposal Alternatives would support individual CERCLA actions and meet most of the ARARs, with the exceptions noted below.

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.

The On-site Disposal Alternative would be designed to meet all ARARs and TBC guidance with the exception of the TSCA hydrologic requirement that specifies a buffer of at least 50 ft above the historical high water table and TDEC hydrologic requirement to not have any groundwater to surface discharge points within the disposal unit footprint. An "equivalent protectiveness" waiver of these ARARs would be requested as described in Appendix E.

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

Bothe on-site and off-site disposal would be effective and permanent in the long-term. The Off-site Disposal Alternative offers the greatest level of long-term protectiveness because the climate and hydrogeology offer the highest potential for permanence of containment. 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 No Action Alternative and the lack of a coordinated disposal capacity may not optimally meet the RAO to facilitate timely cleanup of ORR and associated sites.

Preventing exposure to the contaminants placed in the EMDF over the long term depends on success of the facility's waste containment features, characteristics of waste placed in the EMDF, and institutional controls. The multilayer cover system would be designed to decrease migration of liquids, 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. 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. While the cover remains in place, migration of contaminants into groundwater and surface water is the only credible pathway for exposure. PWAC analysis indicates that exposures would be acceptable at the hypothetical receptor location downgradient of the proposed EMDF site (see Appendix F).

The Off-site Disposal Alternative also relies on engineering and institutional controls at the off-site disposal facilities to prevent inadvertent intrusion, including engineered barriers to intrusion and waste migration. Off-site disposal of waste at Energy*Solutions* and NNSS in the long-term may be more reliable at preventing exposure than on-site disposal on the ORR. Energy*Solutions* and NNSS are in an arid environment that reduces the likelihood of contaminant migration or exposure via groundwater or surface water pathways. Fewer receptors exist in the vicinity of Energy*Solutions* and NNSS than on the ORR.

Long-term effects at the proposed EMDF site would consist of impacts to biota and habitat, primarily by the loss of forest cover and stream and wetland impacts.

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 but does not include the subsequent period of institutional controls.

On-site disposal presents the greatest challenges to the Oak Ridge area during remediation. Construction and operation of the EMDF 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.

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 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 7-3 contains a summary of the calculated risks for the On-site and Off-site Disposal 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. A breakdown of the risks for the individual routes travelled, accident versus routine travel, and fatal/non-fatal statistics is provided in Appendix D.

Table 7-3. Comparison of Risk Factors for On-site and Off-site Disposal Alternatives, All Shipments

Receptor	On-site Disposal Alternative		Off-site Disposal Alternative	
	Radiological Risk Range	Vehicle-related Risk	Radiological Risk Range	Vehicle-related Risk
Maximum Exposed Individuals	5.61×10^{-4} to 1.22×10^{-2}	0.93	1.06×10^{-3} to 7.53×10^{-2}	25.3
Collective Population	2.93×10^{-8} to 1.44×10^{-1}		1.58×10^{-4} to 3.01×10^{-1}	

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. 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 the EMDF would cause local short-term environmental effects typically associated with a large construction project. 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. The potentially sensitive HA at the EMDF site that would be impacted includes a portion of the NT-3 stream and wetlands.

Other potential short-term effects from EMDF construction and operation include the probable slight degradation of surface waters by increased sediment and runoff in NT-2 and NT-3 at the EBCV site. 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.

Lack of a coordinated disposal capacity may hinder remediation. As a result, the No Action Alternative may not meet the RAO to support timely cleanup of ORR and associated sites.

The duration of remedial activities for the No Action Alternative would depend on CERCLA actions selected for the individual remediation sites. The duration of disposal activities for the On- and Off-site

Disposal Alternatives would be similar based on generation schedules at the remediation sites described in Chapter 2 and Appendix A.

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 or at the receiving facility (the Energy*Solutions* facility has 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.

7.3.6 Implementability

All three 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 either the On- or Off-site Disposal Alternative are readily available.

Development of an on-site EMDF 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, 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 both the On- and Off-site Disposal Alternatives, wastes that do not meet the WAC for any disposal facility would be stored in compliant facilities, and could 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 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 the On- and Off-site Disposal Alternatives is the requirement for construction of the EMDF versus the long-distance transport requirements for off-site disposal. Both are readily implementable, but construction of the EMDF is more complex.

Services and materials needed for construction and operation of the EMDF or for shipment and disposal of waste under the Off-site Disposal Alternative are readily available. Disposal capacity is available for waste that would not meet on-site facility WAC under the On-site Disposal Alternative 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 is considered minimal at both representative facilities, NNSS (a DOE facility) and Energy*Solutions* (a non-DOE, commercial facility). However, given the 30 years of anticipated CERCLA waste generation, the On-site Disposal Alternative provides a greater level of certainty than the Off-site Disposal Alternative 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 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 2.8 times that of the On-site Disposal Alternative. Estimated total project cost for the On-site Disposal Alternative at the proposed EMDF site in EBCV is $708M (2012 dollars) and $499M (present worth). For the Off-site Disposal Alternative, the estimated total project cost is $1.992B (2012 dollars) and $1.408B (present worth).

These estimated total project costs in 2012 dollars correlate to an estimated $323per yd^3 as-generated waste (2012 dollars) for the On-site Disposal Alternative and an estimated cost of 910 per yd^3 as-generated waste (2012 dollars) for the Off-site Disposal Alternative, with the same assumed uncertainty of 28% in waste volumes for each alternative.

Fuel surcharges that may be incurred during transportation of the waste to off-site disposal facilities are not included in the Off-site Disposal Alternative cost estimate. Also, rail transportation, which is approximately 11% less expensive than truck transport, is assumed for the majority of shipments.

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 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 Alternative 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 location adjacent to existing waste disposal sites minimizes the potential impact of the presence of a new facility on future use of the area. 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 On-site Disposal Alternative 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 immediate area surrounding the EBCV site is currently unpopulated. The nearest residential area is approximately 0.84 mi north of the EBCV site.

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 On-site Disposal Alternative would permanently alter the proposed EMDF location. The cost differential between the 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 may not support the RAO of facilitating the timely cleanup or release of portions of ORR and associated facilities for beneficial use. The success of the No Action Alternative in meeting the other RAOs would depend on the individual decisions made for each CERCLA remediation site. Overall remediation and disposal costs and local socioeconomic benefits could be lower if less aggressive remedial actions result from the lack of a coordinated disposal program. 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 CERCLA and NEPA evaluation criteria, the differences between on-and off-site disposal are minor. These two alternatives are differentiated by five key criteria, (1) long-term effectiveness, (2) short-term transportation risk, (3) availability of services and materials, (4) land use, and (5) cost.

Long-term Effectiveness: Both the On-site 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. 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 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 Transportation Risk: 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 both alternatives. For the Off-site Disposal Alternative, there would be additional radiological risk and vehicle-related risk due to transportation of the waste to off-site locations. Waste may be transported off-site by rail, truck, or a combination. Comparative analysis of risk incurred by these scenarios demonstrates that rail transport results in a significantly lower health risk overall to MEIs and collective populations than does truck transportation of the waste, both from radiation exposure risk and vehicular accident risk.

Availability of Services and Materials: Currently services and materials needed for pre-construction investigations, construction and operation of the On-site Disposal Alternative and transportation and disposal capacity for the Off-site Disposal Alternative are available. No impediments to continued operation for the On-site Disposal Alternative are likely to arise. State equity issues and reliance on off-site facilities introduce an 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.

Land Use: Construction of the EMDF would result in significant environmental impacts, mainly arising from rerouting a portion of a tributary and permanent loss of wetlands and forested habitat. The proposed EMDF site, while forested and undeveloped, is adjacent to a brownfield area where the existing EMWMF and former waste disposal sites are located. Land use at the on-site EMDF would be restricted in perpetuity. Land at off-site facilities is already committed to waste disposal.

Cost: The estimated project cost for the Off-site Disposal Alternative ($1.992B [2012 dollars] or $1.408B [present worth]) is approximately 2.8 times the estimated project cost of the On-site Disposal Alternative ($708M [2012 dollars] or $499M [present worth]).

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APPENDIX A

WASTE VOLUME ESTIMATES AND WASTE CHARACTERIZATION DATA

CONTENTS

FIGURES

TABLES

ACRONYMS

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
LLW	low-level (radioactive) waste
M	million
ORNL	Oak Ridge National Laboratory
RCRA	Resource Conservation and Recovery Act of 1976
RI/FS	Remedial Investigation/Feasibility Study
TSCA	Toxic Substance Control Act of 1976
UCL	upper confidence limit
WAC	Waste Acceptance Criteria
WACFACS	Waste Acceptance Criteria Forecast Analysis Capability System
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" waste volume estimate was used to predict "as-disposed" waste volumes for the On-site Disposal Alternative and as the basis for waste shipment analysis in the Off-site Disposal Alternative.

Figure A-1 and Figure A-2 present the base as-generated waste volume estimate for Fiscal Year (FY) 2012 - FY 2042 by material type and by waste type, respectively. The base as-generated waste volume estimate includes no applied uncertainty. Table A-1 shows the base as-generated waste volume estimate for FY 2012 - FY 2042 by material type, waste type, and year.

Table A-2 provides the total base as-generated waste volume estimate for FY 2012 - FY 2042 by project, material type, and waste type, with subtotals for the following timeframes:

- FY 2012 - FY 2020 (FY 2020 is the estimated year when the Environmental Management Waste Management Facility [EMWMF] reaches maximum capacity based on a 28% uncertainty allowance[1] added to the as-disposed volume estimate as described below and in Sect. 2.2.2 of the RI/FS.
- FY 2020 - FY 2042 (estimated timeframe for operation of 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 as-generated volume estimate (FY 2020 - FY 2042) with 28% uncertainty[1] that is the basis for the waste shipments for the Off-site Disposal Alternative. Approximately 2.19 million (M) total yd^3 of waste would be shipped for off-site disposal under this alternative. The uncertainty amount applied is equivalent to that used in the as-disposed wastes volume estimate for the On-site Disposal Alternative.

1.2 "AS-DISPOSED" WASTE VOLUME ESTIMATE

Prediction of "as-disposed" waste volumes for the RI/FS used a methodology described in Sect. 2.2.2 of the RI/FS that started with the "as-generated" waste volume estimate.

Table A-4 shows the "as-disposed" waste volume estimate per year through FY 2042 and delineates the volume estimate by debris, waste used as fill, clean fill, and a 28% uncertainty allowance added to total waste plus clean fill. Based on the as-disposed waste volume estimate, the On-site Disposal Alternative assumes maximum capacity of EMWMF (2.18M yd^3) is reached and a new Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) waste disposal facility becomes operational in FY 2020. Table A-4 also shows the estimated dates when new disposal facility cells begin operation and reach capacity, when CERCLA waste disposal is complete, and when disposal facility closure begins.

[1] The actual applied uncertainty is 27.9798%; 28% is a rounded value.

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 Sect. 1.3.1.1 through Sect. 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.

[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.

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, 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.

For these WLs:

- In Step 3 of Data Collection (see Sect. 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 Cij in Step 1 in Sect. 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 D) 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 $j = 1\ to\ m$ 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 $j = 1$ *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.

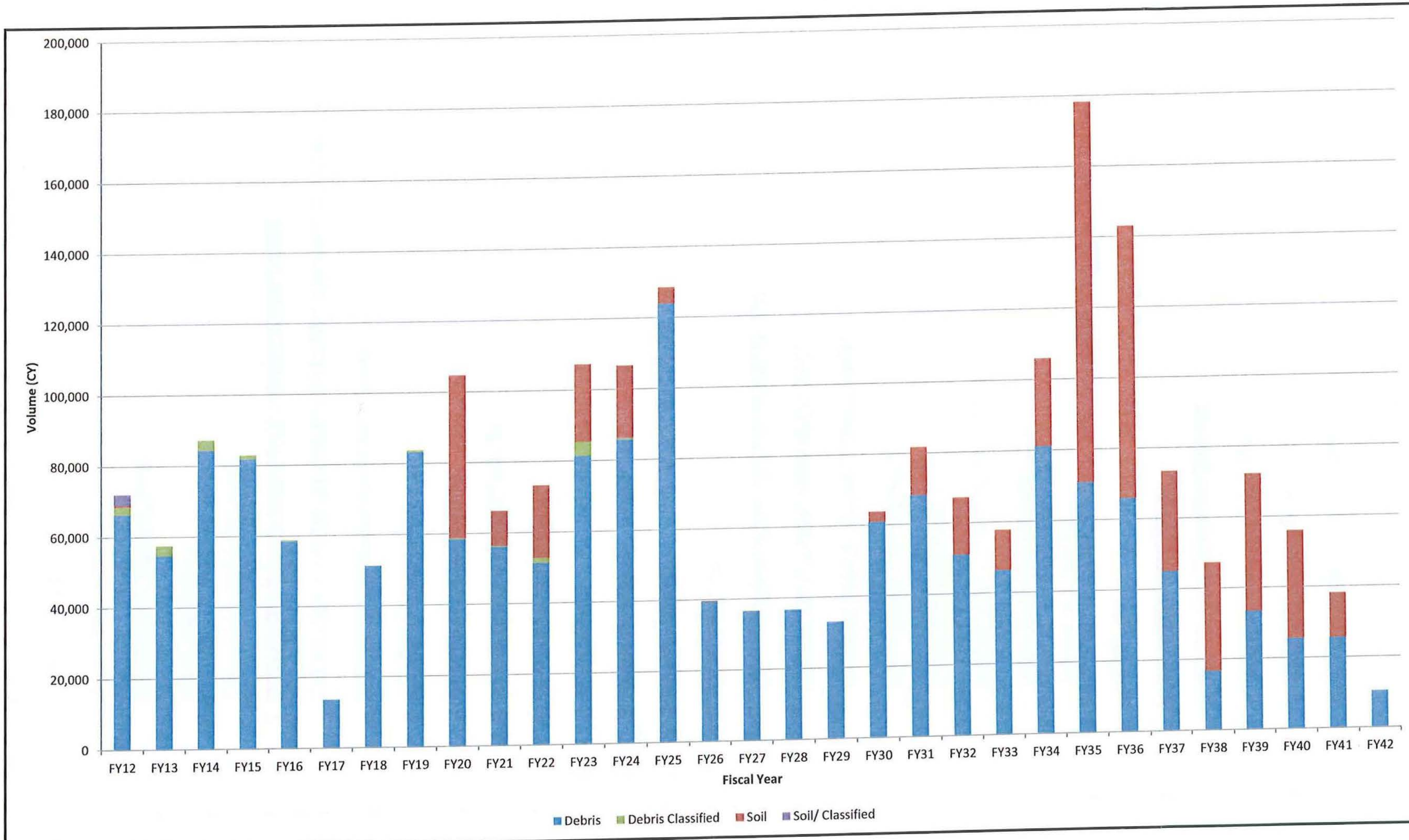
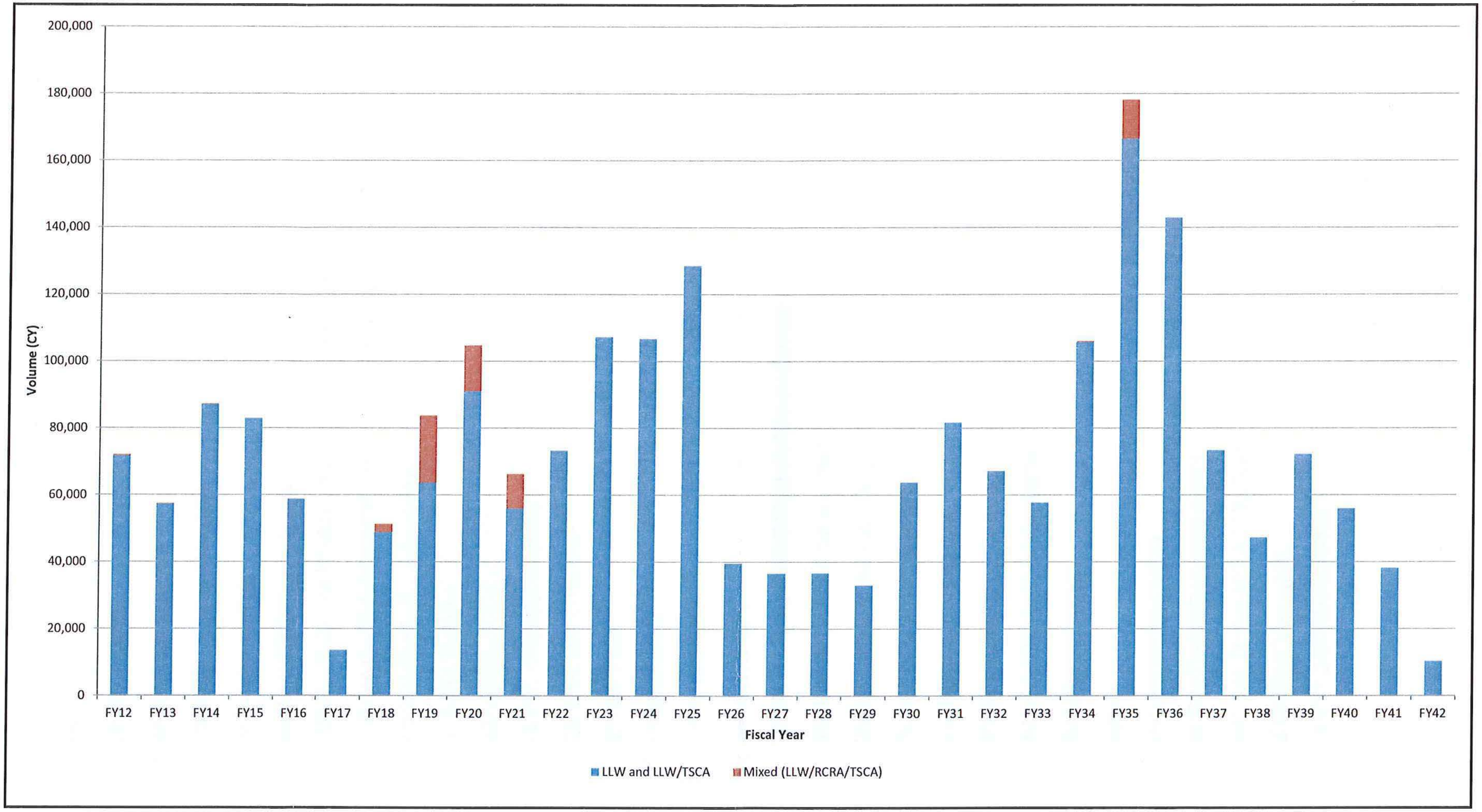


Figure A–1. Base As-generated Waste Volume Estimate by Material Type (FY 2012-FY 2042)



LLW = low-level (radioactive) waste
RCRA = Resource Conservation and Recovery Act of 1976
TSCA = Toxic Substance Control Act of 1976

Figure A–2. Base As-generated Waste Volume Estimate by Waste Type (FY 2012-FY 2042)

Table A-1. Base As-generated Waste Volume Estimate (FY 2012-FY 2042)

Waste Type	Material Type	As-generated Waste Volume Estimate (yd^3)										
		FY2012	FY2013	FY2014	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020	FY2021	FY2022
LLW (includes LLW/TSCA)	Debris	65,963	54,494	84,136	81,739	58,482	13,647	48,769	63,634	44,961	46,064	51,324
	Debris Classified	2,241	2,781	2,904	1,166	314						1,506
	Soil	500								45,990	9,924	20,436
	Soil Classified	2,992										
	TOTAL	**71,696**	**57,275**	**87,040**	**82,905**	**58,796**	**13,647**	**48,769**	**63,634**	**90,951**	**55,988**	**73,266**
Mixed (LLW/RCRA/TSCA)	Debris	354	200	200				2,459	19,574	13,449	10,044	
	Debris Classified							64	508	342	261	
	Soil											
	TOTAL	**354**	**200**	**200**				**2,523**	**20,082**	**13,791**	**10,304**	
TOTAL		**72,050**	**57,475**	**87,240**	**82,905**	**58,796**	**13,647**	**51,292**	**83,716**	**104,743**	**66,292**	**73,266**

Waste Type	Material Type	As-generated Waste Volume Estimate (yd^3)										
		FY2023	FY2024	FY2025	FY2026	FY2027	FY2028	FY2029	FY2030	FY2031	FY2032	FY2033
LLW (includes LLW/TSCA)	Debris	81,429	85,689	123,867	39,428	36,454	36,647	33,000	60,845	68,093	51,018	46,358
	Debris Classified	3,942	500									
	Soil	21,851	20,479	4,634	149	86			2,923	13,599	16,164	11,399
	Soil Classified											
	TOTAL	**107,221**	**106,668**	**128,501**	**39,576**	**36,540**	**36,647**	**33,000**	**63,768**	**81,692**	**67,182**	**57,757**
Mixed (LLW/RCRA/TSCA)	Debris	5	39	39	39	23						
	Debris Classified											
	Soil											
	TOTAL	**5**	**39**	**39**	**39**	**23**						
TOTAL		**107,226**	**106,707**	**128,540**	**39,615**	**36,563**	**36,647**	**33,000**	**63,768**	**81,692**	**67,182**	**57,757**

Waste Type	Material Type	As-generated Waste Volume Estimate (yd^3)									
		FY2034	FY2035	FY2036	FY2037	FY2038	FY2039	FY2040	FY2041	FY2042	Total FY12-FY42
LLW (includes LLW/TSCA)	Debris	81,116	70,687	65,954	45,055	16,602	33,415	25,524	25,558	10,339	1,650,291
	Debris Classified										15,354
	Soil	24,613	95,816	76,964	28,319	30,698	38,805	30,456	12,622		506,426
	Soil Classified										2,992
	TOTAL	**105,729**	**166,503**	**142,918**	**73,374**	**47,300**	**72,220**	**55,980**	**38,180**	**10,339**	**2,175,063**
Mixed (LLW/RCRA/TSCA)	Debris										46,424
	Debris Classified										1,175
	Soil	263	11,712								11,975
	TOTAL	**263**	**11,712**								**59,574**
TOTAL		**105,992**	**178,215**	**142,918**	**73,374**	**47,300**	**72,220**	**55,980**	**38,180**	**10,339**	**2,234,637**

LLW = low-level (radioactive) waste
RCRA = Resource Conservation and Recovery Act of 1976
TSCA = Toxic Substance Control Act of 1976

Table A-2. Base As-generated Waste Volume Estimate by Project (FY 2012- FY 2042)

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 (FY12-42) (yd^3)
		FY12-20 (EMWMF)	FY20-42 (EMDF)	Total LLW	FY12-20 (EMWMF)	FY20-42 (EMDF)	Total Mixed			
2026 Complex	Debris		10,012	10,012					10,012	**10,012**
2528 Complex	Debris		484	484					484	**484**
3019 Ancillary Facilities D&D	Debris		783	783					783	**783**
3019A D&D	Debris		61,891	61,891					61,891	**61,891**
3525 Complex	Debris		7,659	7,659					7,659	**7,659**
9206 Complex	Debris		13,856	13,856					13,856	**13,856**
9212 Complex	Debris		103,770	103,770					103,770	**103,770**
Alpha Buildings Legacy Material Disposition	Debris		34,254	34,254					34,254	**34,254**
Alpha-2 Complex	Debris		50,952	50,952					50,952	**50,952**
Alpha-3 Complex	Debris		24,892	24,892					24,892	**24,892**
Alpha-4 - D&D	Debris	18,836	16,600	35,436	24,051	21,195	45,246	42,887	37,795	**80,682**
	Debris/Classified				625	550	1,175	625	550	**1,175**
Alpha-5 Complex	Debris	42,994	79,629	122,623				42,994	79,629	**122,623**
Balance of Facilities D&D	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 Remediation	Debris		10,017	10,017					10,017	**10,017**
	Soil		62,506	62,506					62,506	**62,506**
Beta 4 LMD	Debris	741		741				741		**741**
	Debris/Classified	1,315		1,315				1,315		**1,315**
Beta Buildings Legacy Material Disposition	Debris	3,793	18,706	22,499				3,793	18,706	**22,499**
Beta-1 Complex	Debris		40,460	40,460					40,460	**40,460**
Beta-4 Complex	Debris	71,994		71,994				71,994		**71,994**
Biology Complex	Debris		29,088	29,088					29,088	**29,088**
	Soil		5,069	5,069					5,069	**5,069**

Table A-2. Base As-generated Waste Volume Estimate by Project (FY 2012- FY 2042) (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 (FY12-42) (yd^3)
		FY12-20 (EMWMF)	FY20-42 (EMDF)	Total LLW	FY12-20 (EMWMF)	FY20-42 (EMDF)	Total Mixed			
Bldg 3026 C&D Hot Cell	Debris	2,742		2,742				2,742		**2,742**
Building 3038 D&D	Debris	1,248		1,248				1,248		**1,248**
BV Chemical Development Lab Facilities D&D	Debris		1,189	1,189					1,189	**1,189**
BV Groundwater Treatment Facilities D&D	Debris		4,466	4,466					4,466	**4,466**
BV Inactive Tanks & Pipelines	Debris		405	405					405	**405**
	Soil		158	158					158	**158**
BV Isotope Area Facilities D&D	Debris		6,102	6,102					6,102	**6,102**
BV Reactor Area Facilities D&D	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 D&D	Debris		3,433	3,433					3,433	**3,433**
	Soil		182	182					182	**182**
Central Neutralization Facility Closure D&D	Debris		5,743	5,743					5,743	**5,743**
Central Stack Hot Cell Facilities Complex	Debris		10,268	10,268					10,268	**10,268**
Centrifuge Facilities D&D	Debris		27,229	27,229					27,229	**27,229**
	Debris/Classified		5,398	5,398					5,398	**5,398**
Deactivation Only Complex (Beta-3 & 97)	Debris		7,256	7,256					7,256	**7,256**
East Bethel Valley Complex	Debris		71,315	71,315					71,315	**71,315**
EGCR D&D	Debris		45,811	45,811					45,811	**45,811**
Fire Station Complex	Debris		812	812					812	**812**
General Maintenance Facilities Complex	Debris		166	166					166	**166**

Table A-2. Base As-generated Waste Volume Estimate by Project (FY 2012- FY 2042) (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 (FY12-42) (yd^3)
		FY12-20 (EMWMF)	FY20-42 (EMDF)	Total LLW	FY12-20 (EMWMF)	FY20-42 (EMDF)	Total Mixed			
Hot Storage Garden	Debris		190	190					190	**190**
HPRR Area D&D	Debris		2,553	2,553					2,553	**2,553**
K-1037 Facility D&D	Debris		35,960	35,960					35,960	**35,960**
	Debris/Classified		500	500					500	**500**
K-1065 Operations and "No Path to Disposition" Waste (ETTP)	Debris	10,853		10,853				10,853		**10,853**
K-1070-B Burial Grounds	Soil/Classified	2,992		2,992				2,992		**2,992**
K-25 Facility D&D (ETTP)	Debris	154,874		154,874				154,874		**154,874**
	Debris/Classified	7,947		7,947				7,947		**7,947**
K-27 Facility D&D (ETTP)	Debris	111,914		111,914				111,914		**111,914**
K-31 Facility D&D	Debris		85,338	85,338					85,338	**85,338**
K-33 Building Demo	Debris	34,982		34,982				34,982		**34,982**
LLLW Facilities D&D	Debris		1,773	1,773					1,773	**1,773**
Melton Valley LGWO D&D	Debris		7,859	7,859					7,859	**7,859**
MV Homogeneous Reactor Experiment D&D	Debris		725	725					725	**725**
MV Legacy Material Disposition	Debris		104	104					104	**104**
Newly Generated LLW/MLLW and Additional Waste - PBS 42	Debris	7		7				7		**7**
NW Quad Soils and Sediments	Debris	8,572		8,572				8,572		**8,572**
ORNL Non-HF Well P&A	Debris		10	10					10	**10**
ORNL Remaining Non-HF Well P&A	Debris		14	14					14	**14**
ORNL Small Facilities Complex	Debris	1,462		1,462				1,462		**1,462**
ORNL Small Facilities D&D	Debris		1,129	1,129					1,129	**1,129**

Table A-2. Base As-generated Waste Volume Estimate by Project (FY 2012- FY 2042) (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 (FY12-42) (yd^3)
		FY12-20 (EMWMF)	FY20-42 (EMDF)	Total LLW	FY12-20 (EMWMF)	FY20-42 (EMDF)	Total Mixed			
ORNL Soils & Sediments	Debris		2,055	2,055					2,055	**2,055**
	Soil		76,561	76,561					76,561	**76,561**
ORNL Surveillance & Maintenance / Environmental Monitoring	Debris	1,236		1,236				1,236		**1,236**
OSY Soil Remediation	Soil	500		500				500		**500**
Poplar Creek Facility D&D	Debris		27,986	27,986					27,986	**27,986**
	Debris/Classified		50	50					50	**50**
Process Facilities Legacy Material Disposition	Debris		11,515	11,515					11,515	**11,515**
Process Wastewater Systems Project	Debris		295	295					295	**295**
RTBF Program - Storage	Debris/Classified	144		144				144		**144**
SE Contaminated Lab Complex	Debris		91	91					91	**91**
SE Services Group Complex	Debris		112	112					112	**112**
Sewage Treatment Plant Complex D&D	Debris		73	73					73	**73**
Southeast Lab Complex	Debris	638		638	304		304	942		**942**
Transition Facility D&D	Debris		8,001	8,001					8,001	**8,001**
TRU Waste Processing Complex	Debris		3,106	3,106					3,106	**3,106**
TSCA Incinerator D&D	Debris		5,385	5,385					5,385	**5,385**
UEFPC Remaining Slabs and Soils	Debris	1,212	155,690	156,902				1,212	155,690	**156,902**
	Soil	2,136	274,504	276,640				2,136	274,504	**276,640**
UEFPC Sediments - Streambed & Lake Reality	Soil					11,975	11,975		11,975	**11,975**
UEFPC Soils 81-10 Area Remediation	Debris				41	239	280	41	239	**280**
	Soil	4,905	28,445	33,350				4,905	28,445	**33,350**
UEFPC Soils Remediation	Soil		3,154	3,154					3,154	**3,154**
Y-12 EM Facilities D&D	Debris		3,000	3,000					3,000	**3,000**

Table A-2. Base As-generated Waste Volume Estimate by Project (FY 2012- FY 2042) (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 (FY12-42) (yd^3)
		FY12-20 (EMWMF)	FY20-42 (EMDF)	Total LLW	FY12-20 (EMWMF)	FY20-42 (EMDF)	Total Mixed			
Y-12 Salvage Yard	Debris	150		150				150		**150**
Y-12 Surveillance & Maintenance / Environmental Monitoring	Debris				450		450	450		**450**
Zone 2 Final Remedial Actions	Debris		30,000	30,000					30,000	**30,000**
Zone 2 Remedial Actions	Debris	9,500	16,670	26,170				9,500	16,670	**26,170**
TOTAL VOLUME		**497,687**	**1,677,376**	**2,175,063**	**25,471**	**34,103**	**59,574**	**523,158**	**1,711,479**	**2,234,637**

LLW = low-level (radioactive) waste; RCRA = Resource Conservation and Recovery Act of 1976; TSCA = Toxic Substance Control Act of 1976

Table A-3. As-generated Waste Volume Estimate (FY 2020-FY 2042) with Uncertainty

As-generated Waste Volume Estimate (yd^3)													
Waste Type	**Material Type**	**FY2020 (EMDF)**	**FY2021**	**FY2022**	**FY2023**	**FY2024**	**FY2025**	**FY2026**	**FY2027**	**FY2028**	**FY2029**	**FY2030**	**FY2031**
LLW (includes LLW/TSCA)	Debris	38,077	46,064	51,324	81,429	85,689	123,867	39,428	36,454	36,647	33,000	60,845	68,093
	Debris Classified			1,506	3,942	500							
	Soil	38,949	9,924	20,436	21,851	20,479	4,634	149	86			2,923	13,599
	Soil Classified												
	TOTAL	**77,026**	**55,988**	**73,266**	**107,221**	**106,668**	**128,501**	**39,576**	**36,540**	**36,647**	**33,000**	**63,768**	**81,692**
Mixed (LLW/RCRA/TSCA)	Debris	11,390	10,044		5	39	39	39	23				
	Debris Classified	290	261										
	Soil												
	TOTAL	**11,680**	**10,304**		**5**	**39**	**39**	**39**	**23**				
	TOTAL	**88,706**	**66,292**	**73,266**	**107,226**	**106,707**	**128,540**	**39,615**	**36,563**	**36,647**	**33,000**	**63,768**	**81,692**
	28% Uncertainty	**24,820**	**18,548**	**20,500**	**30,002**	**29,856**	**35,965**	**11,084**	**10,230**	**10,254**	**9,233**	**17,842**	**22,857**
	Total with UCL	**113,526**	**84,841**	**93,766**	**137,228**	**136,564**	**164,505**	**50,699**	**46,793**	**46,901**	**42,233**	**81,610**	**104,549**

As-generated Waste Volume Estimate (yd^3)													
Waste Type	**Material Type**	**FY2032**	**FY2033**	**FY2034**	**FY2035**	**FY2036**	**FY2037**	**FY2038**	**FY2039**	**FY2040**	**FY2041**	**FY2042**	**Total FY20-FY42**
LLW (includes LLW/TSCA)	Debris	51,018	46,358	81,116	70,687	65,954	45,055	16,602	33,415	25,524	25,558	10,339	992,586
	Debris Classified												5,948
	Soil	16,164	11,399	24,613	95,816	76,964	28,319	30,698	38,805	30,456	12,622		466,200
	Soil Classified												0
	TOTAL	**67,182**	**57,757**	**105,729**	**166,503**	**142,918**	**73,374**	**47,300**	**72,220**	**55,980**	**38,180**	**10,339**	**1,677,376**
Mixed (LLW/RCRA/TSCA)	Debris												21,578
	Debris Classified												551
	Soil			263	11,712								11,975
	TOTAL			**263**	**11,712**								**34,103**
	TOTAL	**67,182**	**57,757**	**105,992**	**178,215**	**142,918**	**73,374**	**47,300**	**72,220**	**55,980**	**38,180**	**10,339**	**1,711,479**
	28% Uncertainty	**18,797**	**16,160**	**29,656**	**49,864**	**39,988**	**20,530**	**13,234**	**20,207**	**15,663**	**10,683**	**2,893**	**478,868**
	Total with UCL	**85,979**	**73,917**	**135,649**	**228,079**	**182,906**	**93,904**	**60,534**	**92,427**	**71,643**	**48,863**	**13,232**	**2,190,348**

LLW = low-level (radioactive) waste
RCRA = Resource Conservation and Recovery Act of 1976
TSCA = Toxic Substance Control Act of 1976
UCL = upper confidence level

Table A-4. As-disposed Waste Volume Estimate

Total As-Disposed (CY)	Thru 2011	FY2012	FY2013	FY1014	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020*	FY2020**	FY2021	FY2022	FY2023	FY2024	FY2025	FY2026
Debris	369,072	34,069	28,561	43,352	41,198	29,218	6,782	25,489	41,601	4,470	24,726	28,011	26,253	42,426	42,849	61,573	19,612
Waste used as fill	366,966	2,689	0	0	0	0	0	0	0	5,423	29,998	7,644	15,739	16,829	15,773	3,569	114
Excess waste fill		0	0	0	0	0	0	0	0			0	0	0	0	0	0
Clean Fill	381,152	74,306	64,548	97,976	93,108	66,032	15,327	57,604	94,019	4,679	25,883	55,661	43,593	79,054	81,067	135,585	44,209
Total waste plus fill	1,117,190	111,064	93,110	141,329	134,306	95,250	22,108	83,093	135,620	14,572	80,607	91,316	85,585	138,309	139,689	200,727	63,936
28% Uncertainty Allowance (Total Waste + Clean Fill)	0	31,075	26,052	39,544	37,579	26,651	6,186	23,249	37,946	4,077	22,554	25,550	23,947	38,698	39,085	56,163	17,889
Total with uncertainty	**1,117,190**	**142,139**	**119,161**	**180,872**	**171,885**	**121,900**	**28,294**	**106,342**	**173,566**	**18,650**	**103,161**	**116,866**	**109,532**	**177,007**	**178,774**	**256,890**	**81,825**
Cumulative On-site Waste Disposal	**1,117,190**	**1,259,329**	**1,378,491**	**1,559,363**	**1,731,248**	**1,853,148**	**1,881,442**	**1,987,784**	**2,161,350**	**2,180,000**	**2,283,161**	**2,400,027**	**2,509,559**	**2,686,566**	**2,865,340**	**3,122,230**	**3,204,054**

FY 2020: New Disposal Facility - Cells 1 and 2 Start Operations

FY 2025: New Disposal Facility - Cells 1 and 2 Full, Cells 3 and 4 Start Operations

EMWMF Reaches Maximum Capacity

EMWMF Maximum Capacity= 2,180,000 yd^3

Total As-Disposed (CY)	FY2027	FY2028	FY2029	FY2030	FY2031	FY2032	FY2033	FY034	FY2035	FY2036	FY2037	FY2038	FY2039	FY2040	FY2041	FY2042	Total
Debris	18,126	18,211	16,399	30,236	33,838	25,353	23,037	40,309	35,126	32,775	22,389	8,250	16,605	12,684	12,701	5,138	1,220,439
Waste used as fill	67	0	0	2,251	10,473	12,449	8,779	19,159	79,386	59,276	21,811	18,645	29,887	23,457	9,721	0	760,107
Excess waste fill	0	0	0	0	0	0	0	0	3,431	0	0	4,998	0	0	0	0	8,429
Clean Fill	40,899	41,157	37,061	66,082	66,000	44,847	43,284	71,940	0	14,795	28,790	0	7,640	5,208	18,982	11,611	1,912,100
Total waste plus fill	59,092	59,368	53,460	98,569	110,311	82,649	75,100	131,408	117,943	106,846	72,990	31,893	54,132	41,349	41,404	16,749	3,901,074
28% Uncertainty Allowance (Total Waste + Clean Fill)	16,534	16,611	14,958	27,579	30,865	23,125	21,013	36,768	33,000	29,895	20,422	8,924	15,146	11,569	11,585	4,686	778,925
Total with uncertainty	**75,626**	**75,979**	**68,418**	**126,148**	**141,176**	**105,774**	**96,113**	**168,176**	**150,944**	**136,742**	**93,412**	**40,817**	**69,278**	**52,918**	**52,988**	**21,436**	**4,680,000**
Cumulative On-site Waste Disposal	**3,279,680**	**3,355,660**	**3,424,078**	**3,550,226**	**3,691,402**	**3,797,176**	**3,893,289**	**4,061,465**	**4,212,409**	**4,349,150**	**4,442,562**	**4,483,379**	**4,552,658**	**4,605,576**	**4,658,564**	**4,680,000**	

FY 2034: New Disposal Facility - Cells 3 and 4 Full, Cells 5 and 6 Start Operations

FY 2042: End CERCLA Waste Disposal, Begin Facility Closure

EMWMF = Environmental Management Waste Management Facility
EMDF= Environmental Mangement Disposal Facility

* Denotes FY2020 Volumes designated for EMWMF
** Denotes FY2020 Volumes designated for EMDF

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 RSMI 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 RSMI 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)

[a]*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)

ᵃUnits 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 RSMI 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-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					1.21E+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 RSMI 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-III (Areas 1 and 2)	7.39E+09	*pCi*											
Y-12	303.02	Old Salvage Yard SY-III 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 RSMI 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-III (Areas 1 and 2)	7.39E+09	*pCi*											
Y-12	303.02	Old Salvage Yard SY-III 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 Tr ansportation 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-III (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-III 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**

2. REFERENCES

DOE 2012. *Environmental Management Waste Management Facility 2012 Capacity Assurance Remedial Action Report, March 2012, DOE/OR/01-2567&D1.*

APPENDIX B

WASTE VOLUME REDUCTION

CONTENTS

FIGURES

TABLES

ACRONYMS

ACM	asbestos-containing material
ANSI	American National Standards Institute
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
DAW	dry active waste
DOE	U.S. Department of Energy
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
HPS	Health Physics Society
IAEA	International Atomic Energy Agency
LANL	Los Alamos National Laboratory
LLNL	Lawrence Livermore National Laboratory
LLW	low-level (radioactive) waste
M	million
NNSS	Nevada National Security Site
NRC	Nuclear Regulatory Commission
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
PPE	personal protective equipment
RA	remedial action
RI/FS	Remedial Investigation/Feasibility Study
TDEC	Tennessee Department of Environment and Conservation
U.S.	United States
VR	volume reduction
WAC	Waste Acceptance Criteria
WGF	Waste Generation Forecast
WMPP	Waste Management Program Plan
WSSRAP	Weldon Spring Site RA Project
Y-12	Y-12 National Security Complex

1. INTRODUCTION

The Remedial Investigation/Feasibility Study (RI/FS) for the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) disposal facility evaluates alternatives that will address disposal of CERCLA waste generated on the Oak Ridge Reservation (ORR). Alternatives being considered are the (1) No Action Alternative, (2) On-site Disposal Alternative, and (3) Off-site Disposal Alternative.

Under the No Action Alternative, 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 Environmental Management Waste Management Facility (EMWMF) capacity is reached. For the On-site Disposal Alternative, consolidated disposal of most future-generated CERCLA waste exceeding the capacity of the existing EMWMF would be in a newly-constructed facility on the ORR, referred to as the Environmental Management Disposal Facility (EMDF). The Off-site Disposal 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.

This Appendix evaluates volume reduction (VR) options that could reduce capacity needed and costs for waste disposal. Information is presented in the following sections:

- 2 Purpose and Scope
- 3 Approach
- 4 Waste Materials
- 5 VR Methods and Benefits
- 6 Previous VR Evaluations
- 7 Lessons Learned
- 8 Summary

Section 9 provides conclusions and recommendations. References are listed in Sect. 10. Attachment A provides vendor data used in the evaluation. Attachment B contains details about the VR processing cost estimate.

2. PURPOSE AND SCOPE

The purpose of this Appendix is primarily to review and assess different approaches for reducing the volume of the CERCLA waste to be disposed in a new EMDF or off-site disposal facilities and to estimate the potential cost savings. The study evaluates physical treatment methods for size-reducing demolition debris and reducing the associated clean fill (soil) demand necessary to occupy the debris void space when placed for disposal at the EMDF. Clean fill occupies a large fraction of the EMDF disposal capacity and constitutes a major fraction of the facility cost. Size reduction increases the bulk density of the materials making off-site disposal less expensive by allowing transportation of more material per shipping container. The study also evaluates recycling possibilities, enhanced segregation of waste, and modified project sequencing to make more efficient use of landfill capacity.

The physical treatment methods evaluated were limited to those that are typically used for commercial construction and demolition (C&D) projects or at recycling facilities by private industry. The issues associated with recycling materials from the United States (U.S.) Department of Energy (DOE) nuclear facilities are discussed 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, saving disposal capacity at the EMDF. The possibility and potential benefits of project sequencing are examined, whereby projects are scheduled in order to make optimal use of waste soil as fill material during placement of debris. The study utilizes the waste volume estimates in Chapter 2 and Appendix A of this RI/FS and information from the EMWMF Capacity Assurance Remedial Action Reports (CARAR) (DOE 2004, DOE 2011a, and DOE 2012a) to determine waste volumes, waste types, and clean fill requirements.

To determine the cost effectiveness of the options, the estimated cost of VR activities is compared to the anticipated cost of EMDF disposal in terms of dollars per cubic yard for on-site disposal at a proposed facility in East Bear Creek Valley. VR costs are also compared with the cost of off-site disposal for equivalent volumes of waste. Recommendations are made regarding VR approaches based on the comparison with estimated EMDF and off-site disposal costs along with appropriate qualifying statements that apply to the conditions. Assumptions are presented where uncertainties 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 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 was used to estimate the benefits of VR in terms of reduced clean fill required to isolate and fill voids in the wastes.

Information from the RI/FS waste volume estimate were reviewed to determine 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 left by demolition 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 to fill the void space created by placement of debris in the landfill. Sequencing of planned projects in the RI/FS waste volume estimate are based on assumptions such as funding, prioritization, and contracting that can be uncertain and subject to change.

Both recycling and enhanced segregation activities would require more intensive characterization efforts to verify that waste materials are clean enough for free-release or to meet the ORR Landfill acceptance criteria. This approach may also involve additional pre-demolition hazard analysis efforts to downgrade the facility hazard category from a "Nuclear" or "Radiological" facility to a non-radiological, industrial facility. Recycling also carries the risk of accidentally releasing contaminated materials into the commercial market place and unintentionally exposing the public to radiation. Preventing this type of occurrence is critically important. The cost of recycling includes the cost of segregating, characterizing, and transporting off-site to a local recycling facility.

The cost effectiveness of physical VR options was evaluated by comparing the cost of implementing the VR method to the cost of on-site or off-site disposal of unprocessed material. Physical VR costs typically include capital, construction, operations, maintenance, repairs, energy (e.g., fuel, electricity), and overhead allowance. The On-site Disposal Alternative cost estimate developed for the EMDF and the Off-site Disposal Alternative cost estimate (see summary in Appendix G of this RI/FS) were used to determine potential on-site disposal cost savings for VR scenarios. VR benefits include reduced transportation costs and reduced construction and operating costs for the on-site disposal facility.

4. WASTE MATERIALS

The buildings selected for this evaluation are representative of the types of contamination present and the variety of waste that will be generated during building demolition. A breakdown of material types and quantities available for several facilities from ORNL and Y-12 Buildings based on cost estimates for D&D activities was used.

Table B-1 is a listing of projected waste streams from each representative building by material type. 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. The waste materials from all the buildings were summed to provide a representative percentage by waste type for materials to be disposed. As described in Sect. 5.2.1, the representative fractional quantities given in this table were applied against the projected as-generated waste volume estimate for debris from Appendix A to determine the total quantity of material that would benefit from VR.

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 require complex and costly containment facilities and safety systems for VR processing. These materials will likely be addressed prior to facility demolition using existing infrastructure and localized containment. Lead brick and sheet will be separated for either recycling as shield materials or transported to an off-site treatment facility for macroencapsulation and disposal. These materials do not comprise a significant fraction of the total EMDF capacity, nor are they in a voluminous form that would show significant benefit by compacting. ACM cannot be 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. Light steel materials such as ventilation duct, conduit, thin-walled pipe, and sheet metal siding can be shredded as well as siding, flooring, wood materials, and roof materials. 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.

Compactors for light materials typically operate using a hydraulic press to compress materials at 2,000 psi in a confined area or bale that conforms to a shape and size that is suitable for transportation and disposal. It is most beneficial for light, soft materials with a large void fraction such as plastic containers or sanitary refuse.

For heavy gauge metal materials (structural steel, large diameter, thick walled piping, process vessels, and equipment items that have a large void fraction) shearing machines such as those used in shipyards and metal recycling facilities may be used. 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 for recycle and disposal.

Table B–1. Waste Streams for Representative Buildings by Material Type

Waste Stream	Description	ORNL Facilities			Y-12 Facilities					Total Volume (yd^3)	Fraction of Total (%)
		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%
Transite	Transite	8	165	0	148	265	120	0	146	853	0.18%
Lead	Bricks, sheet	0	0	94	0	0		2	0	96	0.02%
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%
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%
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%
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%
Light gauge metals and siding	Air ductwork, <2" pipe, siding, panels	770	860	599	1,432	3,565	2,501	97	4,154	13,979	3.01%
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%
Legacy material	Containers, furniture, trash	0	0	27	838	0	0	0	48	913	0.20%
Packaged for EMWMF	Legacy containerized waste	0	0	84	0	0	0	0	0	84	0.02%
Off-site disposal	Mixed waste designated for off-site disposal	0	0	53	0	0	0	0	0	53	0.01%
Total		22,709	45,811	4,245	52,720	122,624	83,262	28,956	103,770	464,129	1.0

*Rows highlighted in green are materials amenable to VR processing, and account for 98.8% of the total.

5. VOLUME REDUCTION METHODS AND BENEFITS

The following provides a description of the VR approaches evaluated in this report. Advantages and disadvantages are discussed along with cost data collected from various sources. The discussion considers types of techniques/technologies available to perform size reduction, the cost of implementing, and the magnitude of VR that can be potentially achieved. This information is used to determine the 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, the impact of VR to various cost elements associated with construction, operations, and maintenance was estimated. 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 SIZE REDUCTION EQUIPMENT

Commercially available size reduction equipment is capable of reducing the size and void space associated with bulk demolition materials. This equipment is most often used at construction sites and commercial recycling facilities across the country. Many models are available in the form of stationary or mobile units that can be deployed at the demolition site. Local deployment at the demolition site takes advantage of additional cost savings associated with transportation from the demolition site to the disposal area. Rising fuel costs will continue to increase the cost of transportation and make localized VR alternatives more attractive.

Equipment used to size-reduce debris materials includes crushers, shredders, compactors, and shears. This equipment could be deployed at the demolition site and are capable of processing capacities sufficiently large so as not significantly impact the demolition schedule. Demolition equipment such as excavators with cutting and crushing attachments is normally used to size-reduce materials to meet the requirements for transportation and placement in the landfill. The same equipment and size requirements are expected to be acceptable for preparing the materials for feed hoppers used for crushers or shredders. These machines can be equipped with conveyors to move the processed materials to a waste container or collection area. Excavators with various boom attachments may be used to manage the product.

5.1.1 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 (Figure B-1). 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 hrs per month assuming 40 hrs per week operating time. Operational availability is typically 75% for the diesel driven units and about 90% for stationary electric units. Attachment A includes selected data sheets and vendor inquiry data for vendor equipment.

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 (radioactive) waste (LLW) VR technologies (DOE 1988) indicates that waste density for a simulated mixture of LLW increased from 13 to 30.8 lbs 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 lbs per ft^3, equivalent to an 84% decrease in volume. The increase in density from 30.8 to 80.3 lbs 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.

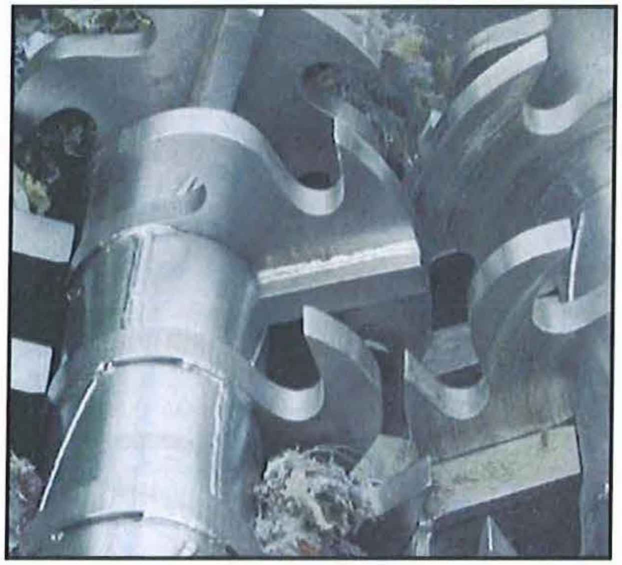


Figure B–1. Shredder Cutter Assembly (SSI Shredding Systems, Inc.)

5.1.2 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 (Figure B-2). 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 hrs for two operators and replacement of wear plates requires about one hr for two operators. Operational availability is typically 80% for diesel driven units. Attachment A includes selected data sheets for vendor equipment.

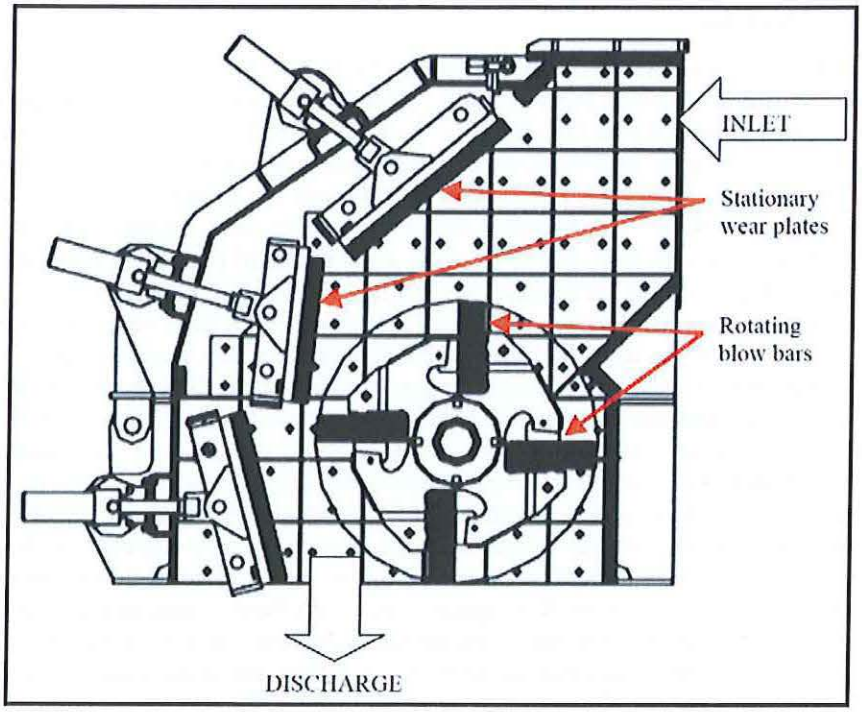


Figure B–2. Rotary Impact Crusher Components (Striker Crushing and Screening Co.)

5.1.3 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. Personal protective equipment (PPE) and dry active waste (DAW), 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-gal drums can be over packed in 85-gal drums with very little void space. PPE is typically bagged and placed in B-25 boxes with very little compaction. At the 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 six 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 large shearing machine deployed at the K-33 building at ETTP 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 addressed in the next section.

5.1.4 Shearing Machines

British Nuclear Fuels Limited (BNFL) used a Harris Model BHS 2205-30 Shear designed for size-reducing scrap metal from shipyards and steel mills (otherwise known as the supercompactor) to process large equipment removed from the K-33 building at the 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 said the project saved $100 million (M) 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-3. The $13M facility (supercompactor 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 supercompactor. 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. Costs would be much lower if the processing equipment was mobile and did not require ventilation containment, however, a significant fraction of the equipment is likely to have been involved in radiological operations and/or utilized hazardous materials in the process.

Structural materials, including heavy steel structural supports and platforms are also a significant fraction of demolition materials, as shown in Table B-1. These materials are far less likely to be contaminated; therefore, a mobile compactor/shear could be deployed at much lower capital and operating costs to process structural materials into smaller volumes for EMDF disposal. This approach is worthy of additional consideration for VR for large quantities of non-contaminated heavy-gauge metals.

Recent characterization data for a large Y-12 facility (DOE 2012b) indicates widespread mercury and beryllium (Be) contamination that would curtail the use of VR methods beyond what is necessary to meet the disposal facility Waste Acceptance Criteria (WAC). It would not be feasible or safe to remove this equipment from the building for a shearing operation due to the size of the equipment and potential for spread of contamination. A likely approach would involve in-place decontamination or contaminant fixation, disassembly, packaging, and removing equipment from the building for disposal prior to building demolition. The site-wide estimated quantity of heavy equipment and structural materials that would be amenable for VR processing is reduced substantially to account for this heavily contaminated equipment.

Figure B–3. BSH Shear by Harris

5.2 EVALUATION OF PHYSICAL VOLUME 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 truck at the D&D site. With continually increasing fuel costs, reducing transportation is becoming a more significant cost benefit, especially for the distances required in the Off-site Disposal Alternative. Additionally, decreasing the number of transport loads decreases roadway duration and the associated risk from traffic accidents. For EMDF disposal, the principal benefit of VR is the reduction in the quantity of fill material required to fill the void spaces within the material being placed in the disposal cell and the corresponding reduction in needed landfill capacity. 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 rolling over the materials. This section analyzes potential VR benefits for the On-site Disposal Alternative.

Similar to the definitions in the CARAR (DOE 2012a) completed annually for the EMWMF based on Waste Generation Forecasts (WGFs), there are two types of quantitative waste volume estimates used in this RI/FS as described below:

- "As-generated" waste volume estimate:
  - An estimate of volume 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 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 estimate:
  - An estimate of volumes of waste after disposal in the disposal facility, at which point debris wastes, waste suitable for use as fill, and clean fill have been mixed and processed to meet compaction and void space requirements (i.e., used for On-site Disposal Alternative).
  - Physically equivalent to survey results taken quarterly to estimate disposal facility airspace utilized.
  - Includes lower amount of void space than as-generated waste volume because it reflects compaction of the waste 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. See Chapter 2 of this RI/FS for additional information about 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. Based on this quantity, VR equipment can be sized and the full impact of processing can be determined.

5.2.1 Waste Volume Amenable to Volume Reduction Processing

As shown in Table B-1, about 98% of D&D debris materials are amenable to size reduction by shredding, crushing, or shearing. The 2001 Waste Management Program Plan (WMPP) (DOE 2001a) predicted that more than half of the debris generated in Y-12 D&D projects would be volume-reducible. The as-generated waste volume estimate data shown in Table A-2 of Appendix A was used to develop the total as-generated volume of debris that is amenable to VR processing shown in Table B-2. Table A-2 in Appendix A includes a listing of the buildings at all three ORR sites that will undergo D&D from the present date until completion of the work scope in the year 2042. The list includes yearly waste volumes and waste types for each of the facilities or facility groupings. This listing was reviewed and pared down to include only those facilities that will produce LLW debris (not soil) during the time that the EMDF is in service (2020 – 2042). This grouping was further pared down by removing all projects that produce less than 3,000 yd^3 of debris. Then an approximate uncertainty of 28% was applied to the as-generated volumes for consistency with the evaluations in the On-site and Off-site Disposal Alternatives (see Sect 2.2.1 of Chapter 2 of this RI/FS).

The total volume of debris from this pared list (Table B-2 with applied uncertainty provides the total estimated as-generated volume from facility demolition for VR processing, 1,405,030 yd^3, shown as "Material 1" in Table B-3. The values shown in the "Fraction of Total" column in Table B-3 are carried forward from the last column in Table B-1 for materials amenable to VR processing. These fraction of total values are used to calculate the waste stream volumes shown in the "Material 1" column of Table B-3. It was further assumed that approximately 75% of this debris would undergo processing due to logistical limitations and that only 30% of the Y-12 heavy equipment would be processed due to the presence of elevated radiological, mercury, or beryllium contamination. After applying these factors, the final estimated volume for VR processing is 936,736 yd^3, shown as Material 2 in Table B-3.

Table B–2. Projects and Debris Volumes for VR Processing

Site	Project Title	Volume (yd³)	2020 to EMDF	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
ORNL	2026 Complex	10,012																3,907		4,079	2,026				
ORNL	BV Reactor Area Facilities D&D	7,076				250	1,911	1,904	1,904	1,107															
ORNL	BV Isotope Area Facilities D&D	6,102		394	3,145	2,563																			
ORNL	Central Stack Hot Cell Facilities Complex	10,268						58	2,139	3,857	2,520	1,694													
ORNL	3525 Complex	7,659								44	5,134	2,481													
ORNL	East Bethel Valley Complex	71,315							136	3,553							13	14,402	26,210	22,564	4,437				
ORNL	EGCR D&D	45,811																			42	5,827	4,384	25,219	10,339
ORNL	3019A D&D	61,891					181	317	3,106	12,253	12,204	12,253	12,253	9,324											
ORNL	BV Remaining Slabs and Soils	30,024															683	2,048	1,992	2,123	3,909	11,407	7,862		
	Total ORNL		0	394	3,145	2,813	2,092	2,279	7,285	20,814	19,858	16,428	12,253	9,324	0	0	696	20,357	28,202	28,766	10,414	17,234	12,246	25,219	10,339
Y-12	Alpha-2 Complex	50,952									3,759	7,706	10,654	15,656	13,177										
Y-12	Alpha-3 Complex	24,892												671	5,324	13,028	5,869								
Y-12	Alpha-4 - D&D	16,600	8,742	7,858																					
Y-12	Alpha-5 Complex	79,629	22,633	32,928	24,068																				
Y-12	Alpha Buildings Legacy Material Disposition	34,254					2,479	11,063	9,520	6,388	4,804														
Y-12	Beta-1 Complex	40,460													1,155	9,822	29,483								
Y-12	Beta-4 Complex	0																							
Y-12	Beta Buildings Legacy Material Disposition	18,706						2,317	4,143	7,023	5,223														
Y-12	Biology Complex	26,944											10,883	12,062	3,181	818									
Y-12	9206 Complex	13,856										1,843	7,518	4,495											
Y-12	9212 Complex	103,770										2,513	15,490	12,152	12,200	15,409	31,096	14,910							
Y-12	Transition Facility D&D	8,001											2,088	3,047	2,392	474									
Y-12	Y-12 EM Facilities D&D	3,000									507	2,189	304												
Y-12	Process Facilities Legacy Material Disposition	11,515						4,087	5,291	2,137															
Y-12	UEFPC Remaining Slabs and Soils	155,690	6,702	4,884	11,548	12,321	10,935	2,519					497	6,426	8,828	6,378	12,636	25,339	32,493	14,183					
	Total Y-12		38,077	45,670	35,616	12,321	13,414	19,986	18,954	15,548	14,293	14,251	47,434	54,509	46,257	45,929	79,084	40,249	32,493	14,183	0	0	0	0	0
ETTP	K-25 Facility D&D (ETTP)	0																							
ETTP	Poplar Creek Facility D&D	27,986				7,765	18,462	1,759																	
ETTP	K-27 Facility D&D (ETTP)	0																							
ETTP	K-31 Facility D&D	85,338						85,338																	

Table B-2. Projects and Debris Volumes for VR Processing (Continued)

Site	Project Title	Volume (yd^3)	2020 to EMDF	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
ETTP	K-1037 Facility D&D	**35,960**					35,960																		
ETTP	Central Neutralization Facility Closure D&D	**5,743**				5,743																			
ETTP	TSCA Incinerator D&D	**5,385**				5,385																			
ETTP	Centrifuge Facilities D&D	**27,229**			7,599	19,630																			
ETTP	Balance of Facilities D&D	**25,115**				24,167	948																		
ETTP	Zone 2 Remedial Actions	**16,670**			3,555	1,560	4,050	4,224	3,189	92															
ETTP	Zone 2 Final Remedial Actions	**30,000**					10,000	10,000	10,000																
ETTP	K-1065 Operations and "No Path to Disposition" Waste (ETTP)	**0**																							
	Total ETTP		0	0	11,154	64,251	69,420	101,321	13,189	92	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Volume		**1,097,853**	**38,077**	**46,064**	**49,915**	**79,385**	**84,926**	**123,586**	**39,428**	**36,454**	**34,151**	**30,679**	**59,687**	**63,833**	**46,257**	**45,929**	**79,780**	**60,607**	**60,695**	**42,949**	**10,414**	**17,234**	**12,246**	**25,219**	**10,339**
Total Volume with 28% Uncertainty		**1,405,030**	**48,731**	**58,952**	**63,881**	**101,597**	**108,688**	**158,165**	**50,460**	**46,654**	**43,706**	**39,263**	**76,387**	**81,693**	**59,200**	**58,780**	**102,103**	**77,564**	**77,678**	**54,967**	**13,328**	**22,056**	**15,672**	**32,275**	**13,232**

Table B-3. Estimated EMDF Capacity Gained for Scenarios A and B

Waste Stream	Material 1: As-G volume , yd^3	Fraction of Total*	Bulk Density (lb/yd^3)	Fraction Processed	Material 2: As-G Volume for Processing, yd^3	As-D volume for Material 2, yd^3	Clean fill for Material 1 without VR, yd^3	Clean Fill Basis	Clean fill required for fraction of Material 1 Not Processed (CF-1), yd^3	Processing Option	Void Fraction After Processing, %	As-G Volume of Material 2 After VR, yd^3
Equipment: large machine tools, large electric motors, process vessels	260,081	0.19	680	0.3	78,024	4,720	150,736	Clean fill ratio is 9.58 for as-disposed equipment (soil: debris)	105,515	Shear	45	39,012
Structural steel, piping	348,217	0.25	1,040	0.75	261,163	24,165	213,614	Clean fill ratio is 6.63 for as-disposed metals (soil: debris)	53,404	Shear	45	130,581
Concrete and masonry: Reinforced concrete, block, brick, shield walls	601,160	0.43	2,600	0.75	450,870	360,696	601,160	Clean fill ratio is 1.25 for as-disposed light concrete (soil: concrete)	150,290	Crusher	5	360,696 (D)
Small structures: small cooling towers, structural framing, interior and exterior finishes, wood	99,822	0.071	1,620	0.75	74,867	37,433	112,799	Clean fill ratio is 2.26 for as-disposed construction debris (soil: debris)	28,200	Shredder	10	44,920
Metal (light gauge): Air ductwork, <2" pipe, siding, panels	42,844	0.030	1,040	0.75	32,133	16,067	48,414	Clean fill ratio is 2.26 for as-disposed construction debris (soil: debris)	12,103	Shredder	10	19,280
Roofing materials: Shingles, built-up roofs, vapor barrier, insulation, roof vents, flashing	50,107	0.036	1,520	0.75	37,580	18,790	0	No clean fill required, self-filling	0	Shredder	10	22,548
Legacy material: Containers, furniture, trash, wood	2,798	0.002	640	0.75	2,098	1,049	2,826	Clean fill ratio is 2.26 for as-disposed construction debris (soil: debris)	706	Shredder	10	1,259
Total	**1,405,030**	**1.000**			**936,736**	**462,920**	**1,129,549 (A)**		**350,219**			**618,297**

*From Table B-1
**Total with uncertainty from Table B-2

Table B-3. Estimated EMDF Capacity Gained for Scenarios A and B (Continued)

Waste Stream	Scenario A				Scenario B			
	Clean Fill Ratio for VR Material 2 (soil: debris)	Clean Fill Volume for VR Material 2, yd^3 (CF-2)	Total clean fill, yd^3 (CF-1+CF-2)	Basis	Clean Fill Ratio for VR Material 2 (soil: debris)	Clean Fill for VR Material 2, yd^3 (CF-3)	Total Clean Fill, yd^3 (CF-1+CF-3)	Basis
Equipment	2.26	10,668	116,183	Shearing reduces volume of equipment by 50% and reduces CARAR clean fill requirement to what is required for construction debris, 2.26.	2.26	10,668	116,183	Shearing reduces volume of equipment by 50% and reduces CARAR clean fill requirement to what is required for construction debris, 2.26.
Structural steel, piping	2.26	54,612	108,015	Shearing reduces volume of heavy steel by 50% and reduces CARAR clean fill requirement to what is required for construction debris, 2.26.	2.26	54,612	108,015	Shearing reduces volume of heavy steel by 50% and reduces CARAR clean fill requirement to what is required for construction debris, 2.26.
Concrete and masonry	0.78	225,435	375,725	Reduces volume by 20%. 50% of material is self-filling. Clean fill ratio is 50% of the CARAR requirement or 0.78 (soil: debris). 25% of crushed concrete replaces clean fill for other debris.	0.78	0	150,290	Reduces volume by 20%. 100% of material is self-filling. No clean fill required. 50% of crushed concrete replaces clean fill for other debris.
Small structures	1.13	50,760	78,959	Reduces volume by 40%. 50% of material is self filling so clean fill ratio is reduced to 50% of the CARAR requirement for debris, or 1.13.	1.13	50,760	78,959	Reduces volume by 40%. 50% of material is self filling so clean fill ratio equals 50% of CARAR requirement, or 1.13.
Metal (light gauge)	1.13	21,786	33,890	Reduces volume by 40%. 50% of material is self filling so clean fill ratio is reduced to 50% of the CARAR requirement for debris, or 1.13.	1.13	21,786	33,890	Reduces volume by 40%. 50% of material is self filling so clean fill ratio is reduced to 50% of the CARAR requirement, or 1.13.
Roofing materials	0.00	0	0	Reduces volume by 40%. No clean fill required.	0.00	0	0	Reduces volume by 40%. No clean fill required.
Legacy material	2.02	1,271	1,978	Reduces volume by 40%. Ratio of clean fill to size-reduced material is the same as CARAR value of 2.02.	2.02	1,271	1,978	Reduces volume by 40%. Ratio of clean fill to size-reduced material is the same as CARAR value of 2.02.
Total		364,532	714,751(B)	Total clean fill required for Scenario A		139,097	489,316(C)	Total clean fill required for Scenario B
			414,798	EMDF capacity gained if crushed concrete is 50% self-filling (A – B), yd^3			640,234	EMDF capacity gained if crushed concrete is 100% self-filling (A – C), yd^3
			90,174	Volume of crushed concrete used to replace clean fill at 25% (D × 0.25), yd^3			180,348	Volume of crushed concrete used to replace clean fill at 50% (D × 0.5), yd^3
			504,973	Total EMDF capacity gained if 50% of crushed concrete is self-filling and 25% of crushed concrete replaces clean fill.			820,582	Total EMDF capacity gained if all crushed concrete is self-filling (no clean fill required) and 50% of crushed concrete replaces clean fill.

5.2.2 Estimated EMDF Capacity Increase

When placing bulky waste materials such as building debris in a landfill, it is necessary to fill the voids within/between the waste with soil, soil-like waste materials, or other engineered fill materials (e.g., flowable fill) in order to reduce settlement of the waste and ensure the long term stability of the final cap placed on the landfill. In addition, the soil and soil-like waste materials must be properly compacted. Previous experience gained from operating the 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 operations has purchased clean soil from off-site borrow sources to fill void spaces in the landfill (DOE 2011a). Use of clean soil to fill void spaces is an inefficient and costly use of valuable landfill air space. Size reduction of certain waste materials, such as bulky building debris, can significantly reduce or even eliminate the volume of clean soil fill required for a particular waste stream (DOE 2003 and 2004).

Two scenarios have been developed for evaluating disposal cell capacity usage and cost savings to be realized through VR of waste. Both scenarios assume that the amount of debris processed is less than the amount considered amenable to VR, as described in Sect. 5.2.1 of this appendix. The difference in the scenarios involves the amount of clean fill required for concrete debris versus crushed concrete and also the amount of crushed concrete that may be used to replace clean fill material that would otherwise be required for placement of debris and equipment items.

Of the debris amenable to VR, 43% is composed of concrete rubble as shown in Table B-3. The table summarizes the estimated reduction in clean fill requirement with the use of various size-reduction equipment. The density information used to develop the CARAR estimates indicates an as-generated void fraction of 25% for concrete, 50% void fraction for general construction debris, and over 90% void fraction for equipment and metals. It is assumed that shredding, crushing, and shearing operations will reduce the void volumes of concrete, debris, and equipment to 5%, 10%, and 45%, respectively. Revised clean fill requirement is determined for size-reduced debris and for debris that is not processed. Since the particle sizes will be much smaller for size-reduced material, it is assumed that a fraction of the material is self-filling and does not require additional clean fill material. In Scenario A, it is assumed that 50% of the processed material (concrete or debris) will be self-filling, thus clean fill requirement is reduced by half of the value given in the 2011 CARAR. Based on the group of facilities analyzed, the quantity of concrete debris is almost half to the total quantity of other debris generated. Consequently, crushed concrete could be used to satisfy the clean fill requirement for a substantial amount of other debris (equipment, heavy structural materials, etc.). D&D material shipments to the landfill could possibly be arranged so that some of the crushed concrete might be used to replace clean fill. In Scenario A, it is assumed that 25% of the crushed concrete (90,174 yd^3) will be used to replace clean-fill material. For roofing materials, the 2011 CARAR indicates these materials are self-filling and no clean fill is required. This is likewise assumed for shredded roofing materials. For shredded legacy materials such as trash, furniture, and wood, the clean fill ratio for volume-reduced materials was assumed to be the same as the value of 2.02 used in CARAR calculations. For equipment and metals, VR processing is not expected to eliminate more than 50% of the as-generated void space. Consequently, fill material will still be necessary to occupy void space in the material, although the fill requirement will be lower. In the case of Scenarios A and B, it was assumed that the fill requirement for equipment and metals would be reduced to an amount that would normally be required for as-generated construction debris (2.26:1 ratio, soil:waste). The total clean fill requirement is determined for as-generated, unprocessed materials and for size-reduced materials with the difference being the reduced quantity of clean fill required and the equivalent "freed up" EMDF capacity. In Scenario A, the EMDF capacity gained through VR is 504,973 yd^3.

The operational settings of crushing equipment can be adjusted to produce a range of product particle sizes. Adjusting the settings to produce a product with 90% of the material being smaller than one inch would only reduce the maximum processing capacity of the machine from 150 to 125 tons per hr, and a higher fraction of the crushed concrete could be used as fill material. It was assumed the processing rate would be limited by the speed that material could be fed to the crushing unit using an excavator and crushing to a smaller particle size would not impact the production rate or delay the operating schedule. The cost analysis for crusher operation assumed a processing rate of 50 tons per hr. At this rate, the particle size could be reduced to one inch or less and would be self-filling such that clean fill would not be required. For Scenario B, it is assumed that the crushed concrete is 100% self-filling, eliminating all clean fill required for concrete and giving a total EMDF capacity gain of 640,234 yd^3. It is also assumed that a larger fraction of the crushed concrete, 50% or 180,348 yd^3, would be used to replace clean fill. This increases the capacity gain to 820,582 yd^3.

5.2.3 Cost of Volume Reduction Processing

The cost of shredding and crushing D&D materials 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. Based on a review of the number, location, and schedule of D&D projects, it was assumed that multiple deployments of VR systems would be necessary. The estimate includes the assumption that one mobile shredder, two mobile concrete crushers, one stationary shear, one mobile shear, and five excavators would be procured. The mobile crusher and shredder units take advantage of the savings in transportation costs and require little effort to move to the site or relocate while on the site. The mobile shear is much heavier and would require more effort to disassemble and transport. The weight of the unit would require rental of an 80-ton crane, a concrete foundation, and about eight weeks to relocate. It is assumed that the stationary shear (also called a "supercompactor") would be installed at the Y-12 plant and would include an enclosure for contamination control. Only LLW debris would be processed in this facility. The facility would be located in close proximity to the larger planned demolition projects such as Alpha-4, Alpha-5, and Beta-4. The VR machines would be equipped with conveyors to move the processed material to a staging pile next to the unit. A dedicated excavator would be provided for each machine to place debris feed into the feed box, to fill 10-yd^3 transport trucks with processed material for transport to the EMDF, or to fill 25-yd^3 intermodal containers for off-site transport. A 150-horsepower excavator with a 7.5-ton lifting capacity was assumed to support VR operations. Of the total quantity of material to be processed by the two shears, it was determined based on Table B-2 that 54% of the material would be generated at the Y-12 site and would be processed by the stationary shear. The remaining 46% was assumed to be processed by the mobile shear.

Compaction of PPE/DAW in drums was also evaluated based on projected quantities of PPE/DAW documented in the 2011 CARAR. It was assumed that four drum crushers would be deployed and these could be easily moved between sites or projects as necessary.

Density information from the 2011 CARAR was used to determine the approximate weight of material to be processed through the VR equipment. The preferred processing rate was determined based on the average quantities of debris generated per year and also on maintaining a reasonable processing duration for a large facility D&D project. For a large facility such as 9201-5 (Alpha-5) at Y-12, a crusher operating at 60 tons per hr would complete the processing of all concrete and masonry in about 18 weeks. The crusher assumed for this operation has a maximum throughput of 150 tons per hr, but was assumed to be slowed to about 50 tons per hr when processing reinforced concrete. For the shredding operation, the average debris generation is about 4,000 tons per year, but the Alpha-5 project will generate about 6,700 tons in less than a year. A shredder operating at 10 tons per hr will process all the Alpha-5 debris in about 17 weeks. The shredder assumed for this operation has a processing capacity of 25 tons per hr, but it was assumed this rate would be reduced due to a high fraction of light voluminous debris mixed with small amounts of concrete. Both shears selected for this work have processing capacities of up to 40 tons per hr, though the actual production rate for the K-33 supercompactor project was about 16 tons per hr. The expected annual average generation rate of about 6,100 tons of heavy steel could be processed in less than 10 weeks at this rate. A large project such as the K-31 Facility D&D (Table B-2) with more than 85,000 tons of debris (approximately 43% heavy steel) would require full-time operation of the shear for most of the year.

The operating life of the equipment was investigated to determine if equipment replacement would be necessary at some point in the 23 years of CERCLA waste generation. Based on manufacturer discussions, these systems can be expected to operate for the duration of the 23-year time period of waste generation evaluated in the On-site and Off-site Disposal Alternatives 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 VR cost estimate.

Tables 1 through 8 in Attachment B provide a breakdown and summary of costs for procurement and operation of the shredder, crushers, shears, and excavators. The costs include the capital cost of the unit with associated engineering and procurement costs; transportation and setup; facility enclosure (if required), labor to operate the machines based on the approximate number of hrs required to process the identified quantity of material from Table B-3; maintenance costs; and fuel. Overhead at 30% was applied to capital, setup, operating, and maintenance costs. Costs are based on current year 2012 costs without escalation. The total cost of equipment and operations for VR is about \$38M, or about \$40.52 per yd^3 of material processed (Attachment B, Table 8). As shown in Table 7, the processing cost for VR equipment varies from about \$6.63 to \$121.14 per yd^3 depending upon the material and process machine being used. For Scenario A (Attachment B, Table 8), the processing cost is about \$75 per yd^3 for the 504,973 yd^3 gained. In Scenario B where all of the crushed concrete is self-filling and half is used to replace clean fill, the cost of VR per EMDF capacity gained drops to \$46 per yd^3.

With the exception of the enclosed shear (i.e., supercompactor) at Y-12, these evaluations assume the materials are not contaminated with radiological or hazardous materials. As such, control of airborne releases is not necessary beyond normal dust control measures through general area misting with water. If materials are contaminated, containment facilities with ventilation controls would be necessary. Radiation Protection personnel would be needed to monitor facilities and personnel for contamination. Operating costs would also be impacted by the use of PPE and the associated loss in worker productivity. The vast majority of ORR D&D projects have involved open-air demolition without containment systems. In some cases, selective removal or stabilization of highly contaminated sections of the buildings has been necessary prior to demolition. Radiation monitoring and dust suppression were sufficient to control contamination releases. With or without VR equipment, contamination controls significantly increase the cost D&D activities.

5.2.4 Impact of Volume Reduction on On-site Transportation Costs

Transportation cost savings are calculated from the number of trips to the EMDF that would not be needed based on the reduced volume from implementing these technologies. It was based on an assumed cost of \$220 per trip[1] and an average load of 10 yd^3.

The total estimated as-generated quantity of waste that would be VR processed is 936,736 yd^3. From Table B-3, the difference between the total volume of debris before and after VR processing is 318,439 yd^3, which is equivalent to the quantity that would not require transportation. At \$220 per 10 yd^3 load, transportation cost savings are about \$7M.

[1] Transportation cost basis: \$250/day for the truck, \$350/day for the driver, \$7/hr for fuel, with an average of 3 loads delivered to the EMWMF or ORR Landfills per truck per day.

5.2.5 Impact of Volume Reduction on EMDF Construction and Operations Costs

This section describes the approach used to determine the potential cost savings associated with EMDF construction activities when VR technology is used to size-reduce concrete and debris. The revised construction cost was compared to the estimated cost in Appendix G for construction of a 2.5M yd^3 facility, a capacity sufficient to receive the projected waste volumes over a 23-year operating lifetime including approximately 28% uncertainty. 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.

VR Scenario A results in a net capacity gain of 504,973 yd^3 for the EMDF (Table B-3). This is estimated to be a 20% reduction in disposal capacity required. Scenario B results in a net capacity gain of 820,582 yd^3, which is equivalent to about a 33% reduction in required disposal capacity. The EMDF is likely to be constructed over time using a phased approach that includes two disposal cells (416,667 yd^3 average size each) per phase. With a total of three construction phases (six cells), VR activities could impact the need for cells that are in the later phases of construction. For a rough-order-of-magnitude estimate of VR cost benefits for Scenario A, construction cost elements associated with Phase III (construction of Cells 5 and 6) were revised to reflect lower costs due to elimination of Cell 6. The avoided cost for Cell 6 was obtained by summing the estimated Cell 6 construction costs, interim capping costs, and $1/6^{th}$ of the final cap and closure costs for the entire facility. Costs that remain unchanged include remedial design, base topographic surveys, geotechnical testing and geological investigations, construction and operation of leachate/contact water treatment system, Phase I and Phase II design and construction, Phase III design, and long-term surveillance and maintenance. These cost elements are not likely to change significantly if the EMDF capacity is reduced by the equivalent of one cell. With a 20% reduced EMDF capacity for Scenario A, operating costs would be expected to be slightly lower, although the duration of operations would not change. It was assumed that total operating costs for the EMDF would be reduced by 10% due to reduced staffing requirements (not including the cost of security). Table B-4 summarizes the EMDF construction cost benefits for both Scenarios. Under Scenario A, the net avoided EMDF construction and operating costs minus the cost of VR are a total of $27,401,291.

The capacity gain for Scenario B allows for the elimination of the entire Phase III construction effort. As in Scenario A, the remaining cost elements associated with surveys, testing, design, and the leachate treatment facility will remain unchanged. With a 33% reduced EMDF capacity for Scenario B, operating costs were assumed to be reduced by 15% due to reduced staffing requirements (not including the cost of security). As shown in Table B-4, the net avoided EMDF construction and operating costs minus the cost of VR for Scenario B are a total of $71,663,628.

5.2.6 Cost Effectiveness of Volume Reduction Processing

Based on the estimated cost of VR processing and the reduced costs of EMDF construction and operations, the data favors the deployment of VR processing equipment. For an investment of $38M for VR processing, the likely cost reduction is about $65.4M for a net savings of $27.4M. (based on Scenario A, see Table B-4). Under Scenario B, the estimated net savings is about $71.7M.

As shown in Attachment B, Table 7, the cost of VR processing varies with the type of debris and equipment used for processing. The concrete and masonry crushing operation costs the least, followed by shredding of light debris, then the shearing operations which cost the most by far to deploy. The cost of deploying both shearing machines is $27.4M and the EMDF capacity gained through reduced clean fill requirement is about 140,152 yd^3 (see Table B-3, "Clean fill for Material 1 without VR" for equipment and heavy steel [150,736 + 213,614] minus "Total clean fill required" Scenario A for equipment and heavy steel following VR processing [116,183 + 108,015]). This is equivalent to a cost per unit volume disposal capacity of about $195 per yd^3 ($27.4M÷140,152 yd^3) for the shearing operation which is greater than the estimated cost of EMDF operations at $128 per yd^3 of disposal capacity (Table B-4 total operations of \$323,348,338÷2,500,000 yd^3). However, the additional EMDF capacity gain through the shearing operation allows the avoidance of construction costs for EMDF Cell 6 at \$27.4M (Scenario A). In contrast to the shearing operation, the combined cost of deploying the shredder and crushers is only about \$8M (see Appendix B, Table 7) including the cost of three excavators. By deploying the shredder and crushers, the EMDF capacity gained is over 274,000 yd^3 determined by summing the Table B-3 clean fill required for as-generated debris ("Clean fill for Material 1 without VR" for concrete and light debris) and subtracting the sum of the clean fill required for VR processed material ("Total clean fill required" for concrete and light debris) for Scenario A. The equivalent cost per unit volume for capacity gained in this case is \$29.20 per yd^3 (\$8M÷274,000 yd^3) which is far less than the cost of EMDF waste placement at \$128 per yd^3.

5.2.7 PPE Compaction Benefits

Compaction of PPE/DAW in drums does not require significant space, labor, or facility support. The cost of a new drum crusher is about \$15,000 and drums filled with PPE/DAW can be crushed to 20% of the initial size in minutes. The typical approach for managing PPE/DAW involves manual placement of collection bags in B-25 disposal boxes for landfill placement. The material, transportation, and clean fill requirements for disposing in B-25 boxes is about \$473 per yd^3 assuming a B-25 box costs \$1,500. If PPE were crushed in 55-gal drums and five crushed drums are over-packed in an 85-gal drum for disposal, the cost would be about \$260 per yd^3. This assumes four drum crushers are deployed at a cost of \$60,000. Container costs would be about \$160 per over-pack and \$30 per drum for refurbished drums. The additional labor costs for crushing were assumed to be \$10 per drum. This is a net savings of \$213 per yd^3 of as-generated PPE/DAW. The 2011 CARAR identifies a projected PPE/DAW quantity of 8,713 yd^3 from 2012 through 2033, most of which is generated during the Alpha-4 D&D and the K-25 Area D&D projects. Total savings by crushing and over packing PPE drums would be \$1.8M. If, however, the PPE/DAW were packaged in 55-gal drums instead of B-25 containers, packaging costs would be greatly reduced and it would not be cost effective to compact the drums due to the additional equipment and handling costs. The capacity gained by compacting PPE includes the smaller as-disposed volume and reduced clean fill requirement. The as-disposed volume of the projected 8,713 yd^3 would be about 4,357 yd^3 based on CARAR density data. Assuming six 55-gal drums of PPE are compacted and over-packed in an 85-gal drum, the as-generated volume for the original 8,713 yd^3 would be 2,550 yd^3. Using CARAR clean fill requirements of 1.35 (soil:debis) for both cases, the total capacity requirement for the original 8,713 yd^3 PPE volume with clean fill would be 16,380 yd^3. For the compacted PPE, the capacity requirement would be 6,069 yd^3 giving a net capacity increase of 10,312 yd^3.

5.2.8 Landfill Compaction Benefits

When large, coarse debris materials are placed in a disposal cell, void space is left in the waste despite the use of fill materials and compaction efforts. When the materials are shredded or crushed, the density of the landfilled materials increases. Studies at municipal landfills where size-reduction equipment is being used have indicated increased landfill capacity of 15 to 30% (CU-2009). The as-disposed volume for the material that is VR processed would be about 462,920 yd^3 (Table B-3). If the landfilled density is increased by 15% for this debris, the capacity gain would be about 69,438 yd^3, or 16% of a complete cell.

Compactors that roll over and compress the debris in the landfills are subject to significant maintenance and repair issues from the tangle of metals and other materials that can jam in the treads and other moving parts of the machines. If these materials are shredded, the amount of wear and tear on compactor equipment is expected to decline with a corresponding decrease in maintenance costs.

Table B–4. Estimate of EMDF Construction and Operations Savings for Volume Reduction Scenarios A and B

EMDF Construction and Operations	
Work Element	**Cost**
Remedial Design	$5,727,300
Early Actions	$3,480,293
Site Development	$5,955,093
Leachate/CW Treatment	$16,600,000
Phase I, Cells 1&2	$63,826,646
Phase II, Cells 3&4, Oversight	$2,622,813
Phase II, Cells 3&4	$24,342,490
Interim Cap, Cells 1&2	$2,165,046
Engineering for Cells 5&6	$1,914,712
Phase III, Cells 5&6, Oversight	$2,402,283
Phase III, Cells 5&6	$29,190,688
Interim Cap, Cells 3&4	$2,002,933
Interim Cap, Cells 5&6	$1,703,839
Final Cap and Closure	$58,125,721
Disposal Operations	$320,232,000
Leachate/CW Treatment Ops	$25,300,000
Cell Security Operations	$83,685,555
Long Term Monitoring	$38,867,482
Project Management	$20,311,832
Overhead	$0
Contingency	$0
Total	$708,456,726

Capacity Increase Value Through VR	
Parameter	**Value**
EMDF Total Capacity, yd^3	2,500,000
Operating cost per yd^3 of disposal capacity	$128.09
Average Volume per Cell, yd^3	416,667
Total Cost of VR	$37,957,934
Scenario A Capacity Gain, yd^3	**504,973**
Scenario B Capacity Gain, yd^3	**820,582**
Scenario A cost reductions:	
On-Site Transportation Savings (Sect. 5.2.4)	$7,000,000
Construction of Cell 6[1]	$26,336,025
Operations[2]	$32,023,200
Total Cost Avoided	$65,359,225
Net Cost Avoided (minus cost of VR)	$27,401,291
Scenario B cost reductions:	
On-Site Transportation Savings (Sect. 5.2.4)	$7,000,000
Construction of Phase III	$54,586,762
Operations[3]	$48,034,800
Total Cost Avoided	$109,621,562
Net Cost Avoided (minus cost of VR)	$71,663,628

[1]Not including engineering, considered sunk cost

[2]Assume 10% reduction for 20% reduction in EMDF capacity

[3]Assume 15% reduction for 33% reduction in EMDF capacity

5.3 RECYCLING

5.3.1 Regulatory Climate

The U.S. Environmental Protection Agency (EPA) is raising awareness and promoting 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 encourage 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 gals 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 lbs 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 2012c). 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 efforts by heavy equipment operators to gut the buildings before they came down. Some 106 tons of metal came from one large building alone, 16 tons more than the original estimate. LANL's demolition program director is quoted as saying, "Recycling metal from a demolition project reduces costs and cuts the amount of waste that goes to a landfill. We put a lot of effort into getting metal separated from the debris and making sure it isn't contaminated so it can be recycled."

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 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 the 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 about measuring 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).

One option to consider when planning D&D work for nuclear facilities would be to selectively remove materials from contaminated zones first, then re-characterize the facility and perform 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, the EPA, and the NRC (DOE 2009a). 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 requires 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.

5.3.2 Recycling Potential

The two materials that would be most beneficial to recycle would be concrete and metals. Concrete can be recycled to use as aggregate for new concrete or for base material or roads or new facilities. Demolition of concrete that is cleared for release could be crushed and screened on site, or could be transported to a recycling facility where crushing and screening could be performed. If the material were crushed and screened to meet aggregate specifications, the commercial value would be about $4.41 per ton in Tennessee, roughly equal to about $7.17 per yd^3 (USGS 2011). The crushed material would have to be moved to a location where the public could access it, so transportation costs would apply, as well as the cost of creating and maintaining a storage area for the material. The cost of crushing the material alone at about $6.63 per yd^3 (Attachment B, Table 7) is nearly equal to the commercial value, not including the additional cost of screening and losses from fines that pass through the screens. In addition, the material would no longer be available to replace clean fill at the EMDF or be used as base fill for other in-house DOE construction projects. The cost of processing and loss of other beneficial uses of crushed concrete appear to outweigh the commercial value of the product in this case, so recycling for commercial use is not recommended.

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) available for VR processing and potential recycle is about 179,042 tons. If 25% (44,761 tons) of the total quantity of metal is recycled at an average of $0.15 per lb, the commercial value is about $13.4M. Recycling will require that the material is free of contamination. Consequently, exhaustive characterization activities would be necessary to certify that the metals are clean unless it can be proven based on process knowledge that the equipment did not handle radiological or hazardous materials.

Bechtel Jacobs Company LLC (BJC) developed a cost estimate for additional contamination surveys that would be required for free-release of metals from D&D projects (BJC 2004). The approach is based on DOE 5400.5 requirements and includes radiation control technician support, PPE, survey instruments, and scanning operations. The estimated cost is \$32 per yd^3 of recycled material. From the CARAR density data, the bulk density of as-generated metal debris is 1,044 lb per yd^3. Using this density, the cost for additional survey requirements is about \$0.03 per lb. Transporting the metals to a local recycler would cost in the range of \$0.02 to \$0.03 per lb based on a cost of \$220 per 10 yd^3 transported. The total for additional surveys and transportation would be about \$5M for 44,761 tons of material. After deducting this from the potential commercial value (\$13.4M), the balance would be about \$8.4M gained through commercial sale.

EMDF capacity gains are realized from metal recycling including the as-disposed volume that would have been required for the metals and the required clean-fill. For the 44,761 tons of metal estimated for recycle, the clean fill required if disposed at the EMDF would be approximately 60,436 yd^3 based on CARAR requirements. The as-disposed volume would be 25% of the Table B-3. "As-D volume for Material 2" for equipment and structural steel, or 11,238 yd^3. Adding this volume to the clean fill requirement gives a total capacity gain of 71,673 yd^3. For this quantity of material, it is assumed that incremental EMDF construction and operating cost savings would not be significant. Assuming the value of clean fill is the same as the cost of transporting at \$220 per 10 yd^3, the cost savings would be \$1.3M. The sum of the potential commercial value and clean fill savings is \$9.7M for metal recycling.

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, especially if the facility has its own land disposal facility.

5.4 PROJECT SEQUENCING

Project sequencing refers to a scheduling approach employed to use contaminated or clean waste soil from RA projects in place of clean fill for filling the debris voids in the EMDF. The required capacity for the EMDF was estimated based on the RI/FS waste volume estimate from the time when the EMWMF fills to capacity in FY2020 through FY2042 (see Chapter 2). The estimate from Appendix A, Table A-4 indicates an as-disposed volume of waste soil of 492,836 yd^3 including approximately 28% uncertainty will be generated in that time frame along with 763,683 yd^3 of debris. The quantity of clean fill needed for this quantity of debris is approximately 1,205,945 yd^3 assuming all of the waste soil is used to replace clean fill material. Current predictions for clean fill demand provided in the 2011 CARAR and in Appendix A of this RI/FS indicate that 98% of the waste soil is used to replace clean fill that would otherwise be needed for placement of the debris.

Sequencing of planned projects in the CARAR and RI/FS waste volume estimate are based on assumptions such as funding, prioritization, and contracting that can be uncertain and subject to change. As a result, the sequence of future projects identified in current plans may not be the actual sequence at the time of implementation.

Sequencing projects in a way that makes use of waste soil as fill material can result in cost benefits and reduce the disposal capacity needed. In cases where there are scheduling difficulties that interfere with the ability to utilize waste soil effectively, placement of waste soil in the landfill could be delayed until debris is placed in the landfill and waste soil can be used to fill the debris voids and replace clean fill. In current EMWMF operations, space within the operating disposal cells is used to stockpile excess quantities of waste soil that can be utilized as debris is delivered for placement. Operating personnel report that the use of waste soil to replace clean fill is routinely performed.

The total as-disposed volume of waste soil at 492,836 yd^3 is slightly greater than the volume of a complete disposal cell; therefore, the consequence of not sequencing disposal of any waste soil with debris disposal would be equivalent to construction and operational cost of an additional cell, or roughly $65.4M as indicated in Table B-4 for VR Scenario A.

5.5 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. When waste generation forecasts are developed, facility type and characterization data is used to determine waste disposition. D&D materials for facilities that are classified "other industrial" are assumed to be acceptable for the ORR Landfill. In most cases D&D materials from facilities that are classified as "nuclear" or "radiological" are assumed to be disposed at the EMWMF. However, there are typically clean areas associated with contaminated facilities that could possibly be demolished in a manner that avoids comingling with materials from potentially contaminated zones, thus creating an opportunity for disposing at the ORR Landfill.

An Industrial Landfill V expansion 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. Additional areas of expansion in Industrial Landfill V and Industrial Landfill VII that are part of the permitted landfills will be developed/built as capacity is needed.

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 deeper liner and capping system with additional geomembrane layers, an additional biointrusion layer, and an additional leachate leak detection system. These requirements would more than double the construction costs of the CERCLA landfill compared to ORR Landfills.

DOE and TDEC have established criteria for disposal of non-hazardous wastes containing low levels of residual radioactive materials at the ORR Landfill operation comprised of Industrial Landfill V and Construction/Demolition Landfill VII. Operation of these landfills for disposal of non-hazardous, non-radioactive waste is permitted by the TDEC Division of Solid Waste. DOE, in cooperation with TDEC, developed site-specific authorized limits for disposal of wastes meeting derived volumetric concentration limits for specified radionuclides, and these authorized limits have been successfully implemented
since 2003.

DOE and its contractors are currently developing documentation for revision of the current authorized limits to allow disposal of wastes containing additional radionuclides for which volumetric concentration limits have not been previously approved, and also to develop site-specific authorized limits for surface contaminated wastes. The WAC and operating practices at the landfills previously have precluded disposal of wastes containing surface contamination in excess of the criteria for unrestricted release, whereas such restrictions are not necessary for protection of worker and public health and safety or the environment. In some cases, wastes expected to contain only low levels of radioactive materials that otherwise would be acceptable for disposal at the landfills have been identified for disposal at EMWMF because the costs for surface contamination surveys required by the landfill operating procedures have been determined to be prohibitive. DOE and its contractors are currently evaluating the landfill acceptance criteria and operational procedures to determine if additional wastes can be safely and cost effectively managed at these facilities in compliance with current DOE requirements.

5.6 VOLUME REDUCTION AND OFF-SITE DISPOSAL

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. The use of VR equipment to size-reduce and increase the bulk density of demolition debris would 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 G. This information was used as a basis for determining the economic benefit of various VR approaches.

Under the Off-site Disposal Alternative, all non-classified LLW and LLW/Toxic Substance Control Act of 1976 waste and classified LLW 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 NNSS in Nye County, NV. The remaining 3% of LLW/RCRA waste would be shipped to Energy*Solutions* in Clive, UT. For purposes of this VR comparison, shipment of LLW debris to NNSS is assumed.

Transportation for the off-site disposal estimate assumes that LLW debris would be transported by intermodal container to the truck-to-rail transfer facility at ETTP for rail shipment to Kingman, AZ and subsequent transfer to trucks for transport to NNSS. It is assumed that DOE would lease dedicated railcars. Incoming intermodal containers could be staged directly on the cars until one or more cars could be transferred to the main line and shipped.

The capacity of an intermodal container is assumed to be a maximum of 36,000 lb or 11 yd^3 and a single railcar is assumed to carry eight intermodal containers. Transportation cost for one railcar from the ETTP to Kingman, AZ is \$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 the NNSS is about \$1,370 per intermodal container. The intermodal containers are taken into the appropriate disposal cell, and emptied per approved procedures. Empty containers would be surveyed at the disposal facility for release and return to ORR.

The cost effectiveness of size reduction would depend upon the type and quantity of material to be shipped off site. As-generated materials that have a relatively high bulk density such as concrete and masonry may not be as cost effective to crush further because the truckload quantity would be limited by weight rather than volume. However, larger quantities of low-density materials could be shipped per truckload by size-reducing, increasing the bulk density, and increasing the quantity and weight shipped per truckload. These materials include equipment with large void fraction, large diameter ductwork and pipe, structural steel, light framing, siding, small tanks, asphalt shingles and other roofing materials, containers, furniture, trash, and wood. An analysis was performed to determine those materials that would benefit from VR processing prior to off-site disposal. Table B–5 summarizes the analysis. 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 assuming a maximum volume of 11 yd^3 and maximum net weight of 36,000 lb per intermodal. 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. The cost per unit volume for Off-site Disposal was applied to the avoided shipment volume determine the final cost value.

The results indicate that decreasing the void fraction of these materials could reduce the number of shipments required for a given mass by a large margin. The avoided shipping volume would be expected to be more than 318,000 yd^3 which is equivalent to an avoided cost of over \$251M in 2012 dollars (after subtracting the VR processing costs). This reduces the unit costs for off-site shipment from \$909.50 per yd^3 to \$640.84 per yd^3, or nearly 30%.

Comparing on-site and off-site unit costs indicates a substantial difference in favor of on-site disposal. The unit rate for on-site disposal was determined by dividing the total cost of the EMDF at \$708,456,726 (from Table B-4) by the total as-generated volume of debris and soil 2,194,348 from Appendix A, Table A-3, resulting in a unit cost of about \$323 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 and clean fill required. The unit cost of air space is given by the total EMDF cost divided by the total as-disposed air space of 2,500,000 yd^3 giving \$283.38 per yd^3. Table B-6 applies this unit cost to the as-disposed volume of waste types with clean requirements. Unit costs are higher for materials that occupy more landfill air space due to higher ratios of as-disposed to as-generated volumes and significant clean fill requirements.

A similar evaluation was performed to determine on-site disposal costs by waste type including VR processing. The VR conditions defined in Table B-3 for both Scenarios A and B were used in the evaluation and the cost per unit of EMDF air space was determined by dividing the reduced EMDF cost by the reduced landfill capacity required as a consequence of VR processing. The estimated Scenario A cost savings, \$27,401,291, subtracted from the initial EMDF cost, \$708,456,726, gives \$681,055,435. For Scenario B, the new reduced cost is \$636,793,098. When these revised costs are divided by the reduced capacity values (2,083,333 yd^3 for Scenario A and 1,666,667 yd^3 for Scenario B), the unit values of EMDF air space are \$326.91 per yd^3 for Scenario A and \$382.08 per yd3 for Scenario B. These air space values are somewhat higher than the initial air space value of \$323 per yd^3, mainly because it was conservatively assumed that the cost of many work elements (remedial design, early actions, leachate treatment, cell security operations, long term monitoring, and project management) would not change as a consequence of VR processing, and also due to the cost of VR. The revised EMDF unit cost was applied to the estimated as-disposed volumes for the various waste types after VR processing with the revised clean fill requirements. The unit cost for each waste type was determined by dividing the original as-generated volume by the total cost of air space for each waste type as shown in Table B-7.

Similarly, the cost of off-site disposal varies by waste type. To determine transportation costs by waste type, the cost data used in Appendix G was applied to the waste types given in Table B-5 and the cost per unit volume determined both with and without VR processing. In this case, the volume transported per intermodal containers was determined based on waste density and maximized for each waste type to minimize packaging costs and the number of shipments. Table B-8 provides a summary of unit costs in \$/yd^3 as-generated material by waste type for off-site disposal. Materials with higher density and lower void volume exhibit higher off-site disposal costs because shipments are weight limited and lesser volumes can be transported per shipment. Table B-9 provides a summary of the unit costs in \$/yd^3 as-generated material for both on-site and off-site disposal with and without VR processing. In almost all cases, off-site disposal costs are significantly higher than on-site disposal. The exception is legacy material due to its lower initial bulk density and the ability to transport greater quantities per trip after VR processing. The results indicate that waste management strategies that attempt to conserve EMDF capacity through off-site disposal are unlikely to be cost effective.

Table B–5. Estimate of VR Cost Benefit for Off-site Disposal Alternative

Description	As-G bulk Density (lb/yd³)	As-G Volume for Processing*, yd³	Weight, Tons	Volume After Size-Reducing mat'l, yd³	Size Reduction Basis	Bulk Density After VR (lb/yd³)	Net wt. Per Intermodal Container with 11 yd³ As-G mat'l	Net wt. Per Intermodal Container with 11 yd³ VR mat'l	Additional wt. Per Intermodal, lb	Additional wt. Overall, lb	Equivalent As-G Off-site Disposal Volume Avoided, yd³
Thick walled steel, large machine tools, large electric motors, process vessels	680	78,024	26,528	39,012	50% size reduction	1,360	7,480	14,960	7,480	26,528,309	39,012
>2" pipe, structural steel, crane structures	1,040	261,163	135,805	130,581	50% size reduction	2,080	11,440	22,880	11,440	135,804,637	130,581
Reinforced concrete, concrete block, brick, shield walls	2,600	450,870	586,131	360,696	20% size reduction	3,250	28,600	35,750	7,150	234,452,532	90,174
Small buildings, small cooling towers, structural framing, interior and exterior finishes, flooring, wooden structures	1,620	74,867	60,642	44,920	40% size reduction	2,700	17,820	29,700	11,880	48,513,514	29,947
Ventilation duct, light framing, < 2 inch pipe, siding, small tanks	1,040	32,133	16,709	19,280	40% size reduction	1,733	11,440	19,067	7,627	13,367,386	12,853
Asphalt shingles, low-slope built-up roofs, vapor barrier, insulation, roof vents, flashing, felt	1,520	37,580	28,561	22,548	40% size reduction	2,533	16,720	27,867	11,147	22,848,878	15,032
Containers, furniture, trash, wood	640	2,098	671	1,259	40% size reduction	1,067	7,040	11,733	4,693	537,126	839
Totals:		936,736	855,048	618,297						482,052,383	318,439

Off-site Disposal Cost per yd³ (2012 dollars)	$909.50
Off-site Disposal Savings, 2012 dollars	$289,620,214
Total VR Costs for Materials	$37,957,934
Net transportation costs avoided:	$251,662,280
Off-site Disposal Cost per yd³ with VR (2012 dollars)	$640.84

* From Material 2 in Table B-3
**Assumes 36,000 maximum net weight per intermodal.

Table B–6. On-site Disposal Cost by Waste Type without Volume Reduction

Description	As-G vol., yd^3	As-D vol., yd^3	Clean fill required for As-G vol., yd^3	Basis	As-disposed vol. for waste and clean fill, yd^3	Cost of EMDF airspace for waste and clean fill	Cost per yd^3 of As-G material
Thick walled steel, large machine tools, large electric motors, process vessels	260,081	15,734	150,736	Clean fill ratio is 9.58 for as-disposed equipment (soil: debris)	128,787	$36,495,894	$140.32
>2" pipe, structural steel, crane structures	348,217	32,219	213,614	Clean fill ratio is 6.63 for as-disposed metals (soil: debris)	192,430	$54,531,381	$156.60
Reinforced concrete, concrete block, brick, shield walls	601,160	480,928	601,160	Clean fill ratio is 1.25 for as-disposed dense concrete (soil: concrete)	931,799	$264,055,573	$439.24
Small buildings, small cooling towers, structural framing, interior and exterior finishes, flooring, wooden structures	99,822	49,911	112,799	Clean fill ratio is 2.26 for as-disposed construction debris (soil: debris)	134,510	$38,117,864	$381.86
Ventilation duct, light framing, < 2 inch pipe, siding, small tanks	42,844	21,422	48,414	Clean fill ratio is 2.26 for as-disposed construction debris (soil: debris)	57,733	$16,360,403	$381.86
Asphalt shingles, low-slope built-up roofs, vapor barrier, insulation, roof vents, flashing, felt	50,107	25,054	0	No clean fill required, self-filling	25,054	$7,099,755	$141.69
Containers, furniture, trash, wood	2,798	1,399	2,826	Clean fill ratio is 2.26 for as-disposed construction debris (soil: debris)	3,518	$996,910	$356.35
Totals	1,405,030	626,668	1,129,549		1,473,830		

Table B–7. On-site Disposal Cost by Waste Type with Volume Reduction

Description	Initial As-G vol., yd³	As-G vol. for VR processing, yd³	As-D vol. for VR processed material., yd³	As-G vol. not VR processed, yd³	As-D vol. for material not VR processed, yd³	Scenario A				Scenario B			
						Clean fill for VR and non-VR material, yd³	As-D vol. of VR and non-VR material with clean fill, yd³	Cost of EMDF air space	VR and EMDF disposal cost per yd³ of As-G Material	Clean fill for VR and non-VR material, yd³	As-D vol. of VR and non-VR material with clean fill yd³	Cost of EMDF air space	VR and EMDF disposal cost per yd³ of As-G Material
Thick walled steel, large machine tools, large electric motors, process vessels	260,081	78,024	4,720	182,057	11,014	116,183	131,918	$43,124,788	$165.81	116,183	131,918	$50,402,592	$193.80
>2" pipe, structural steel, crane structures	348,217	261,163	24,165	87,054	8,055	108,015	140,235	$45,843,683	$131.65	108,015	140,235	$53,580,332	$153.87
Reinforced concrete, concrete block, brick, shield walls.	601,160	450,870	360,696	150,290	120,232	285,551	766,479	$250,567,192	$416.81	-30,058	450,870	$172,266,639	$286.56
Small buildings, small cooling towers, structural framing, interior and exterior finishes, flooring, wooden structures	99,822	74,867	37,433	24,956	12,478	78,959	128,870	$42,128,540	$422.04	78,959	128,870	$49,238,216	$493.26
Ventilation duct, light framing, < 2 inch pipe, siding, small tanks	42,844	32,133	16,067	10,711	5,356	33,890	55,312	$18,081,808	$422.04	33,890	55,312	$21,133,321	$493.26
Asphalt shingles, low-slope built-up roofs, vapor barrier, insulation, roof vents, flashing, felt	50,107	37,580	18,790	12,527	6,263	0	25,054	$8,190,186	$163.45	0	25,054	$9,572,374	$191.04
Containers, furniture, trash, wood	2,798	2,098	1,049	699	350	1,978	3,377	$1,103,839	$394.58	1,978	3,377	$1,290,124	$461.17
Total Volumes	1,405,030	936,736	462,920	468,294	163,747	624,577	1,251,244			308,968	935,635		

Table B–8. Off-site Disposal Cost by Waste Type, with and without Volume Reduction

Waste Type	Waste Density, As-G (lb/yd^3)	Net Volume Shipped (yd^3)	Net Volume per Container (yd^3)	Number of intermodal trips	Number of containers purchased	Packaging Cost	Number of round-trips	Total Transport Cost	Total Disposal Cost	VR Processing Cost/yd^3 of As-G Material	Total VR, transport, and disposal cost	Cost per yd^3 of As-G material
Without VR Processing												
Thick walled steel, large machine tools, large electric motors, process vessels	680	78,024	18	4,335	42	$2,865,415	542	$19,727,007	$30,567,635	NA	$53,160,056	$681.33
>2" pipe, structural steel, crane structures	1,040	261,163	18	14,509	139	$9,581,125	1,814	$66,025,548	$102,315,736	NA	$177,922,410	$681.27
Reinforced concrete, concrete block, brick, shield walls	2,600	450,870	7.2	62,621	597	$41,333,621	7,828	$284,934,910	$176,637,439	NA	$502,905,971	$1,115.41
Small buildings, small cooling towers, structural framing, interior and exterior finishes, flooring, wooden structures	1,620	74,867	11.5	6,510	63	$4,302,980	814	$29,627,043	$29,330,462	NA	$63,260,485	$844.98
Ventilation duct, light framing, < 2 inch pipe, siding, small tanks	1,040	32,133	18	1,785	18	$1,184,505	224	$8,144,249	$12,588,800	NA	$21,917,554	$682.09
Asphalt shingles, low-slope built-up roofs, vapor barrier, insulation, roof vents, flashing, felt	1,520	37,580	12.3	3,055	30	$2,022,190	382	$13,903,863	$14,722,870	NA	$30,648,923	$815.56
Containers, furniture, trash, wood	640	2,098	18	117	2	$82,538	15	$541,292	$821,991	NA	$1,445,821	$689.09
With VR Processing												
Thick walled steel, large machine tools, large electric motors, process vessels	1,360	39,012	13.8	2,827	27	$1,866,283	354	$12,878,712	$15,283,817	87.93	$36,889,502	$472.79
>2" pipe, structural steel, crane structures	2,080	130,581	9	14,509	139	$9,581,125	1,814	$66,025,548	$51,157,868	87.93	$149,728,584	$573.32
Reinforced concrete, concrete block, brick, shield walls	3,250	360,696	5.8	62,189	593	$41,049,300	7,774	$282,969,491	$141,309,951	11.8	$470,649,012	$1,043.87
Small buildings, small cooling towers, structural framing, interior and exterior finishes, flooring, wooden structures	2,700	44,920	6.9	6,510	63	$4,302,980	814	$29,627,043	$17,598,277	19.18	$52,964,240	$707.45
Ventilation duct, light framing, < 2 inch pipe, siding, small tanks	1,733	19,280	10.8	1,785	18	$1,184,505	224	$8,144,249	$7,553,280	19.18	$17,498,348	$544.56
Asphalt shingles, low-slope built-up roofs, vapor barrier, insulation, roof vents, flashing, felt	2,533	22,548	7.4	3,047	30	$2,017,235	381	$13,867,111	$8,833,722	19.18	$25,438,860	$676.92
Containers, furniture, trash, wood	1,067	1,259	17.5	72	1	$49,462	9	$327,513	$493,195	19.18	$910,412	$433.91

Table B–9. Summary of Unit Costs* for On-site and Off-site Disposal with and without Volume Reduction

Description	On-site Disposal			Off-site Disposal	
	Unit costs without VR	Unit costs with VR, Scenario A	Unit costs with VR, Scenario B	Unit costs without VR	Unit costs with VR
Thick walled steel, large machine tools, large electric motors, process vessels	$140.32	$165.81	$193.80	$681.33	$472.79
>2" pipe, structural steel, crane structures	$156.60	$131.65	$153.87	$681.27	$573.32
Reinforced concrete, concrete block, brick, shield walls	$439.24	$416.81	$286.56	$1,115.41	$1,043.87
Small buildings, small cooling towers, structural framing, interior and exterior finishes, flooring, wooden structures	$381.86	$422.04	$493.26	$844.98	$707.45
Ventilation duct, light framing, < 2 inch pipe, siding, small tanks	$381.86	$422.04	$493.26	$682.09	$544.56
Asphalt shingles, low-slope built-up roofs, vapor barrier, insulation, roof vents, flashing, felt	$141.69	$163.45	$191.04	$815.56	$676.92
Containers, furniture, trash, wood	$356.35	$394.58	$461.17	$689.09	$433.91

*Unit Costs are in $/yd³ as-generated material

6. PREVIOUS VOLUME REDUCTION EVALUATIONS

DOE published the *Remedial Design Report for the Disposal of Oak Ridge Reservation Comprehensive Environmental Response, Compensation, and Liability Act of 1980 Waste*, Oak Ridge, Tennessee in January 2001 (DOE 2001b). In August 2001, DOE published the *Waste Management Program Plan for Oak Ridge Reservation Comprehensive Environmental Response, Compensation, and Liability Act – Generated Waste* (DOE 2001b). 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 may require additional clean soil to achieve an appropriate soil-to-debris ratio. Also, the volume of contaminated/slightly contaminated soil disposed at EMWMF should be maximized to reduce the demand for clean soil fill.

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 the EMWMF did not have adequate capacity to accommodate the projected CERCLA waste volumes and the EMWMF has since been expanded.

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. The study did not consider VR of concrete and masonry debris materials. The study was intended to replace the need for individual projects to assess the appropriateness of implementing VR technologies. Two size-reduction technologies were evaluated, including shredding and compacting. It was concluded that, at most, 100,000 yd^3 of capacity could be gained by applying size-reduction technologies to the targeted waste streams. The size reduction technologies were evaluated against a 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 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.

Since opening of the EMWMF in 2002, waste VR methods, segregation, and recycling of CERCLA wastes, have been implemented on a limited project basis. The limited implementation of waste VR technologies may be due to cost competition among bidders of individual projects and the added expense of deploying size reduction equipment for individual projects that generate relatively small volumes of waste. Cost savings and other benefits could be realized by implementation of waste VR across projects. Uncertainty factors such as funding, project sequencing, and contracting that could impact practical implementation of a multiple project approach are a significant consideration.

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, also to primarily maximize transport efficiency but also resulting in reduction of waste volume placed in the cell.

The FEMP constructed an on-site disposal facility with a capacity of over 2.9M yd^3 for disposal of the vast majority of remediation waste, including demolition debris, generated by the closure of the former Feed Materials Production Center. The WAC for the 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; sequencing of D&D and soil remediation projects was essential to maintaining this balance. Early stages of the RAs focused almost exclusively on soil remediation; this caused most of the first cell to be filled with waste soil since D&D had not yet begun. Upon realization of this disparity, new sequencing was initiated to assure that the proper balance was kept. Additionally, Fernald did implement concrete crushing actions, especially on building foundations/slabs. This crushed concrete was used in lieu of soil as filler material and in the construction of the liner.

A strong recommendation from former site personnel was to size reduce debris at the demolition site prior to transport to and placement in the disposal cell. This could be 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.

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. It was also recognized that crushed concrete could be used as fill material at the EMWMF to reduce clean fill requirements. However, the concrete-based fill material had an unwanted consequence of leaching unacceptable quantities of chromium-6 (Cr+6) into contact water and leachate collected on site. Additional treatment units were introduced in the EMWMF contact water system to reduce the Cr+6 ions to Cr+3 that precipitates and alleviates the environmental issue. In addition, landfill operations procedures were modified to require the crushed concrete be mixed or layered with soil to inhibit Cr+6 leaching.

Excavator attachments for size-reduction are used routinely for D&D projects, however, the primary purpose of the excavators is for building demolition and could not be used cost effectively for VR processing alone. As described previously, excavators would be required to support VR operations by size-reducing as necessary for placement in VR equipment feed hoppers.

8. SUMMARY

VR approaches and the potential benefits, based on this study, are summarized in Table B-6. The largest payback and EMDF capacity gain could be achieved with deployment of size reduction equipment on a multiple project or programmatic basis. Projections indicate that the volume of concrete and mortar debris is a large fraction of total debris volumes and can be used to reduce the demand and cost of clean fill. Based on the predicted waste volumes, EMDF capacity gains from size-reduction operations could potentially reduce disposal capacity needs by up to two disposal cells (over 800,000 yd^3). As shown in the estimated cost of the stationary shear operation, the cost of VR processing increases substantially if the debris is contaminated to a level that requires an enclosure and contamination control measures. It is assumed in this case that only the equipment and heavy steel from demolition of Y-12 facilities would require enclosed facilities for VR. To date, most of the D&D projects executed on the ORR have been performed as open-air demolitions.

If funds are committed to additional characterization efforts, cost and capacity gains from recycling and segregating more material to the ORR Landfill are also significant. Once the NRC and DOE have established a sound technical basis for survey and release solid materials associated with radiological facility activity, recycling efforts should focus on recovery and recycle of metals. Segregation of additional wastes to the ORR Landfill is beneficial due to the lower construction costs associated with the liner and final cover systems. Additional efforts to segregate and selectively remove non-contaminated materials during D&D activities along with revision of the current authorized limits to allow disposal of wastes containing additional radionuclides at the ORR Landfill could conserve EMDF capacity and reduce disposal costs significantly.

The benefits of project sequencing are apparent from experience at other DOE sites and therefore are inherent in the existing plan for the EMDF. If waste soil is not used as fill material for void space within debris material, additional disposal space beyond the EMDF design capacity may be needed. The EMDF approach for waste placement must include space allowance for stockpiling waste soil for use as fill material to avoid the cost and capacity loss from the use of excessive amounts of clean fill.

VR approaches discussed could be cost effective when applied to the Off-site Disposal Alternative addressed in this RI/FS. The cost of transportation and off-site disposal exceeds the cost of VR processing. Consequently, increasing the bulk density of debris translates directly to a lesser number of costly off-site shipments and lower disposal fees for the off-site facilities.

Table B–10. Summary of Volume Reduction Benefits for the EMDF

Parameter	Volume Reduction Approach				
	Size Reduction	**Recycling**	**Compaction**	**Sequencing**	**Segregation**
Basis	Shredding, crushing, and shearing operations are deployed at multiple sites as a programmatic effort.	Recycling of 25% of metal debris (44,761 tons)	Drum compactor used for PPE and DAW	RI/FS waste volume estimate assumes virtually all waste soil is used to replace clean fill (492,836 yd^3 as-disposed)	Debris is segregated and diverted to the ORR Landfill.
Cost of method	$37.96M	$5M for characterization and transportation	$60,000 capital; $260/yd^3$ materials and labor	Negligible	The cost of additional facility characterization and field surveys
Cost savings	Scenario A:$27.4M Scenario B: $71.7M	$9.7M from sale and EMDF clean fill savings	$1.8 M	$65.4M (cost avoided through assumed sequencing)	Reduced landfill construction and operations costs.
EMDF capacity gained	Scenario A: 504,973 yd^3 Scenario B: 820,582 yd^3	71,673 yd^3	10,312 yd^3	492,836 yd^3	To be determined
Additional potential benefits	Increased landfill density with additional capacity gain of 69,438 yd^3; lower equipment maintenance costs				
Additional notes		Assumes commercial value of $0.15/lb for metals	Compares packaging PPE in B-25 box to compaction and over-packing	RI/FS waste volume estimate soil demand is based on successful sequencing.	ORR landfill construction costs are significantly lower than for EMDF.

9. CONCLUSIONS AND RECOMMENDATION

This study indicates substantial benefits are possible if VR efforts are pursued. The paybacks are greatest if the overall EMDF capacity gained is equivalent to at least one disposal cell or 416,667 yd^3. If VR is performed in combination with efforts to characterize, recycle, and segregate a moderate amount of material, EMDF capacity gains could reach the equivalent of two full cells.

Uncertainty factors such as funding, project sequencing, and contracting could impact the ability to implement VR on multiple projects. Potential ways to address the logistics of multiple project implementations include:

- Contract incentives for VR
- Including VR requirement in WAC of the new EMDF
- Deploying one VR contractor for multiple projects

Incorporating VR efforts (size reduction, recycling, enhanced characterization, and sequencing efforts) in project planning and practical field implementation could result in significant cost savings and reduced need for disposal capacity.

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ATTACHMENT A

VENDOR INQUIRY FORMS AND DATA

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.

ATTACHMENT B

VOLUME REDUCTION PROCESSING COST ESTIMATE

Table 1. Basis for Size Reduction Cost Estimate

Basis for Estimate		
Volume (yd^3)	**Weight (tons)**	**Description**
1,405,030	1,193,120	Total debris amenable to volume reduction processing, yd^3
Quantity for Processing		
146,678	106,584	Total for shredding
450,870	586,191	Total for crushing
183,161	87,660	Total for stationary shearing operation at Y-12 (54% of total)
156,026	74,673	Total for mobile shearing operations (46% of total)
936,736	855,048	Overall total for processing

Table 2. 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.
Transportation and Setup	$20,500	Assume $5K to transport; SSI tech support for one week at $100/hr with airfare and per diem ($1,500).
Labor Description	1 Operator	Operator of the shredder.
Labor Cost	$799,377	$60/hr (operating hrs + downtime).
Availability	75%	SSI
Operating hrs	10,658	10 tons per hr.
Fuel	$277,117	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.	$150,549	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.
Engineering	$10,000	Specification development, sizing, capabilities, operating features; assume 100 hrs at $100/hr.
Indirect Costs	$285,830	28% of capital, setup, fuel, maintenance, and overhaul costs.
Procurement	$7,500	Procurement documents, QA inspections, vendor qualifications, etc.; assume 100 hrs at $75/hr.

Table 3. 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)	$912,800	Quote from Eagle Crusher.
Transportation and Setup	$22,000	Assume $5K to transport; Eagle Crusher tech support for one week at $100/hr with airfare and per diem ($1,500).
Labor Description	1 Operator	Operator of the crusher.
Labor Cost	879,197	$60/hr (operating hrs + downtime).
Availability	75%	Eagle Crusher
Operating hrs	11,723	50 tons per hr.
Fuel	$468,905	10 gal/hr diesel fuel or $40/hr at $4/gal diesel.
Maintenance: Changing oil and filters; rotation of wear plates.	$50,356	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	$155,890	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.
Engineering	$10,000	Specification development, sizing, capabilities, operating features; assume 100 hrs at $100/hr.
Indirect Costs	$482,685	28% of capital, setup, fuel, maintenance, and overhaul costs.
Procurement	$7,500	Procurement documents, QA inspections, vendor qualifications, etc.; assume 100 hrs at $75/hr.

Table 4. Cost Data for Excavator Operation

Excavator Summary Information		
Parameter	**Data**	**Basis**
Manufacturer	Volvo	
Model	2010 VOLVO ECR235C	
Capacity	7.5 ton	
Capital Cost (5 units)	$1,017,500	Source of cost information: McAllister Equipment Company,. Anticipate needing five excavators at $203,500 each over the course of the operation.
Transportation and Setup	$52,500	Assume $5K to transport; Volvo tech support for one week at $100/hr with airfare and per diem ($1,500) for two units.
Labor Description	1 Operator	This excavator operator loads crushed concrete and shredded debris into transport trucks. There are dedicated operators in charge of running the crusher and shredder.
Labor Cost	2,157,398	$60/hr (operating hrs+downtime).
Availability	90%	Engineering judgment.
Operating hrs	32,688	Combined hrs for shredder and crusher.
Fuel	$653,757	5 gal/hr diesel fuel or $20/hr at $4/gal diesel for 150 HP diesel engine.
Maintenance: Changing oil and filters; inspections	$134,837	Oil/filter change requiring 2 operators for 2 hrs every 200 hrs + 1/2 hr/day checkout.
Major overhauls	$200,000	Five major engine overhauls.
Engineering	$2,000	Specification development, sizing, capabilities, operating features; assume 20 hrs at $100/hr.
Indirect Costs	$617,578	30% of capital, setup, fuel, maintenance, and overhaul costs.
Procurement	$1,500	Procurement documents, Quality Assurance inspections, vendor qualifications, etc.; assume 20 hrs at $75/hr.

Table 5. Cost Data for Stationary Shear Operation

Stationary Shear Summary Information		
Parameter	**Data**	**Basis**
Manufacturer	Harris	
Model	BHS-30-1123-B	
Rated Capacity	30 Tons/hr max (2.75 cuts per minute at rated thickness)	15.75 tons per hr based on K-33 shear performance (Harris contact)
Capital Cost	$6,850,000	Quote from Harris
Transportation and Setup	$478,720	Per Harris contact, 6 months to assemble for K-33 project; assume 6 personnel and lease of crane.
Labor Description	8 personnel	One supervisor, one operator for the shear, two operators to work with the excavator operator to manage the feed and product, one maintenance technician, one facility manager, and two radiation protection technicians.
Labor Cost	$3,562,049	$60/hr (operating hrs + downtime)
Availability	75%	Per Harris contact
Operating Hours	5,566	15.75 tons per hr based on K-33 shear performance
Utility Costs	$1,011,384	1,600 HP total for electric motors of shear in addition to utility requirements for the containment enclosure
Maintenance	$400,512	Rotating and replacing knife blades and greasing the equipment and support systems occupies 6 personnel in two 12-hr shifts, once per month. Three sets of blades are replaced per year at about $10K per set (total $30K/yr). Replacing hydraulic fluid (5,000 gal per change) every 2 years using AW46 hydraulic fluid costs at $5/gal = $12.5K/yr.
Enclosure	$5,033,053	This enclosure is designed for contamination control for materials suspected to be rad contaminated at low-level criteria. The facility cannot accept mixed waste.
Engineering	$1,236,177	Assume 10% of total construction costs.
Indirect Costs	$3,609,040	30% of capital, setup, power, and maintenance costs
Procurement	$7,500	Procurement documents, QA inspections, vendor qualifications, etc.; assume 100 hrs at $75/hr

Table 6. Cost Data for Mobile Shear Operation.

Mobile Shear Summary Information		
Parameter	**Data**	**Basis**
Manufacturer	Harris	
Model	GS-11-E-4 S/B/L	
Rated Capacity	15-40 tons/hr	15.75 tons per hr based on K-33 shear performance (Harris contact)
Capital Cost	$1,800,000	Budget quote from Harris
Transportation and Setup	$1,027,800	Assume $5K to deliver; Harris tech support for 60 days at $100/hr with airfare and per diem ($1,500). Three operating personnel required in addition to Harris rep. System relocation would occur three times, 60 days per move, and require the lease of a 80 ton crane.
Labor Description	4 personnel	One supervisor, one operator for the shear, two operators to work with the excavator operator to manage and package the product.
Labor Cost	$1,422,346	$60/hr (operating hrs + downtime)
Availability	75%	Per Harris contact
Operating hrs	4,741	15.75 tons per hr based on K-33 shear performance
Electricity	$151,300	1,600 HP total for electric motors
Maintenance	$234,036	Rotating and replacing knife blades and greasing the equipment and support systems occupied 4 personnel in two 12-hr shifts, once per month. Three sets of blades are replaced per year at about $7K per set (total $21K/yr). Replacing hydraulic fluid (3,700 gal per change) every 2 years using AW46 hydraulic fluid costs at $5/gal = $9.25K/yr. It can be filtered and re-used in the unit for up to 10 years if necessary.
Foundation pads	$60,000	It is assumed that the materials processed by this shear are primarily non-contaminated structural steel and other heavy-walled materials. Assume three equipment pads at $20/ft^2 based on PWS project zeolite system foundation with overhead and contingency. Assume 1,000 ft^2 per pad.
Engineering	$215,700	Assume 10% of total construction costs.
Indirect Costs	$963,941	30% of capital, setup, power, and maintenance costs
Procurement	$7,500	Procurement documents, QA inspections, vendor qualifications, etc.; assume 100 hrs at $75/hr

Table 7. Compiled Cost Data for Size Reduction Operations

VR Processing Costs					
Cost Element	**Shredder**	**Crushers (2)**	**Stationary Shear**	**Mobile Shear**	**Excavators (5)**
Equipment	$325,000	$912,800	$6,850,000	$1,800,000	$1,017,500
Transportation and Setup	$20,500	$21,000	478,720	$1,027,800	$52,500
Labor	$799,377	$879,197	3,562,049	$1,422,346	$2,157,398
Fuel	$277,117	$468,905	1,011,384	$151,300	$653,757
Maintenance	$330,149	$206,245	400,512	$234,036	$334,837
Facility	NA	NA	$5,033,053	$60,000	NA
Engineering	$10,000	$10,000	1,236,177	$215,700	$2,000
Indirect Costs	$285,830	$482,685	3,609,040	$963,941	$617,578
Procurement	$7,500	$7,500	7,500	$7,500	$7,500
Total cost	$2,055,474	$2,988,333	$21,566,330	$5,882,623	$4,843,070
Cost per hr, including capital	$193	$255	$3,875	$1,241	$148
Yd^3 processed	146,678	450,870	183,161	156,026	936,736
$Cost/yd^3$	$14.01	$6.63	$121.14	$37.70	$5.17

Table 8. Summary Volume and Cost Data for VR Operations.

Item	Volume, yd^3	Cost
Total capital costs, including equipment, setup, facility, engineering, and procurement costs		$19,110,251
Total operating costs		$12,888,610
Indirect costs		$5,959,074
Total VR costs		$37,957,934
Volume of debris processed, yd^3	936,736	$\$40.52/yd^3$
EMDF capacity gained for Scenario A, yd^3	504,973	$\$75.17/ yd^3$
EMDF capacity gained for Scenario B, yd^3	820,582	$\$46.26/ yd^3$

APPENDIX C

ON-SITE DISPOSAL ALTERNATIVE SITE DESCRIPTION

CONTENTS

FIGURES

TABLES

ACRONYMS

ANA	Aquatic Natural Area
AWQC	ambient water quality criteria
BCBG	Bear Creek Burial Ground
BCV	Bear Creek Valley
BNI	Bechtel National, Inc.
BYBY	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
ETTP	East Tennessee Technology Park
MSL	mean sea level
NAAQS	National Ambient Air Quality Standards
ORERP	Oak Ridge Environmental Research Park
NT	Northern Tributary (of Bear Creek)
ORNL	Oak Ridge National Laboratory
ORO	Oak Ridge Office
ORR	Oak Ridge Reservation
RA	Reference Area
RCRA	Resource Conservation and Recovery Act of 1976
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
S.U.	standard unit
SNS	Spallation Neutron Source
SR	State Route
TCE	trichloroethene
U.S.	United States
USGS	U.S. Geographic Services
UEFPC	Upper East Fork Poplar Creek
VOC	volatile organic compound
WAC	waste acceptance criteria
WAG	Waste Area Grouping
WBCV	West Bear Creek Valley
WWSY	White Wing Scrap Yard
Y-12	Y-12 National Security Complex

1. SITE DESCRIPTION

This Appendix to the Remedial Investigation/Feasibility Study (RI/FS) describes the regional and detailed environmental setting of the proposed site 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 RI/FS evaluates alternatives for disposing of most future CERCLA waste expected to be generated during environmental restoration of the ORR after the existing Environmental Management Waste Management Facility (EMWMF) reaches capacity.

The site description includes regional and site-specific information about geography and physiography, land use and demographics, transportation, climate and air quality, geology, soils, hydrogeology, surface water, ecologic resources, and historical and cultural resources. The purpose of this Appendix is to provide information regarding the site screening and selection process and to document conditions at the proposed Environmental Management Disposal Facility (EMDF) site.

1.1 REGIONAL GEOGRAPHY AND PHYSIOGRAPHY

East Tennessee is located in the central portion of the Southern Appalachian physiographic region. The region's distinctive terrain is naturally divided into three internally complex physiographic subregions based on differences in geology, ecology and biodiversity, and a wide range of local climates and soils. 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 faults and the long axes of the tilted beds associated with thrust faults control the shapes and orientations of a series of long, narrow 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, traverse the ORR (Lemizski 2000; Hatcher, et al. 1992). The axes of the ridge-and-valley terrain within the ORR lie approximately along an east-northeast–west-southwest axis (60–240°). Bedrock at the ORR consists of interbedded fractured weathered shale and limestone, resulting in significant vertical and horizontal heterogeneity. The differing degrees of resistance to erosion of the shales, sandstones, and carbonate rocks that comprise the regional bedrock help to determine local relief. Limestone units are extensively weathered to massive clay lenses with dispersed residual nodules of limestone bedrock. The more resistant shale has weathered to an extensively fractured residuum (saprolite) containing highly interconnected fracture networks.

There are six continuous ridges and one short ridge on the ORR. From north to south the ridges are Blackoak, East Fork, a short unnamed ridge, Pine, Chestnut, Haw, and Copper ridges. These ridges are separated by (in the same order) East Fork Valley, two unnamed valleys, Bear Creek Valley (BCV), Bethel Valley, and Melton Valley. The ground elevations within the ORR ranges 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.

1.2 REGIONAL 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.

1.2.1 Land Use

Uses of the land area 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 2008a). 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 2011a). 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.

BCV is approximately 10 miles long and extends west from the eastern end of the Y-12 industrial area to the Clinch River. The BCV Watershed extends from the divide between BCV and Upper East Fork Poplar Creek (UEFPC) west to the Bear Creek water gap through Pine Ridge. The water gap begins approximately where Bear Creek turns northward at State Route (SR) 58/95.

The BCV Phase I Record of Decision (ROD) (DOE 2000) divides BCV into three zones for the purposes of establishing and evaluating performance standards for each zone in terms of resulting land and resource uses and residential risks following remediation, as shown in Figure C-1 The proposed EMDF site is located in Zone 3, which is a historical waste management area and has designated future land use classification of "Controlled Industrial Use" in the BCV Phase I ROD.

The candidate site is adjacent to existing waste disposal facilities and 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 anticipated land use classification is expected to be required if the EMDF is constructed at this site.

1.2.2 Demographics

The five counties nearest to the proposed EMDF candidate site, Anderson, Knox, Loudon, Morgan, and Roane, have a total 2010 census population of 632,079, and over 286,000 housing units. Table C-1 summarizes basic demographic data for the five-county area.

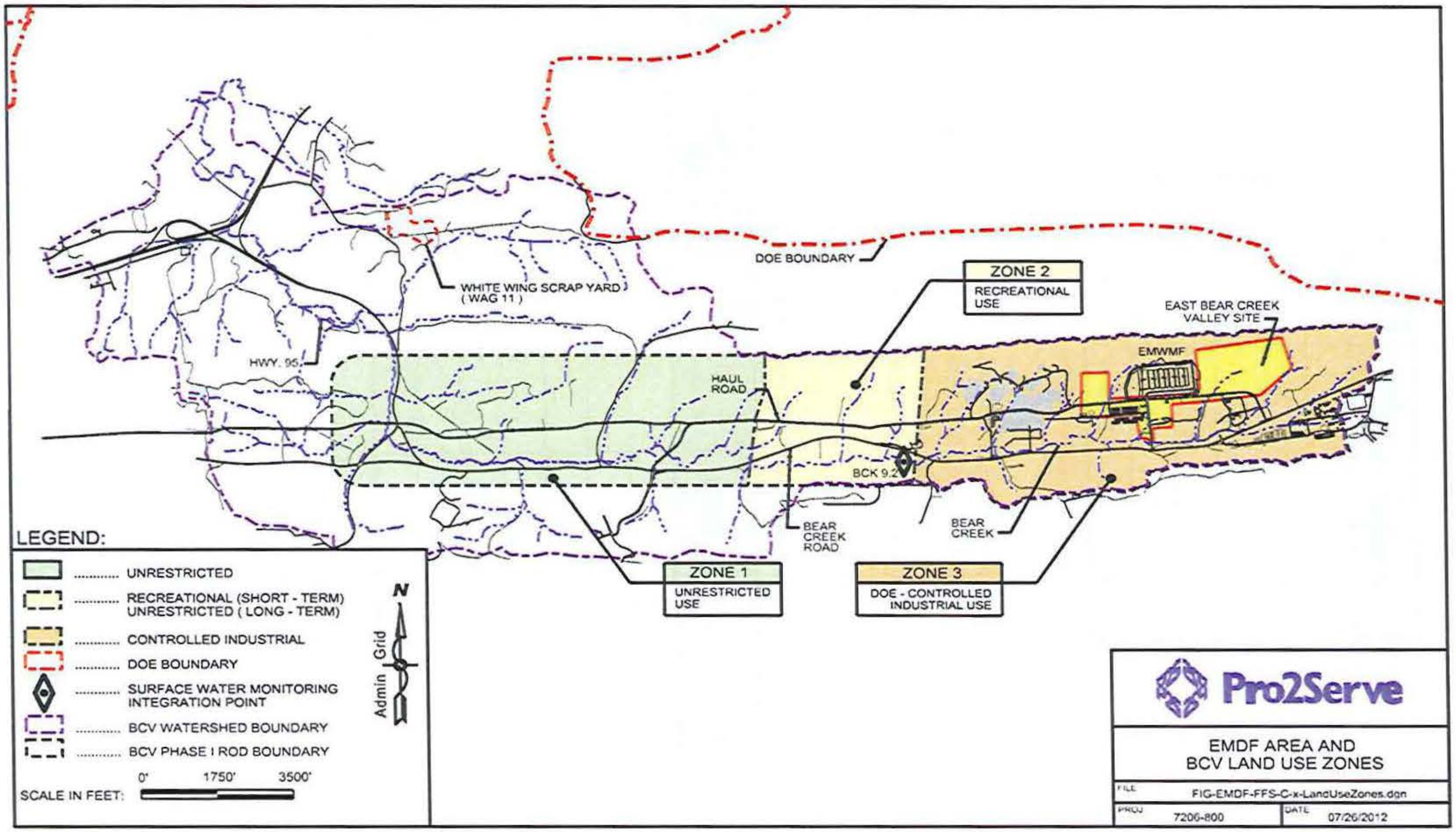


Figure C-1. Bear Creek Valley and Land Use Zones Established in the Phase I ROD

Table C-1. Total 2010 Population 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

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 proposed EMDF site lies in Roane County census tract 9801, which has no residential population. Populations of adjoining census tracts are provided in Table C-2. Counties and nearby census tracts in vicinity of the proposed EMDF are shown in Figure C-2.

Table C-2. Population Data for Adjacent Census Tracts in 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

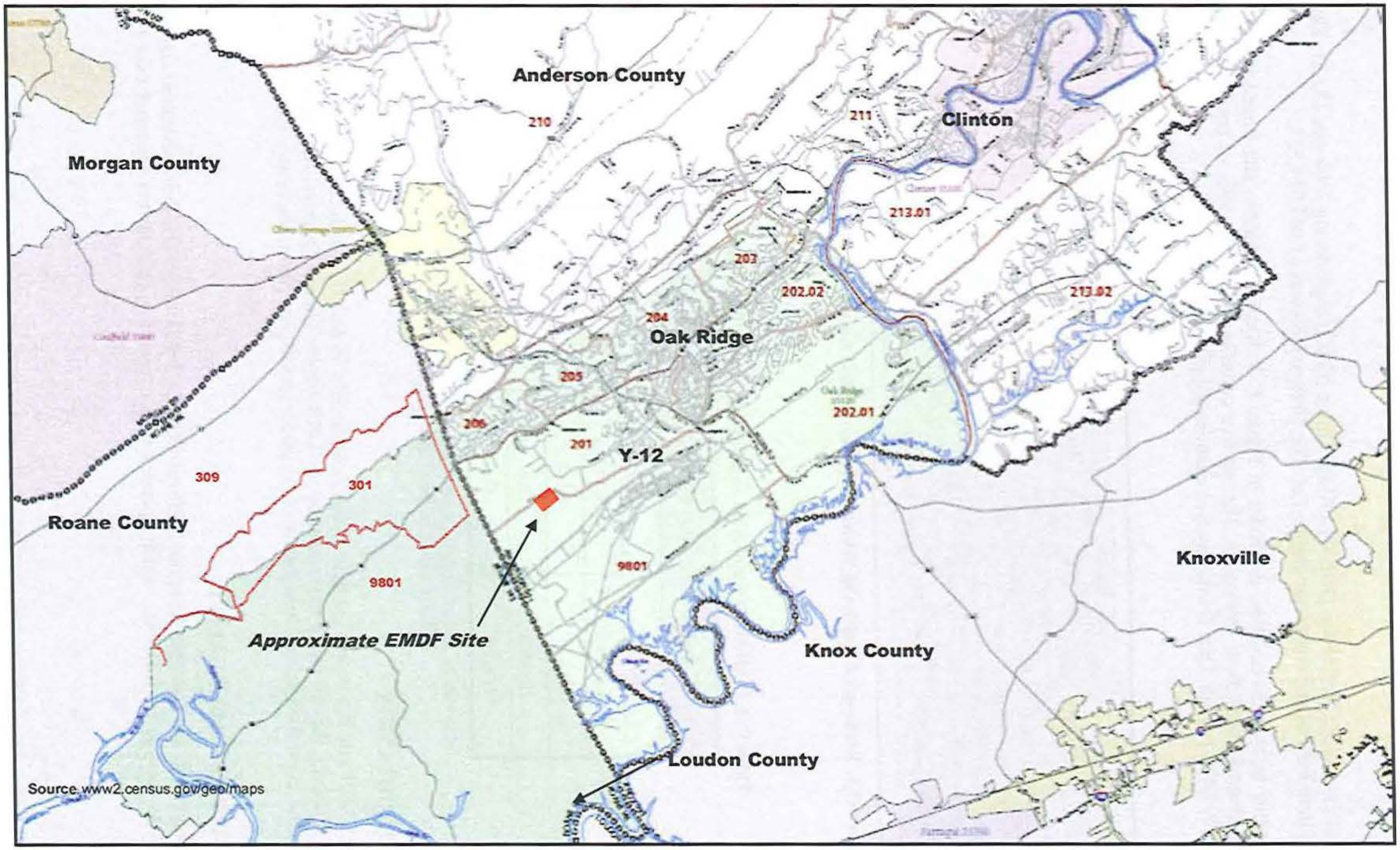


Figure C-2. Oak Ridge Reservation and Nearby Census Tracts in Vicinity of the Proposed EMDF

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 C-3. 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 C-3.

Figure C-3. Tennessee Counties in Which 10 or More ORO Employees Lived During 2009

Table C-3. DOE-ORO Employees and Payroll for the Top Five Counties

County	2009 Employees	2009 Payroll
Knox	5,437	$467,457,101
Anderson	3,357	$259,963,826
Roane	2,318	$163,056,092
Loudon	706	$53,004,744
Blount	434	$33,794,209

Source: http://www.oakridge.doe.gov/External/LinkClick.aspx?fileticket=BP_PIwu9sDA%3D&tabid=189&mid=746

1.3 TRANSPORTATION

The proposed EMDF site has access via Bear Creek Road to SRs 58 and 95, which connect to I-40 within 4.5 mi. 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.

1.4 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.

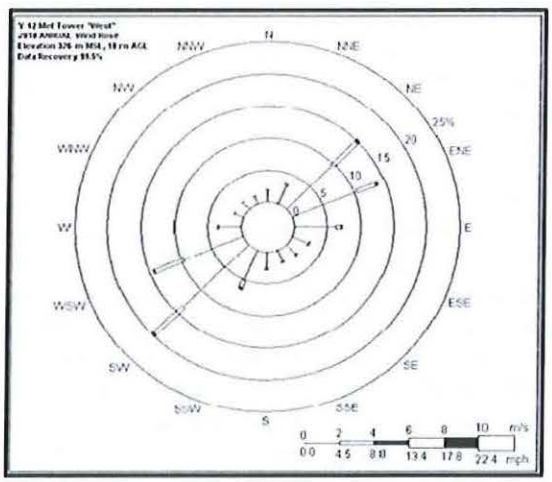
1.4.1 Climate

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 in. water-equivalent, with an average of 10.4 in. snow (http://www.ornl.gov/~das/web/Normals/30YRNorm.pdf) per year. The wet season occurs from November to May, and there is a short 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 (http://www.ornl.gov/~das/web/ Normals/30YRNorm.pdf). The 30-year average minimum temperatures vary from 28°F in January to 67.5°F in July (http://www.ornl.gov/~das/web/ Normals/30YRNorm.pdf). 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 C-4 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 mi northwest of the proposed EMDF site. In essence, the primary wind directions parallel the ridges.



Source: http://www.ornl.gov/~das/web/page7.cfm

Figure C-4. Representative Wind Rose Diagram for the Y-12 West Meteorology Tower in 2010

1.4.2 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-hr 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. CANDIDATE SITE SCREENING

The 13 candidate sites considered for this RI/FS screening evaluation were selected utilizing previous data and information collected during a 1996 DOE site screening study (DOE 1996), the Environmental Management Waste Management Facility RI/FS (DOE 1998) and the 2008 ORR Planning document (DOE 2008a). The screening process consisted of candidate site identification, development of screening criteria to evaluate the candidate sites, and application of the criteria based on data and information gathered during the screening process. 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.

A 1996 DOE site-screening study evaluated 35 sites on the DOE ORR as potential sites for an on-site disposal facility (DOE 1996). The EMWMF RI/FS pared the original 35 candidate sites down to three sites that were carried forward as potentially suitable, including the East BCV (EBCV) (where the existing EMWMF is located), West BCV (WBCV), and White Wing Scrap Yard (WWSY) sites (DOE 1998). The 13 candidate sites considered for this RI/FS screening evaluation include some of the sites identified in the 1996 siting study as well as other possible favorable locations. The 2008 ORR planning document helped identify potential conflicts in land-use priorities between various DOE mission goals and objectives, specifically delineating long term research areas and protected land areas. Table C-4 lists the 13 candidate sites and indicates the basis for their consideration. The site locations are identified by number on Figure C-5.

Screening of the 13 candidate sites 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 C-5 identifies and briefly describes the preliminary siting criteria the candidate sites were screened against. 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. 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. The presence of surface water features, such as streams and wetlands, were a consideration. Candidate sites that presented critical construction/engineering obstacles were deferred from further consideration in the preliminary screening phase. The "discussion" column in the table identifies those candidate sites retained, identifies the option designs that are derived from an updated or modified design of another listed option, and why candidate sites were eliminated from further consideration

Table C–4. Candidate Sites Identified for the RI/FS Screening Evaluation

Candidate Site*	Basis for Consideration
(1) East BCV-Option 1	Adjacent to EMWMF, avoids tributaries
(2) East BCV-Option 2	Adjacent to EMWMF, combines Bear Creek Burial Ground (BCBG) remedy component with EMDF siting
(3) East BCV-Option 3	Adjacent to EMWMF
(4) East BCV-Option 4	Adjacent to EMWMF
(5) East BCV-Option 5	Adjacent to EMWMF
(6) East BCV-Option 6	Two separate disposal cells (6a & b), adjacent to EMWMF on west and east, avoids tributaries
(7) East BCV-Option 7	Two separate disposal cells (7a & b), avoids tributaries
(8) WBCV	Previous waste disposal facility siting study
(9) WWSY	Previous waste disposal facility siting study; Adjacent to or surrounded by contaminated area Waste Area Grouping (WAG) 11
(10) Chestnut Ridge, east of Spallation Neutron Source (SNS)	Possible favorable location
(11) West-Central Chestnut Ridge	Previous waste disposal facility siting study
(12) East Chestnut Ridge	Previous waste disposal facility siting study; Fanny Knob area, hill slope, avoids tributaries
(13) Former Breeder Reactor area	Possible favorable location

*Numbers in parentheses correspond to the areas shown on Figure C-5.

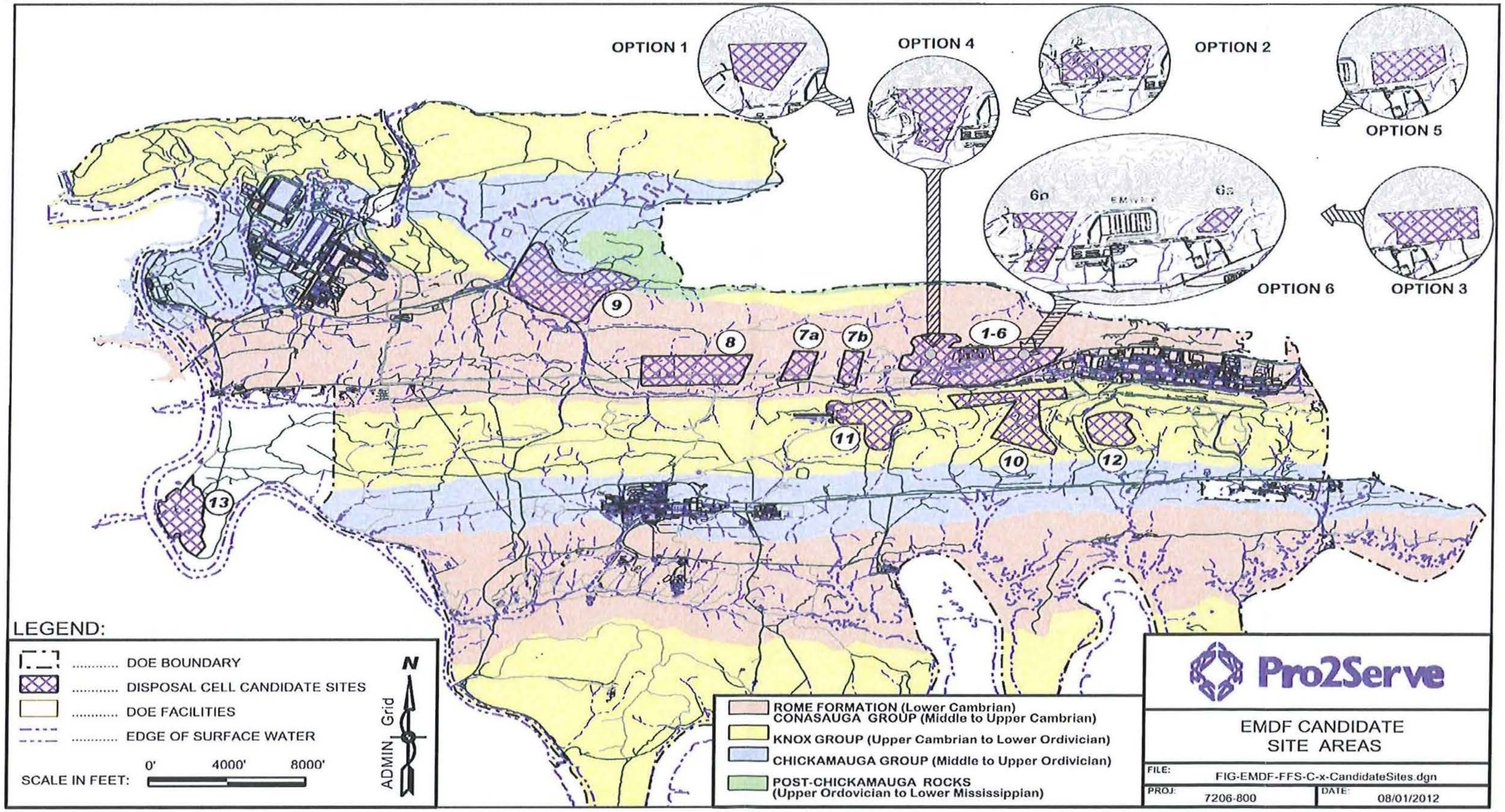


Figure C-5. EMDF Candidate Site Areas

Table C–5. Preliminary Screening of Candidate Sites

Candidate site	Preliminary Screening Criteria				Discussion
	Insufficient Area	Unfavorable Topography	Surface Water Impacts	Karst Features	
(1) East BCV-Option 1		X			Site eliminated due to unfavorable topography and excessive cut and fill.
(2) East BCV-Option 2			X		**Carried forward to secondary screening, see Table C-6**
(3) East BCV-Option 3			X		Site eliminated. Crosses headwaters of two tributaries (NT-2 and NT-3).
(4) East BCV-Option 4			X		**Carried forward to secondary screening, see Table C-6.**
(5) East BCV-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 C-6**
(6) East BCV-Option 6					A modified version of Option 4 design with an additional separate cell to the east. **Carried forward to secondary screening, see Table C-6.**
(7) East BCV-Option 7					**Carried forward to secondary screening, see Table C-6.**
(8) WBCV					**Carried forward to secondary screening, see Table C-6.**
(9) WWSY					**Carried forward to secondary screening, see Table C-6.**
(10) Chestnut Ridge		X		X	**Carried forward to secondary screening, see Table C-6.**
(11) West-Central Chestnut Ridge	X			X	Lack of suitable area for development due to proximity of SNS. Karst features are present.
(12) East Chestnut Ridge	X	X			Lack of suitable area for development due to site configuration and natural and anthropogenic features.
(13) Former Breeder Reactor Area				**X**	**Carried forward to secondary screening, see Table C-6.**

The preliminary screening phase reduced the original 13 candidate sites to 9 for further evaluation. The remaining candidate sites were evaluated in a second screening phase against a set of modifying criteria. As shown in Table C-6, the modifying criteria used for the secondary screening phase were location and access, site contamination, buffer zones, land use, and disposal capacity. Modifying criteria were designed to defer 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. These criteria generally represent concerns that would need to be addressed for areas carried forward as final candidate sites, rather than a basis for elimination. The "discussion" column in Table C-6 identifies the candidate site retained and notes why other sites are eliminated from further consideration.

Geologic Buffer: Requirements for geologic buffers underlying landfills of the Tennessee Department of Environment and Conservation Waste Management System were not used as a basis to defer candidate sites from further evaluation because these buffers can be engineered if they are not naturally occurring, or "equivalent or superior protection" may be employed. The Toxic Substance Control Act of 1976 geologic buffer requirement was not used as a threshold criterion because, although a buffer of such thickness may not reasonably be constructed, a waiver of this requirement is considered to be achievable on the basis of the design-achieving equivalent protection. Strict application of this requirement in the screening phase of the process would result in premature elimination of otherwise viable locations.

Bear Creek Burial Grounds Remedy Component: Candidate Site Option #2 shown on Figure C-5 combines a Bear Creek Burial Grounds (BCBG) remedy component with siting of the proposed landfill. Construction of a new landfill under Candidate Site Option #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 C-6) and would impact a portion of Northern Tributary (NT)-6. Excavated waste would be placed in the new landfill and/or disposed offsite. As shown in Table C-6, Candidate Site 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 excavation, treatment, and disposal of BCBG buried waste and high cost of implementation.

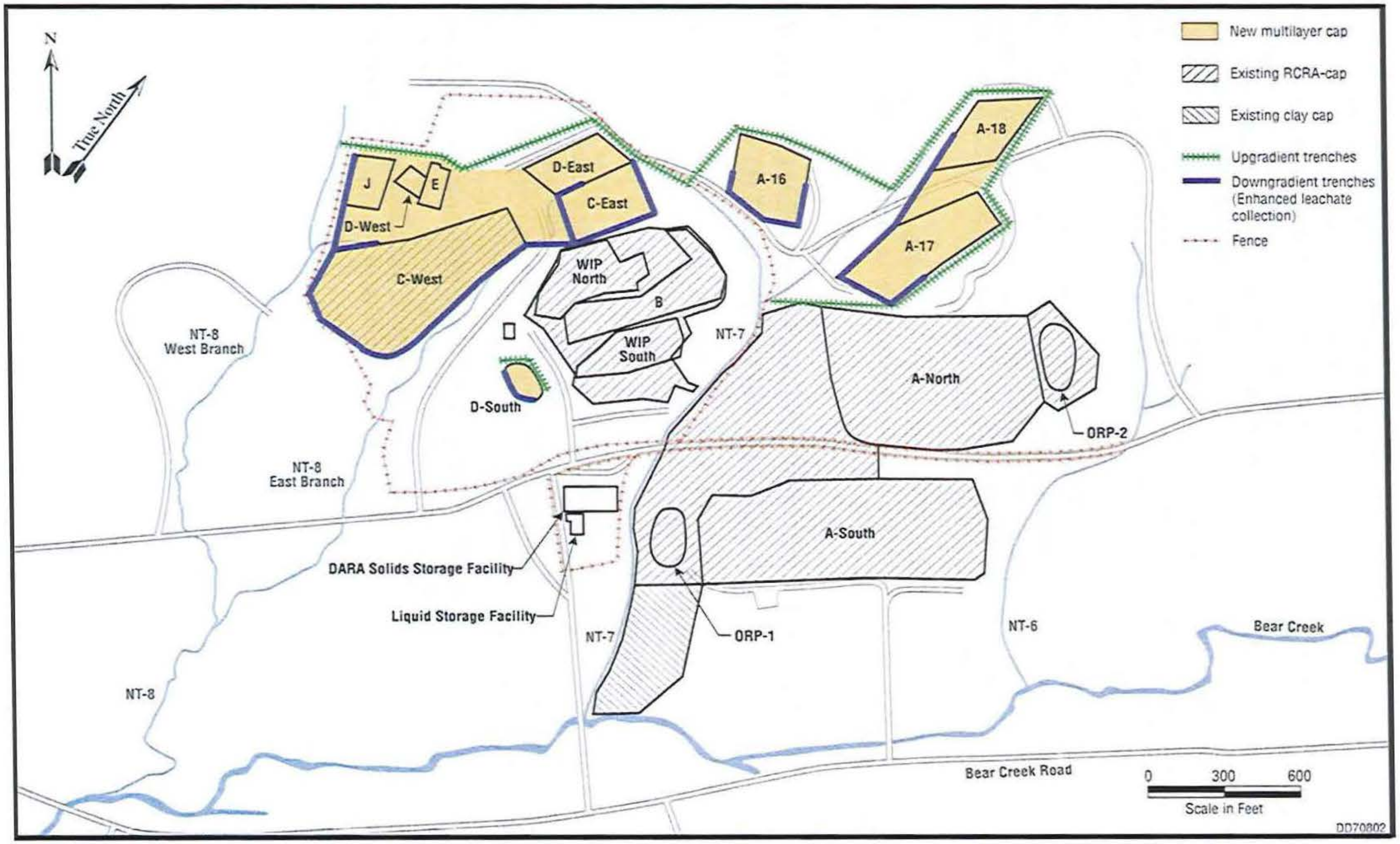


Figure C-6. Remedial Action components for the Preferred Alternative for the BCBG

Candidate Site Option #2 would be inconsistent with the preferred alternative of hydrologic isolation identified in the Proposed Plan for BCBG (DOE 2008b). The preferred alternative (see Figure C-6) includes construction of multilayer engineer caps for all previously uncapped BCBG disposal units plus one previously capped unit (BCBG C-West), construction of upgradient stormflow trenches to intercept and divert shallow groundwater 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 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.

An on-site treatment facility for treatment of contact water and leachate from the proposed landfill is included in the On-site Disposal Alternative (see Sect. 6.2.2.7 of this RI/FS). A potential modification to the design, construction, and operation of the proposed on-site treatment facility to allow treatment of contaminated water from a future BCBG action is described in Sect. 6.2.2.8 of this RI/FS. A future BCBG action would be determined as a separate CERCLA action.

The secondary screening phase reduced the remaining nine candidate sites to one final candidate site, Candidate Site Option #5, that is evaluated as the proposed site for the On-site Disposal Alternative and described in the following section.

3. PROPOSED ENVIRONMENTAL MANAGEMENT DISPOSAL FACILITY SITE DESCRIPTION

The proposed EMDF site location and setting, site geology, groundwater, surface water hydrology, conceptual flow model, ecological setting, and cultural resources are described below.

3.1 LOCATION AND SETTING

The proposed EMDF site is located in EBCV adjacent to and east of the existing EMWMF. East BCV is a historical waste management area that contains several closed land disposal facilities, in addition to the currently operating EMWMF. The proposed EMDF site is on the lower south-facing slopes of Pine Ridge and north of Bear Creek and will permanently occupy 60 to 70 acres.

The site is situated on undeveloped land between NT-3 and NT-2, with the Haul Road marking the approximate south boundary, and the north boundary being on the flank 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 conceptual EMDF footprint (see Figure 6-2 in Chapter 6 of this RI/FS).

Table C–6. Secondary Screening of Candidate Sites

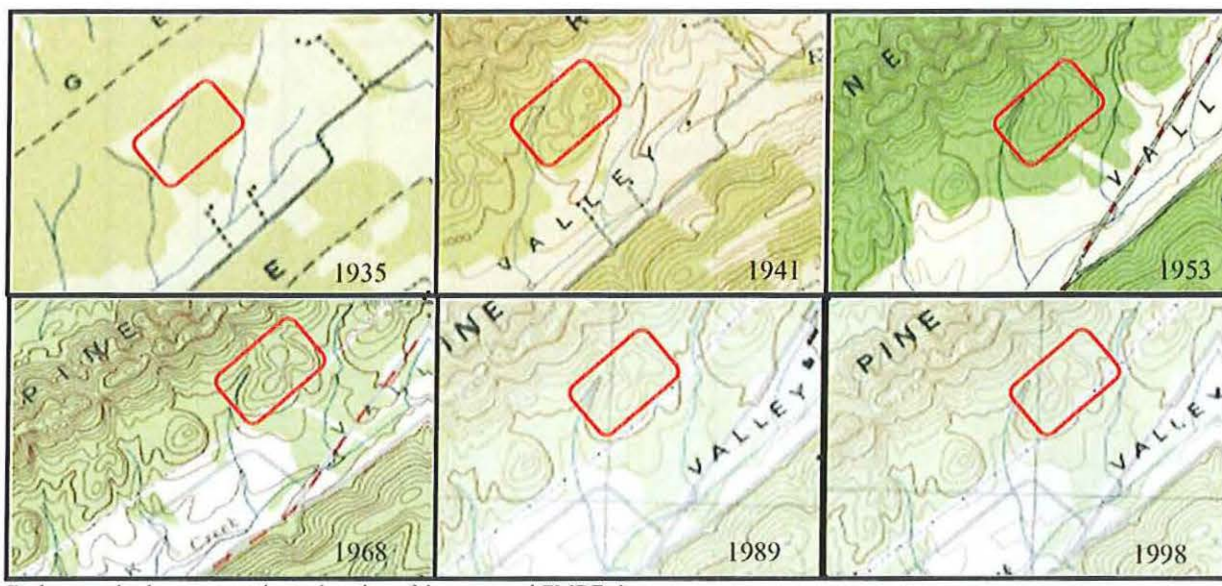
Candidate Site	Secondary Screening Criteria					Discussion
	Location and Access	Site Contamination	Buffer Zones	Land Use	Disposal Capacity	
(2) East BCV-Option 2		X	X			Site eliminated. Presence of buried waste and site contamination present significant challenges to facility construction.
(4) East BCV-Option 4			X		X	Site eliminated. Concern about adequate disposal capacity and shallow groundwater table south of the Haul Road.
(5) East BCV-Option 5						**Proposed candidate site.** Site is located in BCV Watershed Zone 3 designated for future controlled industrial use.
(6) East BCV-Option 6			X		X	Site eliminated. Concern about adequate disposal capacity. Two separate cells increase design, construction, and operations cost.
(7) East BCV-Option 7			X	X	X	Site eliminated. Adequate disposal capacity could potentially be achieved using two separate cells. Separate cells increase design, construction, and operations cost. Site is located in BCV Watershed Zone 2 designated for future recreational land use (short-term) and unrestricted land use (long-term).
(8) WBCV			X	X		Site eliminated. Site is located in BCV Watershed Zone 1 designated for future unrestricted land use.
(9) WWSY			X	X		Site eliminated. Site is located in an area designated for future unrestricted land use.
(10) Chestnut Ridge				X		Site eliminated. Located in the Walker Branch Watershed Research area, a long-term ecological research area.
(13) Former Breeder Reactor area	X		X	X		Site eliminated. Concern about proximity to the Clinch River. Site is located on karst bedrock and outside the DOE-ORR boundary.

3.1.1 Current And Former Land Use

As stated in Sect. 2 of this appendix, the proposed EMDF site is located in BCV Watershed Zone 3, designated for future controlled industrial use. The proposed EMDF site is heavily wooded and shows little indication of anthropogenic alterations. There are no current operations at the site.

Review of the U.S. Geographic Services (USGS) 7.5-minute quadrangle maps for the Bethel Valley Quadrangle for 1935, 1941, 1953, 1968, 1989, and 1998, shown in Figure C-7, 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, the 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. Other than drives from Bear Creek Road to the structures, no roads or trails are shown for the area. By 1941, much of the rectilinear cleared area had become forested, although the large cleared area east of NT-2 had expanded across NT-2. The core wooded area remained wooded throughout the entire period.

By 1953, the rectilinear clearing was entirely wooded, as was much of the open area east of NT-2. The flatter areas nearer to Bear Creek remained open, and the structures were no longer evident. (DuVall and Souza [1996] indicate that there was little remaining indication of a structure at one of these sites when they surveyed it in the 1990s). Reforestation of the area continued, so that by 1968, the entire candidate area was again covered, except for two power line rights of way. The forested area has remained essentially constant since 1968. except that the north trending power line track disappeared. Based on this review, it appears that much of the candidate site remained forested from 1968 to 1998, except for some apparent agricultural clearing. It does not appear from map reviews that any industrial activities beyond installation and maintenance of a power line occurred in the area of the proposed EMDF site.



Red rectangle shows approximate location of the proposed EMDF site.

Figure C-7. Historical Map Progression for the Candidate Site

3.1.2 Local Demographics

The nearest resident is approximately 0.84 mi north of the proposed EMDF site, and a larger residential subdivision is about 1.1 mi to the northwest. Figure C-8 shows these residential locations.

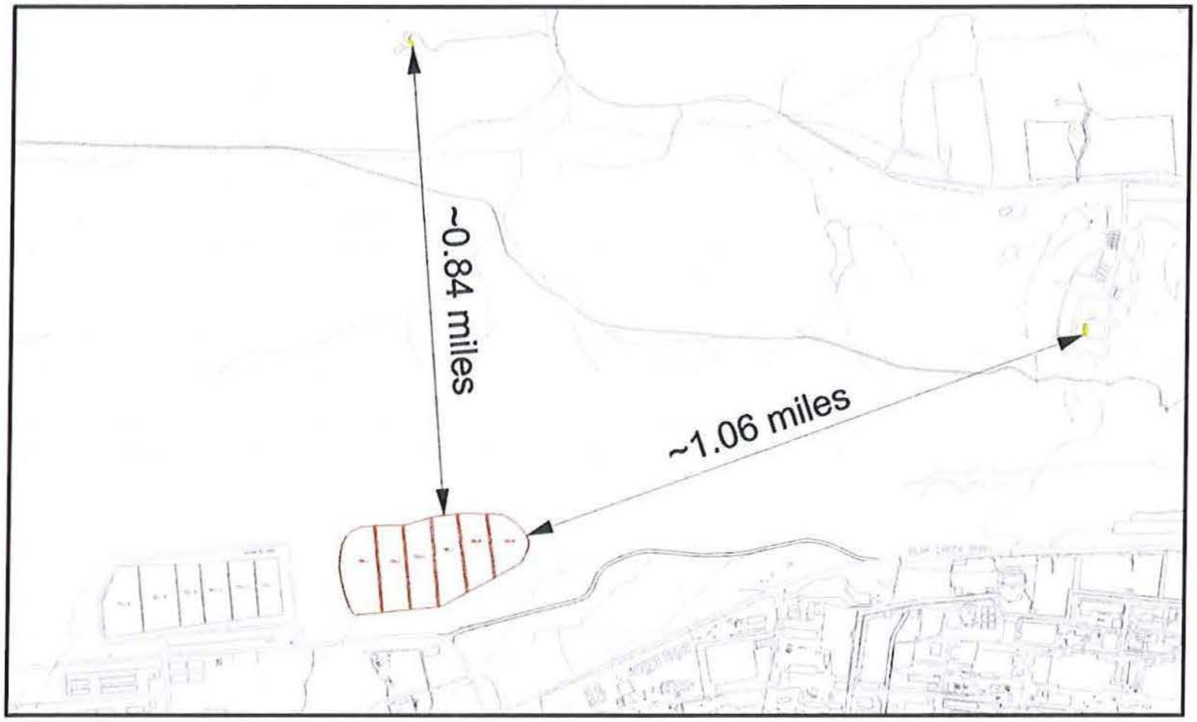


Figure C-8. Distance to Nearest Residents from the Proposed EMDF

3.2 SITE GEOLOGY

The proposed EMDF site topography and geomorphology, stratigraphy, and geologic structure are discussed below.

3.2.1 Topography and Geomorphology

This discussion of site topography and geomorphology are based primarily on Lietzke, et al. (1988), who reported on an intensive investigation of the WBCV site for the Low-Level Waste Disposal Development and Demonstration Program. Additional geologic data and interpretations for the EBCV disposal area are from Bechtel National, Inc. (BNI) (1984) and the BCV RI (DOE 1997). The WBCV and EMDF sites share common geology, hydrologic and geomorphic history, and hydrogeology, such that the Lietzke et al. (1988) findings, while differing in specifics, can be generally applied to the proposed EMDF site.

The proposed EMDF site, like the WBCV site, is on the south flank of Pine Ridge. Pine Ridge is underlain by the Rome Formation and lower units of the Conasauga Group, and has a very steep scarp (north-facing) slope, and a concave, very steep (~30° or 1:2) to moderately steep (<15° or 1:4) dip (south-facing) slope, and saw-tooth crest line. The dip slope is broken by a series of lower elevation knolls formed on harder rock units in the lower Maryville Limestone.

The geomorphic history of BCV is characterized by slow structural uplift, downward erosion, and sedimentation of colluvium and alluvium that extends for millions of years. Though the general landforms of East Tennessee have remained relatively constant for millions of years, the present-day land surface has been affected by changes caused by human activity (farming and associated erosion) and changes related to the dramatic climate fluctuations of the Pleistocene Epoch. These fluctuations, and the advent of farming in Anderson County sometime after about 1795, resulted in periods of increased erosion and deposition (Leitzke, et al 1988).

The current geomorphic surface is stable. Slopes on the south flank of Pine Ridge are concave. Upper slopes feature sharp interfluves separated by deep, steep-sided ravines and zero-order and first order stream valleys organized in a trellis pattern with typical dip slopes. Valleys coalesce and open on lower slopes to form broad bowl-shaped valleys drained by first and second-order streams. Streams are moderately incised at the apparent boundary between the Rogersville Shale and the Maryville Limestone. There is no visible evidence of recent mass movement in the area. There are no indications of sink-holes or other surface features related to karst terrain.

A discontinuous subsidiary ridge, apparently supported by resistant beds in the Maryville Limestone, parallels the main spine of Pine Ridge. This subsidiary ridge exhibits the same features as the main ridge.

Extensive colluvium was noted along the base of Pine Ridge at the WBCV site, and can be expected also to be present at the EMDF site. Alluvium is not expected to be a major component of surficial materials along the north tributaries.

3.2.2 Stratigraphy

The site is underlain by rock units of the Middle Cambrian Conasauga Group, consisting primarily of moderately to steeply dipping, weakly resistant calcareous shales, mudstones, siltstones and limestones. The Conasauga Group is overlain by the Knox Group and underlain by the Rome Formation. Figures C-9 and C-10 provide a geologic map and representative cross-section for the site, respectively.

Unless otherwise noted, the material presented in the following sections about stratigraphy has been adapted from Hatcher, et al. (1992), Lemizski (2000), Lietzke, et al. (1988), and the BCV RI (DOE 1997).

3.2.2.1 Rome Formation

The Rome Formation underlies the Pumpkin Valley Shale and forms the crest of Pine Ridge. The lower Rome Formation is dominantly variegated maroon to yellow-brown or green micaceous fissile shale with thin interbeds of gray clayey limestones and dolomites.

The upper units of the Rome Formation consist of interbedded maroon sandstone, siltstone, and shale. A dolomite bed, present on the Copper Creek thrust sheet and elsewhere in East Tennessee, is not present on the White Oak Mountain thrust sheet underlying the proposed EMDF site. The upper Rome Formation is characterized by greenish-gray, yellow-brown, and olive-green sandstones, interbedded with maroon medium grained quartzose sandstones and siltstones. Glauconite occurs occasionally, and ripple bedding, cross-bedding, bioturbation, flaser bedding, and mud cracks suggest deposition in relatively shallow waters. Shale interbeds are variegated olive green, light brown, and maroon, and are thin-bedded. Massive dolomite units with interbedded dolomitic sandstones also occur within the Rome Formation. The boundary of the Rome Formation with the overlying Pumpkin Valley Shale is marked at the top of the uppermost massive to laminar gray-green sandstone in the Rome Formation.

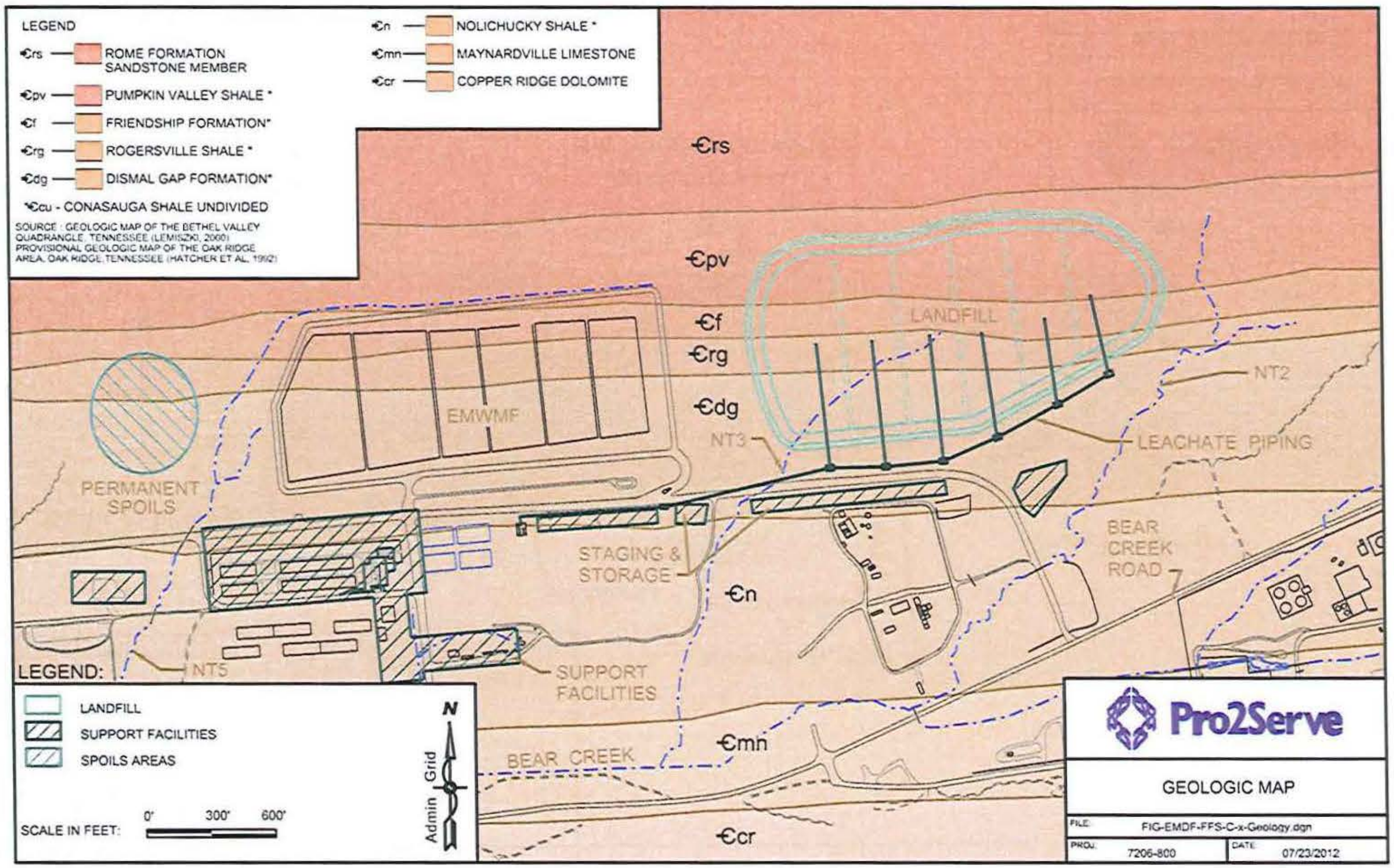
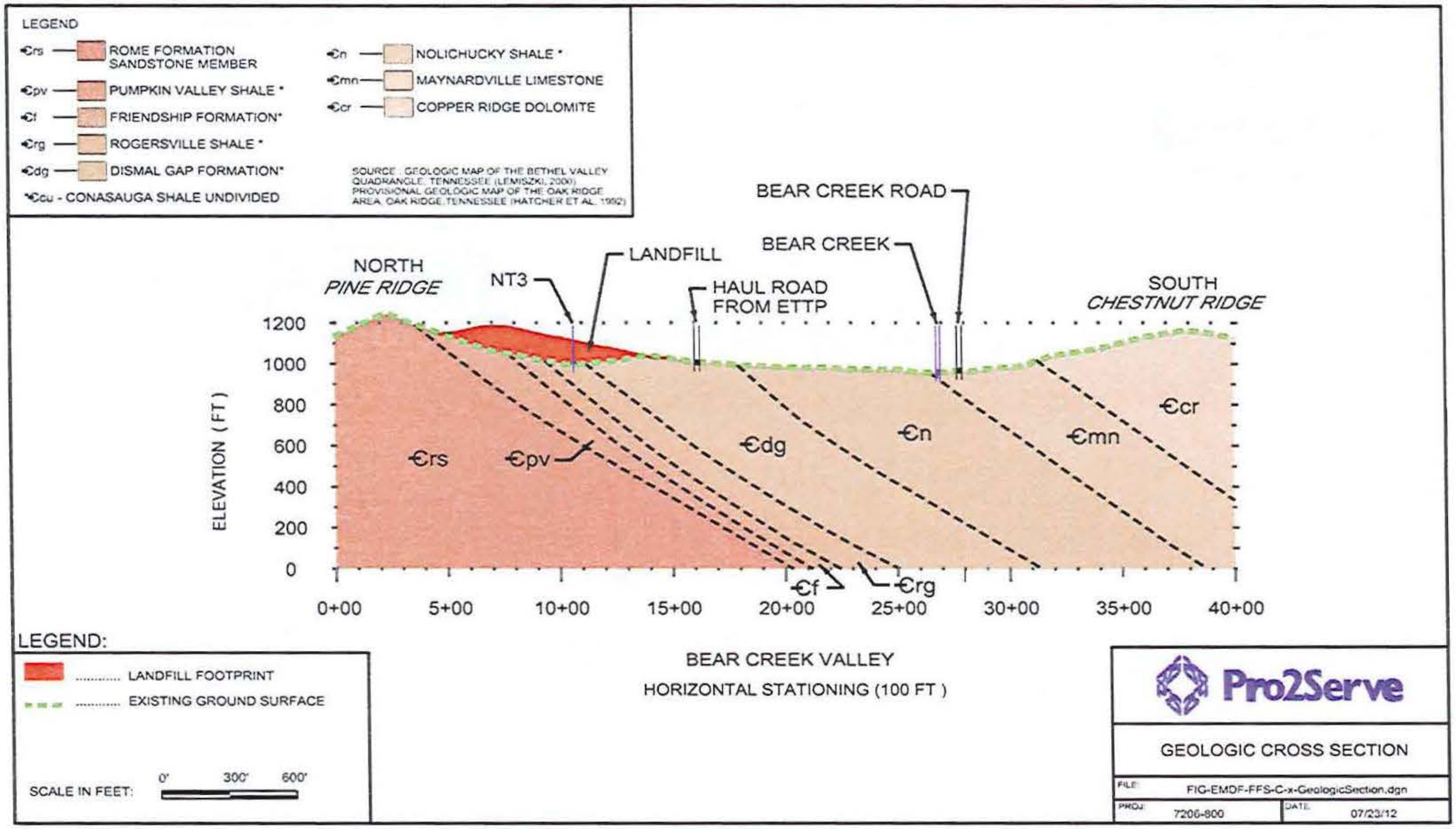


Figure C-9. Geologic Map of the EMDF Area



Adapted from Hatcher, et al. 1992

Figure C-10. Generalized Structural-Stratigraphic Cross-Section for the Proposed EMDF Site

3.2.2.2 Conasauga Group

The Conasauga Group in BCV consists of the Pumpkin Valley Shale, Rutledge Limestone, Rogersville Shale, Maryville Limestone, Nolichucky Shale, and Maynardville Limestone (Lemizski 2000; Hatcher, et al., 1992).

3.2.2.2.1 Pumpkin Valley Shale

The Pumpkin Valley Shale is a 295 to 360 ft (90 to 109 m) thick maroon, red-brown, to gray mudstone and shale interbedded with siltstone. Glauconite is common to abundant throughout, and bioturbation is pronounced in some beds. The lower Pumpkin Valley Shale is composed of maroon-brown to gray and gray-green thin-bedded to massive highly bioturbated siltstone and mudstone. Glauconite is abundant in the bioturbated layers.

The upper Pumpkin Valley Shale is composed of reddish-brown, reddish-gray, and gray mudstone and shale interbedded with siltstone. Siltstone layers contain abundant glauconite, and is locally cross-bedded.

3.2.2.2.2 Rutledge Limestone

In the vicinity of the ORR, the Rutledge is a dominantly clastic with limestone interbeds varying in thickness from 70 ft to 160 ft (21 to 48 m). The base is marked by three limestone beds separated by maroon shale and mudstone approximately 20 ft (6 m) thick. The remaining thickness of the Rutledge consists of light gray micritic to coarsely crystalline thin to medium bedded limestone interbedded with dark gray and maroon shales. Limestone beds are bioturbated and non-fossiliferous. Individual beds range from 2 to 5 ft (0.6 to 1.5 m) thick. The upper contact with the Rogersville Shale is abrupt.

3.2.2.2.3 Rogersville Shale

The Rogersville Shale is a massive to very thinly bedded mudstone with siltstone interbeds. It varies from 70 to about 120 ft (21 to 36 m) in thickness on the ORR. The lower part dark gray mudstone with some maroon shale in the lower part. Siltstone interbeds are glauconitic, gray to gray-green, wavy to lenticular, and exhibit cross-bedding. Siltstone textures fine upwards in graded bedding sequences, and the bases of siltstone layers may show erosional scour marks and bioturbation. According to Hatcher, et al. (1992), a 1 to 2 ft glauconitic limestone bed may be present in the lower Rogersville Shale.

The upper Rogersville is composed of maroon shale containing thin (< 1 in. thick) partings of wavy, light gray siltstone or clayey limestone lenses. These are often associated with glauconite laminae. The top of the Rogersville is marked by reddish, thick-bedded to massive 3 to 6 ft (1 – 2 m) thick mudstone.

3.2.2.2.4 Maryville Limestone

The Maryville Limestone on the ORR is informally subdivided into upper and lower units, and its total thickness ranges from 310 to 520 ft (95 to 158 m). Lee and Ketelle (1989) report that the Maryville Formation at the West Bear Creek Valley study site is 430 ft thick (down-hole depth, uncorrected for structural dip). The lower unit consists of calcareous mudstones with thin, even to wavy interbeds of calcareous siltstones and oolitic or peloidal calcarenites that occur in 1 to 2-in thick upward-coarsening cycles, with mudstones at the base and oolitic beds at the top. Glauconite is present near the tops of some thin limestone beds (Lee and Ketelle 1989). Upward coarsening sequences are highly variable, and the oolitic cap may be missing from individual sequences. Individual beds within the coarsening upward sequences may exhibit upward-fining textures; the top of the sequence often terminates abruptly. The lower unit contains several limestone beds ranging from 20 to 40 ft (6 to 12 m) thick. The lower unit of the Maryville Limestone underlies a discontinuous subsidiary ridge on the south flank of Pine Ridge.

The upper unit of the Maryville Limestone contains abundant intraclastic flat limestone pebble conglomerate beds. Beds are medium gray and range from thinly bedded to medium bedded. Intraclastic conglomerates are separated by beds of siltstone, mudstone, and shale. Siltstones are gray to gray-green, locally calcareous, and thinly bedded to laminated. Mudstones and shales are dark gray to black, locally calcareous, and thin to medium bedded.

Thin maroon shales occur in both the lowermost and uppermost section of the Maryville Limestone, suggesting gradational transitions. The contact between the Maryville and Nolichucky is gradational, recognized by increased shale and decreased limestone beds. The Maryville Limestone contains more shale than the Nolichucky Shale in EBCV.

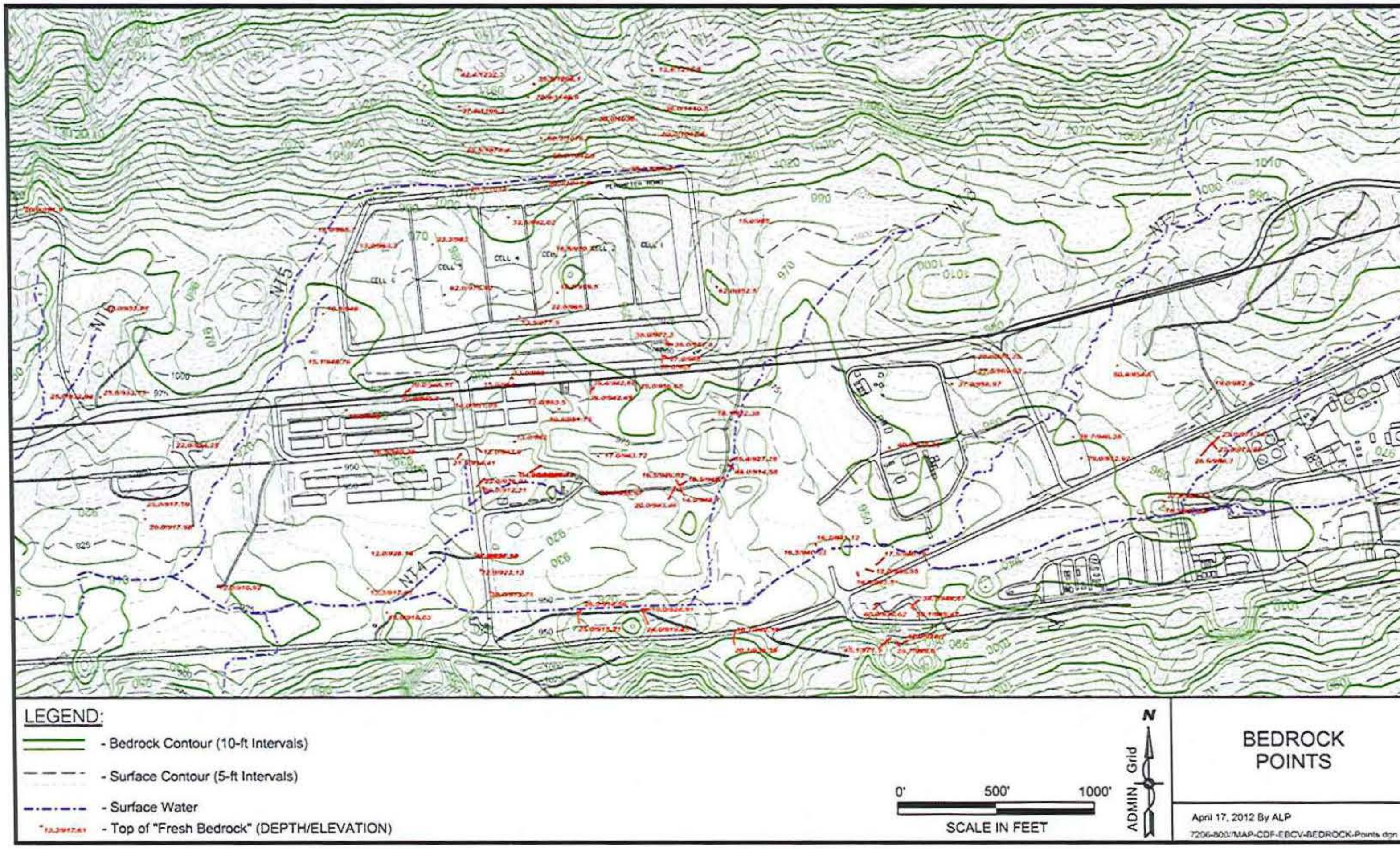
Maryville bedrock weathers to form a strongly weathered saprolite with translocated clay layers and iron and manganese staining. Differential weathering leads to formation of an irregular bedrock surface. Logs of borings drilled into the Maryville Formation presented in MACTEC (2003, boring H-2) and BNI (1984, wells GW-24, -25, -27, -31, -32, -33, and -38) indicate that weathered Maryville saprolite extends from 25 to over 50 ft below grade. A review of these logs suggests that the average depth to competent bedrock is in the 28 to 32 ft range. However, the MACTEC (2003) H-2 boring log noted severe weathering in some Maryville Formation shale beds at depths of 66 to 79 ft below grade, while limestone and calcareous shale beds above and below this zone were unweathered. Figure C-11 shows bedrock topography in the EBCV area.

3.2.2.2.5 Nolichucky Shale

The Nolichucky Shale is dominantly a dark gray to black fissile massive shale with substantial interbedded carbonates, mainly dolomite and limestones. Intraclastic carbonates are common in the lower Nolichucky. The middle portion of the Nolichucky contains oolitic packstone and grainstone. The upper Nolichucky Shale grades from oolitic limestones to mudstones, to fossiliferous and peloidal packstones and wackstones and gray calcareous shales. Individual beds are sharply delineated, and in the mudstones, exhibit soft-sediment deformation features. Algal structures are also present in the upper Nolichucky Shale. The contact between the Nolichucky Shale and Maryville Formation is gradational. The clay fraction of Nolichucky shales is dominated by illite clay, with lesser amounts of chlorite and kaolinite (Dreise, 2002).

Fractures are the dominant macropores in the saprolite (Driese 2001). Two sets of fractures, one parallel to bedding and the second normal to bedding, are present in the saprolite. Illuviated pedogenic clays commonly partially to completely fill the fractures. Iron-manganese deposits are also common fracture filling materials in the Nolichucky saprolite. Some fractures contain illuviated sand to pebble sized fillings deposited by water moving downward through the saprolite (Dreise 2001. Most of the fracture filling clays and iron-manganese coatings occur in the interval between 1 and 3 ft below grade, which corresponds to a zone of low hydraulic conductivity.

Nolichucky Shale saprolite is brown to olive, acidic, and has a relatively low iron and carbonate content. Saprolite extends to considerable depth due to water penetration along joints and fractures. In contrast with unweathered Nolichucky clays, saprolite clays are dominantly smectite-chlorite and vermiculite; this difference is the result of pedogenetic remineralization (Driese, et al. 2001). Depth to competent bedrock is highly variable and gradational, but appears to range from 5 ft to over 50 ft. Numerous boring logs note that the shale becomes increasingly harder and shows less weathering with depth.



Based on DOE 1997

Figure C-11. Bedrock Topography of East Bear Creek Valley

3.2.2.2.6 Maynardville Limestone

The Maynardville Limestone is a thin-bedded to massive limestone, non-cherty and dolomitic in the upper beds, and containing a few shale partings. Hatcher, et al (1992) indicates that thickness varies from 260 ft (79 m) to 415 ft (127 m), while the 1996 siting study (DOE 1996) indicates a thickness of 328 ft (100 m) to 360 ft (110 m) for the East Bear Creek area. The Maynardville Limestone is subdivided into a basal unit, the Low Hollow Member, and an upper unit, the Chances Branch Member.

The Low Hollow Member is characterized by evenly thin-bedded to massive fine to medium grained dolomitic calcarenite with interbeds of oolitic calcarenite and intermittent shale partings. The massive lower beds of the Low Hollow Member contain abundant stylolites, while oolitic beds are more common near the top of the sequence.

The Chances Branch Member consists of thin- to medium-bedded tan to light gray dolomite, thin-bedded dolomitic calcarenite and micrite, and oolitic calcarenite. The top of the Chances Branch Member is marked by thin- to thick-bedded dolomite and dolomitic calcirudite with evidence of bioturbation.

Residuum formed on the Maynardville is saprolitic (i.e., retains sedimentary and structural features, such as beds and fractures), deeply weathered (>5 ft/1.5m to competent rock) and clay-rich near the Maynardville – Nolichucky contact, but thinner (± 3 ft/1m to competent rock) near Bear Creek due to erosion. Pinnacles and ledges are common within the weathered Maynardville residuum. Soils developed on Maynardville parent materials exhibit a strongly marked, sticky B_t (clay) horizon.

3.2.2.3 Knox Group

The Knox Group is the principal aquifer system on the ORR, and consists of five dolomite formations. Only the Copper Ridge Dolomite, the basal unit of the Knox Group, is described here because it forms the south side of BCV.

The Upper Cambrian Copper Ridge Dolomite is 800 to 1,100 ft (250 to 350 m) thick and consists of massively bedded cherty dolomite characterized by brownish-gray medium to coarsely crystalline dark-brownish gray dolomite that has a petroleum-like odor on freshly exposed surfaces. The upper portion of the Copper Ridge Dolomite is medium to light grey, becomes more fine-grained and more thick-bedded. Nodular, bedded, and oolitic chert (a type of quartz) become increasingly common in the upper Copper Ridge, as do thin siliceous sandstone beds.

3.2.3 Geologic Structure

The EMDF candidate site is located in the upper plate of the Whiteoak Mountain thrust fault, an imbricate fault with surface traces surfacing on the northeast side of Pine Ridge in Gamble Valley and McNew Hollow, as shown in Figure C-10. The Whiteoak Mountain Thrust was formed during the Taconic Orogeny 245 to 470 million years ago (middle to late Paleozoic Period).

Lee and Ketelle (1989) observed that small and intermediate-scale structural features, such as drag folds and high angle shears are ubiquitous in Conasauga Group units. Deformational features were well developed in the heterogeneous thin to medium bedded units in the Nolichucky and Maryville Formations, and least well developed in the more homogeneous units, such as the Rogersville, Rutledge, and Pumpkin Valley Formations.

Lee and Ketelle (1989) were able to correlate one deformational zone in several wells in the WBCV area. This feature is characterized by extensive drag folds, gouge and shear fractures in the upper Maryville Limestone and lower Nolichucky Shale. The geometry of these features suggest they are boudinage, a structural feature that relates to rock extension (Fossen 2010).

Thrust faults result in repetitive sequences of strata, so that many Conasuaga Group units, for example, appear in Melton and Bear Creek Valleys, and again in Poplar Creek Valley northwest of Blackoak Ridge. Bedding plane orientations measured in Rome Group exposures on Pine Ridge near the EMDF site strike approximately N55°E and dip to the southeast. Dip angles in the vicinity of the proposed EMDF range from 33° to 62°, averaging about 46°, as measured in outcrops on Pine Ridge (Lemiszski 2000).

Smaller high-angle reverse and normal faults and extensive fracture systems may be associated with the stress adjustments that result from more or less brittle rock sliding over other rock. Rothschild, et al. (1984) noted that tear faults oriented perpendicular to regional thrust faults were identified in Conasauga Group rocks near the Hydrofracture Facility in Melton Valley. Rothschild, et al. (1984) also indicated that four possible tear faults had been located at Solid Waste Storage Area 7 in Melton Valley. Lemizski (1995) mapped several relatively short normal (tensional) and thrust (compressional) faults associated with folding at the ETTP site. Dreier and Koerber (1990) and King and Haase (1987) identified cross-cutting tear faults in Bear Creek Valley and Pine Ridge based on ridge crest offsets and subsurface data. Many of these ridge offsets are coincident with valleys on the flank of Pine Ridge, and King and Haase (1987) show a possible fault crossing through the proposed EMDF site, apparently on the basis of lineation of ridge off-sets. Evidence of faulting observed in bedrock cores includes slickensides, striations created by rocks sliding against rocks, that was noted in cores from the Maryville and Nolichucky Formation shales in the main plant area (MACTEC 2003) and from the BCBG area (BNI 1984). A number of core logs describe brecciated and gouge zones (BNI 1984), indicating possible fault zones. Hatcher, et al. (1992) interpreted these ridge-crest offsets as indications of folding related to detached blocks (horses) underlying the thrust sheet. Lee and Ketelle (1989) expressly examined the possibility that a tear fault controlled the location of NT-15 at the WBCV site by evaluating core and boring data and trenching through saprolite at the Maryville Limestone – Rogersville Shale contact. They found no evidence of a tear fault or other high-angle fault at that location, and concluded that the location of NT-15 and other streams on the flank of Pine Ridge is related to regional joints or fractures. No confirmed high-angle faults are mapped in the BCV. Moore (1988) noted the presence of a few high angle faults near ORNL, but tentatively concluded that ". . .groundwater conduits can occur along and near faults . . .but that such features are uncommon and may be rare."

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. 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 mi northwest in the New Madrid (Reelfoot Rift) Fault Zone (DOE 2011a). 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.

The multiple episodes of tectonism and structural deformation in the Valley and Ridge have resulted in the formation complex systems of fractures (Hatcher, et al., 1992) in ORR bedrock. A fracture, or joint, is any essentially planar parting or discontinuity in rock, and occur in all of the lithologies found on the ORR. Fractures are distinguished from faults in that little or no actual movement occurs on fractures. Bedrock under the ORR typically has very low effective matrix porosity, and for this reason, fractures are of primary importance in groundwater occurrence and movement, as will be discussed in more detail in the following sections.

The fracture systems on the ORR are the result of multiple tectonic events, stress relief resulting from erosional removal of rocks reducing vertical compression on underlying rocks, and from lithology discontinuities across bedding planes. Two orthogonal sets plus a set parallel to bedding planes, illustrated in the top diagram of Figure C-12, are common throughout the ORR.

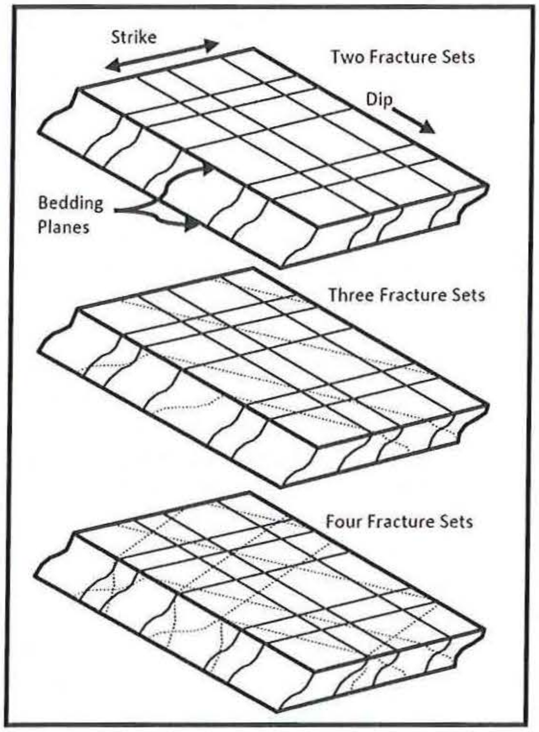


Figure C-12. Increasing Complexity Added by Multiple Fracture Sets

One major fracture set consists of bedding planes which dip to the southeast and strike northeast to southwest. Two additional sets are more or less vertical and trend northwest to southeast, parallel to strike, and northwest to southeast, parallel to dip. Other fracture systems that have been documented on the ORR trend east northeast to west southwest (Lemizski 1995; BNI 1984) or north-south and north-northwest (Moore and Toran 1992). Lee and Ketelle (1989) noted that fracturing is ubiquitous throughout Conasauga Group rocks at the WBCV site, reporting two major fracture orientations. One set trends northwest to southeast, with dips in the 10° to 30° range to the east. The second set exhibits highly variable orientation, but trends roughly north-south and dips 5° to 50° to the west. Bedding planes are oriented northeast to southwest with dips ranging from 10° to ~70° to the southeast. Sledz and Huff (1981) and Rothschild, et al. (1984) also noted that fracture systems in the Conasauga Group in Bear Creek Valley were more complex than those in Melton Valley, reflecting multiple phases of deformation. Rothschild, et al. (1984) suggests that a north – south fracture set, possibly related to shear forces, is common to Conasauga rocks in both Bear Creek and Melton Valley.

Regional fracture systems formed by large-scale regional deformational stresses may be over-printed with smaller-scale local fracture systems related to folds and faults, which add complexity to the fracture systems. In some areas three and even four orthogonal fracture sets may be present, together with bedding planes, as illustrated in the lower two diagrams of Figure C-12.

Moore and Young (1992) used subsurface flow meters to determine fracture density and conductivity in Bethel and Bear Creek Valleys. 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 groundwater 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 spacings. Further, they corroborate the notion that the most conductive zone is near the water table.

Fractures may terminate at changes in lithology (e.g., at bedding planes), changes in bed thickness, at intersections between different fracture systems, and other discontinuities (e.g., stylolites in carbonates or fault planes, or by simply ending. Orthogonal terminations may be at acute angles or nearly perpendicular. The combination of two orthogonal sets of fractures and bedding plane fractures break the host rock into rectilinear blocks (Lemizski 1995; Solomon et al. 1992). Additional over-printed fracture sets reduce overall block size and shape.

3.3 GROUNDWATER

All geologic units underlying the ORR are water-bearing to some degree, although the ability of some units to produce water at useful rates is poor. The Knox Group has been termed an aquifer because it is capable of sustaining the high production rates needed for residential, farm, and industrial use. The Maynardville Limestone is often lumped with the Knox Group aquifer (Hatcher, et al. 1992) because it can sustain useful production rates. Brahana, et al. (1986) note that the Knox Group is the most important aquifer in East Tennessee.

The remaining geologic units under the ORR have been termed aquitards, meaning that they contain water, but have less capacity for transmitting water than do aquifers. This is not to say that groundwater does not exist in these units, but that these units do not yield water in the quantities normally needed for most water production wells. However, DeBuchananne and Richardson (1956) and Brahana, et al. (1986) note that these aquitards are tapped for residential and other uses throughout East Tennessee, and that units of the Conasauga Group commonly yield from several gallons per minute (gpm) to as much as 200 gpm from cavities.

3.3.1 Aquifer Characteristics

Groundwater occurs in three types of pores on the ORR: rock matrix, fractures, and cavities or conduits. Porosity is defined as void space in an otherwise solid material, in this case, rock. The volume of pore space is generally given as a percent of the bulk rock. Pores can contain water or gases, and if interconnected with other pores, can transmit fluids under the influence of gravity or induced pressure. Effective porosity is a measure, as a percent of the bulk rock, of how well the pores are interconnected. Rock with high porosity but low effective porosity transmit fluids poorly.

Worthington (2007), among others, points out that in carbonate aquifers, matrix pores provide long-term storage of water (and contaminants), but little flow; conduits provide rapid flow but little storage, and fractures provide both storage and flow.

3.3.1.1 Matrix

Matrix porosity is composed of small voids in the rock that may or may not be well enough interconnected to allow water to flow. Matrix porosity is generally an original feature of sedimentary rocks, but can be modified by post-depositional physical and chemical changes. There are conflicting interpretation regarding the ability of matrix pores to contribute to flow, and most indicate that they do not contribute significantly to flow. However, their ability to absorb and release contaminants make them both reservoirs and sources in contaminated environments.

Matrix porosity of the soil and residuum over Conasauga Group rock units ranges from 30% to 50%, typical of clayey materials (Driese, et al. 2001; Solomon, et al. 1992, Moore 1988). Moore (1988, 1989) indicates that specific yield, the amount of water that will drain under gravity alone, is only about 10%, but further states that effective porosity is only 0.2%. Conversely, Dorch, et al. (1996) reported effective porosity ranged from 26.8% to 39% for weathered Nolichucky Shale saprolite, and that the proportion of effective porosity decreased with depth, in tandem with a decrease in the degree of weathering.

Much of the effective porosity in very shallow soil and residuum is due to outside influences, for example, plant roots and animal or insect burrows. These large aperture pores, termed mesopores, compose only about 0.2 % of the soil volume, but account for over 90% of flow in the storm-flow zone (Solomon, et al. 1992; Moore 1989).

Moore and Toran (1996) note that data from the Joy-1 core hole indicates that total porosity in unweathered bedrock is unrelated to depth. Goldstrand, et al. (1995) documents matrix porosities in the Maynardville Limestone ranging from 0.1% to as high as 7% where diagenetic processes dissolved gypsum and anhydrite nodules and replaced of dolomite with calcite. Some vuggy and fenestral porosity was associated with stromatolites. Goldstrand, et al. (1995) reported that matrix porosity decreased with depth.

Worthington and Ford (2009) found that matrix porosity in selected carbonate rocks varied from ~1% to ~40%, but associated hydraulic conductivity ranged from 10^{-4} to 10^{-11} m/s (10^{-2} – 10^{-9} cm/s).

3.3.1.2 Fractures

The majority of groundwater flow on the ORR occurs in fractures (Solomon et al. 1992; Moore 1988). Overall, fracture spacing and density was found to be highly complex and anisotropic, because some fracture sets and orientations are more well developed than others. Sledz and Huff (1981) attempted, without success, to use linear regression to find relationships between fracture length, density, lithology, and bed thickness. Results indicated little correlation between the parameters evaluated. They found fracture densities in the Pumpkin Valley Shale in BCV as high as 100 to 200 fractures per meter in some Conasauga Group rocks. The mean range of fracture density in siltstones of 6 to 45 fractures per meter, and 12 to 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. Moore and Toran (1992) reported an average orthogonal fracture spacing of 13.75 in (35 cm). Lee and Ketelle (1989) reported numerous and ubiquitous fractures in cores from the WBCV site, noting that fracture density is higher in the Maryville and Nolichucky Formations than in the rest of the Conasauga Group.

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 1 in to 30 in. (2 cm to 76 cm). Further, fracture length 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.

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 is the ratio of aperture to spacing (35 mm), porosity averages about 0.34%. Bedding plane fractures tend to be wider and more open that 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.

Moore and Young (1992) conducted flow meter studies on isolated lengths of wells to examine fracture density and behavior. They report higher fracture height and density, and wider aperture, in the top 10 ft of the saturated zone with lower height and density, and narrower apertures, in deeper zones.

In carbonates, such as dolomite and especially limestones, fractures are typically solution-widened, and this dissolution process often forms cavity systems near the base of the carbonate bed (Lemizski 1995). Worthington & Ford (2009) found that for fractures in carbonates, porosity varied from 0.001% to 1%, but hydraulic conductivity varied from 100 cm/s to 0.01 cm/s. Thickly bedded limestones having a more homogeneous lithology are most susceptible to this process (Lemizski 1995; Solomon, et al, 1992; Moore 1988). Cavities are discussed in greater detail below.

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 aperture in sandstone saprolite ranges from 0.005 mm to 0.5 mm, but in shale and siltstone saprolite the range is 0.005 mm to 1.5 mm, and in limestone saprolite the range is 0.005 mm to 2.0 mm. White & White (2005) modeled a three pore system (matrix, fracture, and conduit) and found that while the largest portion of flow in karstic aquifers occurs in conduits, the main portion of storage is in fractures. Further, they found that fracture aperture is more important than fracture spacing, and that fractures will dominate flow if apertures approach 1 cm or if gradient is very low so that no preferred pathway develops.

Fractures are often partially to completely filled with mineral deposits, including calcite, pyrite, and coatings of iron and manganese (DOE 1997; Lee and Ketelle 1989; BNI 1984). Driese, et al. (2001) document 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 and the deeper vadose zone. Logs of wells cored as part of the assessment of the BCBG (BNI 1984) clearly indicate the presence of open, partially-filled, and filled fractures in Conasauga Group rocks. These fillings are formed by minerals crystallizing from solution in waters moving through the fracture. Fracture fillings reduce the aperture and therefore, the ability of the fracture to store and conduct water. Lemizski (1995) found that the apertures of filled and open fractures were essentially the same, suggesting that fracture fillings had been dissolved from the open fractures.

3.3.1.3 Cavities

Cavities in bedrock are formed by chemical solution and mechanical abrasion. Enlargement of fractures begins with slow dissolution of carbonate rock by acidic meteoritic water penetrating from the surface and longitudinally along fractures. Dissolution is most rapid near the point where acidic water first contacts the rock, and slows considerably, but does not entirely cease, as the water infiltrates deeper into the rock (Worthington and Ford 2009).

Turbulent flow begins once openings are enlarged above some critical size (Solomon, et al. 1992; Moore 1988). Mechanical abrasion by entrained sand and silt then increases the rate of cavity enlargement and remove at least part of the resulting detritus. Any remaining detritus accumulates at the bottom of the cavity and partially protects this rock surface against further erosion. While dissolution does not stop, abrasion by particulates entrained in turbulent flow becomes the main force in developing larger cavities. Deposition of detrital materials, such as clays, may protect the cavity floor from abrasion and thus force upward extension of the opening, resulting in an oval cross-section. However, the cross-sectional area of a cavity may change considerably from one location to another as a result of local differences in rock resistance to dissolution or abrasion; the largest cavities typically occur in the purest and most massive beds (Moore 1988). Borehole logs in Conasauga Group units record numerous cavities that are filled or partially filled with soft sediment. As Moore (1988) points out, a cavity may be filled at one point, but open at another. Moore (1988) reports that detected Conasauga cavities range from about 0.1 ft (0.03 m) to a maximum of 18 ft (5.9 m), with a mean of about 1.5 ft (0.51 m). Moore (1988) also estimated the vertical height of cavities as a fraction of borehole length is 0.012, which is close to the porosity values given by Worthington & Ford (2009), who found that cavities occupied <1.2% of bulk rock volume. Further, fracture porosity was reported to be in the range of 0.1% to 0.01% of bulk rock volume.

According to Moore (1988) cavities in the Conasauga Group have been reported only in the Maryville Limestone, Nolichucky Shale, and Maynardville Limestone, all of which contain limestone beds. More than one cavity was present in 46% of wells that intercepted cavities in the Conasauga Group. However, the data set is likely biased towards the Maynardville Limestone. A few of these have been reported to exhibit high velocity groundwater flow. Moore (1988) and Solomon et al. (1992) suggest that a relatively small number of wells actually intersect cavities, but Shevnell, et al. (1995) stated that cavities in the Maynardville Limestone "...were intersected in numerous wells in all pickets..." and further noted that the GW-705A & B borehole encountered numerous cavities and had to be abandoned because the borehole collapsed.

A number of reports (Shevnell, et al. 1995; Solomon et al. 1992, Moore 1988) on ORR hydrogeology note that most cavities develop at relatively shallow depths, and that the number of cavities decreases with depth. Moore (1988) statistically evaluated 170 wells containing cavities, and determined that the geometric mean depth for Conasauga Group cavities is 25 ft (8.3 m), and the maximum depth is over 215 ft (71 m). Therefore, it is possible that flow occurs in deeper conduit systems, or tiers, in the Maynardville Limestone, that may have developed in response to base level. Pre-Watts Bar base level in the Clinch River at the west end of BCV and at Poplar Creek is approximately 710 ft above mean sea level. Estimates of phreatic flow depth based on equations presented in Worthington (1991) suggest that flow, and therefore cavities/conduits, could occur to depths of over 450 ft (150 m). The known depths of cavities in the Conasauga Group are within this range.

Shevnell, et al. (1995) established five "pickets" or lines of wells across (roughly perpendicular to strike) the Maynardville Limestone from the WBCV site on the west to the east end of Y-12. They then injected distilled water into one well and measured responses in the other wells in the picket. Two pickets, B and C, were located in EBCV and each picket had multiple wells that exhibited immediate response to injected water, both in water level rise (pressure) and in temperature and specific conductivity. Spring SS-4, which is on strike relative to the injection well for Picket B, also showed immediate response to injection. This indicates very rapid movement of water. Drainage in several wells was also rapid, indicating pure conduit flow, while others showed a slower drainage indicating that fracture flow may be dominant in those wells. Flow among picket wells was across the stratigraphic grain of the Maynardville Limestone; however, pickets did not extend into the Nolichucky Shale.

Shevnell, et al. (1995) concluded the significant conduit development occurs at shallow depths in the Maynardville Limestone, and the conduits are well interconnected. Conduits appear to have a stacked and anastomosing pattern that allows for local flow directions to change in response to changes in the water table elevation, so that underflow conduits handle baseflow, and overflow conduits fill and flow during high water periods. Conduits also are connected to surface waters. However, at the valley scale, the dominant flow direction in the Maynardville Limestone is to the west along strike. Responses in wells at different depths in several of the pickets indicate hydrologic communication in the down-dip direction, perhaps along bedding planes.

Soil pipes are a special case of cavity that form in clay soils as a result of mechanical erosion along subsurface zones of weakness. Soil piping can occur anywhere in the lower portion of the soil column, but are more generally found at the soil-bedrock interface. Moore (1988) and BNI (1984) noted the presence of soil piping in Conasauga Group regolith, particularly at the base of the regolith. A small cavity was reported in weathered shale and sandstone while drilling the borehole for GW-46 (BNI 1984). This may be evidence for soil piping.

3.3.2 Hydraulic Conductivity and Results of Tracer Tests

Various methods have been used to estimate the rate of flow in ORR aquifers. Hydraulic conductivity is a measure of how well water can move through a given rock area, and with water table gradient, can be used to estimate flow velocity. Tracer tests offer one means of direct groundwater flow rate measurement, although they require either a large number of sampling points, or knowledge of or good predictions of flow patterns.

3.3.2.1 Range of Hydraulic Conductivity

Hydraulic conductivity is difficult to measure in fractured or karstic aquifers, and its significance as a measure of gross hydraulic behavior is arguable. Hydraulic conductivity is measured in a variety of ways, most of which involve artificially stressing the aquifer by suddenly raising or lowering the water table, or by pumping, and measuring the response over time. Calculations are made on the basis of the recovery rate, and assumptions as to aquifer thickness, homogeneity and isotropy, and whether the aquifer is confined or unconfined, and other assumptions. These methods work reasonably well in aquifers characterized by homogeneous isotropic matrix porosity, but do not fare so well in fractured or karst applications. Assumptions regarding isotropy, aquifer thickness, and confinement are not reasonable in fractured or karstic systems.

Although matrix porosity may be large for some lithologies, permeability in the clastic and carbonate rocks underlying BCV tends to be very small, because effective porosity is very small. White and White (2005) tabulate matrix hydraulic conductivities ranging from 10^{-4} cm/sec for granular limestones in the Floridan Aquifer to 10^{-8} cm/sec for dolomites in Ontario. On the ORR, hydraulic conductivities range from 10^{-9} cm/sec in deep wells to essentially infinite in large open cavities. Hydraulic conductivity varies by lithology, degree of weathering, and depth. Tables C-7 and C-8 summarize hydraulic conductivity data from several sources and compare the values to those used in preliminary waste acceptance criteria (WAC) modeling described in Appendix F.

Bedrock hydraulic conductivity tends to be higher in a more pure limestone like the Maynardville Limestone, and lower in shaley units, such as the Maryville Limestone. Excluding the Maynardville Limestone, hydraulic conductivity in the Conasauga Group regolith and bedrock generally ranges between 10^{-3} to 10^{-5}cm/s. Conductivity tends to be slightly higher in the Nolichucky, Maryville, and Pumpkin Valley formations than in the Rutledge Limestone and Rogersville Shale.

Moore and Young (1992) calculated the effective porosity, specific yield, hydraulic conductivity, and transmissivity of the permeable fractures from a combination of borehole flowmeter surveys and injection and pumping tests. The geometric mean of transmissivity for permeable fractures is 9.7×10^{-5} cm/s, and the geometric mean of hydraulic conductivity is 1.4×10^{-4} cm/s. Average hydraulic conductivity and transmissivity are nearly the same between depths of 7 to 55 ft (2.1 - 17 m), but probably are smaller at deeper levels. For a fracture spacing of 3 in. to 30 in. (0.15 - 0.73 m), the specific yield of a permeable interval is likely to be in the range 9.2×10^{-5} to 7.5×10^{-4} (specific yield is dimensionless). Within 20 ft (6 m) of the water table, average specific yield is probably in the upper half of this range because more fractures occur at these levels. At deeper levels, some fractures are closely spaced, but the average specific yield may be in the lower half of the calculated range. Saprolite conductivity has a wider range, from 10^{-2} to 10^{-5} cm/s, than bedrock, and this has been attributed to an increase in fracture width due to weathering and demineralization (Driese, et al. 2001; Dorsch and Katsube 1996; Moore 1989).

Hydraulic conductivity in Conasauga Group rocks is strongly anisotropic, with higher conductivity in the strike parallel direction than in the down-dip direction or across beds. Anisotropy is the result of differences in fracture orientation, propagation and development. Some estimates of the degree of difference are presented in Table C-9. Anisotropy is expressed in the tendency of tracers and contaminant plumes to elongate in the direction of strike. Drawdown cones observed during pump tests also show strong elongation. Qualitatively, the relationship of strike-parallel, dip-parallel, and cross-strata hydraulic conductivity is $K_{strike} >> K_{dip} > K_{cross\text{-}strata}$ on a whole-rock basis.

As noted above, use of single point hydraulic conductivity data to characterize fractures and karstic aquifers is problematic. Sara (1994, p. 6-4 – 6-5) states that:

> *"[t]he 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 hydraulic conductivity of the whole-rock mass, or continuum, that determine groundwater flux. 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 preliminary WAC modeling for the EMDF presented in Appendix F.

Table C-7. Mean Hydraulic Conductivity by Formation Compared to Preliminary WAC Model Input

Stratigraphic Unit	Connell and Bailey (1989)				Summary Data from Preliminary WAC Model		
	Regolith		Unweathered Rock		Geometric Mean Hydraulic Conductivity (cm/s)		
	N	Hydraulic Conductivity(cm/s)	N	Hydraulic Conductivity (cm/s)	Dip direction (K_x)	Strike direction (K_y)	Vertical Direction (K_z)
Maynardville Limestone	5	2.22E-05 – 4.8E-02	13	1.09E-05 – 2.48E-02	6.71E-06	5.64E-05	6.71E-06
Nolichucky Shale	24	1.31E-05 – 1.15E-03	45	1.62E-07 – 2.80E-03	8.44E-07	7.35E-06	8.44E-07
Maryville Limestone	15	1.06E-05 – 7.34E-04	33	1.59E-07 – 7.34E-04	4.52E-07	3.94E-06	4.52E-07
Rogersville Shale & Rutledge Limestone	5	1.83E-05 – 9.88E-05	20	1.62E-07 – 1.94E-04			
Pumpkin Valley Shale	4	1.55E-05 – 4.13E-04	26	1.62E-07 – 2.96E-04	5.02E-07	4.37E-06	5.02E-07
Rome Formation	—	—	13	2.89E-06 – 2.60E-03	7.06E-07	6.14E-06	7.06E-07
Deep Bedrock, undifferentiated	—	—	5	7.06E-09 – 4.94E-08	—	—	—

Table C-8. Summary Hydraulic Conductivity Data by Depth in Conasauga Formation Rocks at the WBCV Site Compared to Preliminary WAC Model Input

Depth Range (ft)		Golder Associates (1989, p. 12)			Preliminary WAC Model				
		K_x (K_{Dip}) (cm/s)	K_y (K_{Strike}) (cm/s)	K_z (K_{Vert}) (cm/s)	Model Layers	Thickness (ft)	K_x (K_{Dip}) (cm/s)	K_y (K_{Strike}) (cm/s)	K_z (K_{Vert}) (cm/s)
Shallow	0 – 50 ft	1.0E-04	2.0E-04	1.0E-06	1 - 3	10 – 25 (variable)	4.61E-05	2.30E-04	4.61E-05
Intermediate	50 – 300 ft	2.0E-05	4.0E-05	2.0E-07	4-8	20	2.07E-06	2.07E-05	2.07E-06
					9	150	7.37E-07	7.37E-06	7.37E-07
Deep	>300 ft	2.0E-06	4.0E-06	2.0E-08	10	200	2.02E-07	2.02E-06	2.02E-07
					11	300	1.99E-08	1.99E-07	1.99E-08

[1] Geometric mean of 40, 36, and 20 values, respectively

Table C-9. Hydraulic Anisotropy in the Conasauga Formations

Ratio of Strike-Parallel to Dip-Parallel Hydraulic Conductivity	Test Method	Analytic Method	Reference
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		Papadopulos Infinite Aquifer Solution	
4:1	Pump test in Conasauga Group, Melton and Bear Creek Valleys	Gringarten & Witherspoon Fractured Aquifer Solution	Davis et al. 1984*
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	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.

3.3.2.2 Results of 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 karstic aquifers because they are strongly anisotropic and flow paths are difficult to determine. A number of tracer tests have been conducted in Conasauga Group units on the ORR, and the results of several are briefly summarized below. Not all of these tests were in BCV, but all are illustrative of Conasauga Group tracer flow characteristics.

Goldstrand and Haas (1994) reported on two tracer tests conducted in the Maynardville Limestone in UEFPC during low-flow and high-flow conditions. The tests simply noted whether the dye appeared at a monitoring station, and did not address first or peak arrival. The initial test, conducted in July – October 1990, used fluorescein dye injected into a well screened in the Maynardville Limestone on the south-central side of the main Y-12 plant. Eight of the 39 springs, surface water sites, and wells that were monitored had confirmed detections of dye, while four others had possible detections. Most of the sites where dye was detected were in UEFPC Valley, Scarborough Valley, or in a small stream on the south flank of Chestnut Ridge. Two possible detections occurred in EBCV near the BCBG area. Calculated first arrival times ranged from 36 to 843 ft/day.

The second test used the same injection well, but only monitored 35 wells, surface water sites, and springs. Well GW-734, at the eastern edge of the Y-12 plant site in UEFPC Valley, has a large cavity in the Maynardville Limestone, was therefore added to the monitoring program. The test used multiple dyes and was conducted from March to August, 1992. Results of the second test were equivocal because detections were only slightly above detection limits in most cases, and there were some naturally-occurring fluorescent compounds that may have interfered with dye detection. The dyes arrived at different times, and were not always detected together – possibly due to different sorption characteristics. Estimates of groundwater flow velocities from the second test ranged from 14 to 1,000 ft/day for the Calcofluor White dye and from 47 to 1,314 ft/day for the Rhodamine WT.

Lee, et al, (1989) conducted dye tracer tests at the WBCV site using Rhodamine WT dye injected in a shallow well screened in weathered Maryville Limestone in April 1988, and observation wells were monitored biweekly through June 1989. Observation wells and piezometers were screened in weathered shale and in unweathered bedrock. Fifteen falling head tests, seven in the vadose zone and eight in the bedrock, and 12 straddle packer tests were conducted to determine hydraulic conductivity. Hydraulic conductivities ranged from 9.0×10^{-4} to 1.94×10^{-6} cm/s. Mean hydraulic conductivity is 4.56×10^{-5} cm/s for saprolite and 6.72×10^{-5} cm/s for bedrock; the difference is not considered significant. Hydraulic conductivity results for limestone and shale were essentially the same.

Tracer movement was found to be predominantly strike-parallel and not simply in the direction of steepest gradient. The near-field tracer plume was long and narrow, while the distal end bifurcated. The dye remained in the saprolite and was not detected in bedrock, possibly because the vertical hydraulic head in the test area was upward. The rate of tracer movement was initially very rapid (6 to 8 ft/day) then declined to a more steady-state value of less than 0.5 ft/day. This may have been related to declining water table elevations. The long, narrow plume and initial high movement rate is interpreted as being due to migration in a high-conductivity conduit, followed by migration in lower-conductivity fractures.

Initial reports of tracer studies at the WBCV site and a site in Melton Valley using dissolved neon and helium were reported by Sanford et al. (1996) and Sanford and Solomon (1998). Gases were injected into Maryville Limestone saprolite. Important findings from these two tracer tests are that solute tracer plumes tend to develop along strike, with little transverse dispersion; and 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.

Webster (1996) conducted tracer studies using tritium in Conasauga Group rocks at Waste Area Groupings (WAGs) 4 and 6 from 1977 through 1982. Both sites are on Conasauga Group bedrock, mainly the Pumpkin Valley and Nolichucky Shales. Observation wells were evenly spaced around a circle 12 ft from the injection well, and screened at a depth of roughly 30 ft in the saprolite regolith. Water table elevations at WAG 4 were typically 15 to 16.5 ft below grade, and at WAG 6, 23 to 26 ft below grade. Initial measurements detected tritium in all of the observation wells, and the wells with the highest tritium concentrations were directly down-gradient and strike-normal relative to the injection well. Concentrations at the three downgradient wells increased to a maximum 5 to 14 months after injection and the maximum concentration remained roughly the same or declined slightly over the duration of the project. Over time, the initial elongate plumes at each site widened and became more circular, and the center of tracer mass moved slightly down-gradient and widened over time. Matrix diffusion retarded tracer movement by uptake in small blind fractures and pores, and maintained high tracer concentrations by diffusing back into the flowing groundwater in fractures over time.

McKay, et al. (2000) conducted tracer test in Maryville Limestone saprolite at the WBCV site using colloidal tracers (latex microspheres and three bacteriophages). Colloidal tracers were introduced into a 21-ft deep well in shale saprolite under normal groundwater gradient and samples were collected from multiple wells downslope, normal to strike. All tracers were detected at distances of up to 45 ft, and two of the tracers were found in all downgradient wells. Tracers arrived rapidly as a distinct pulse, followed by one to six days of high concentrations, then a rapid decline. Flow rates calculated from arrival times ranged from 15 to over 650 ft/day. Two of the bacteriophages tracers were detected in a few wells up to five months after injection, indicating retention of colloids in matrix pores and small fractures.

Results of tracer tests 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 groundwater zone of Conasauga Group units, but peak concentrations took much longer to arrive. Solomon et al. (1992) also noted that peak concentrations arrived considerably later than the first arrival. The orders-of-magnitude difference between first and peak concentration arrival velocities indicates that the peak arrival is retarded by longitudinal dispersion and uptake in matrix pores and fine fractures. Solomon et al. (1992) suggests that the relatively short distances used in many tracer tests underestimate the effects of longitudinal dispersion. It is not the arrival time, but the peak concentration, that is of interest, since this represents the greatest risk. Contaminant peak concentrations are used to determine the preliminary WAC provided in Appendix F.

3.3.3 Groundwater Flow

Groundwater occurrence and flow under the ORR has been divided into unsaturated, saturated, and aquiclude zones (Solomon, et al. 1992; Moore and Toran 1992).

3.3.3.1 Unsaturated Zone

The unsaturated zone is subdivided into the storm flow zone and the vadose zone.

3.3.3.1.1 Storm-Flow Zone

Precipitation falling on the land surface is distributed in one of four ways: by direct evaporation and transpiration by vegetation (evapotranspiration), as run-off to streams, by infiltration to groundwater, or by storage in the soil or bedrock. The largest portion of precipitation is temporarily stored in the soil or depressions (puddles) and released to the atmosphere by evapotranspiration (direct evaporation and transpiration by vegetation). A smaller portion, on the order of 10% of infiltrating water (Driese, et al. 2001; Moore 1988, 1989) passes through the vadose zone to be stored in soil or saprolite, or to eventually reach the water table. The second largest portion of precipitation is lost via run-off, most of which flows through the storm-flow zone.

Because little or no overland flow occurs in forested areas except during very heavy rains, a large proportion of rain entering the soil is conducted down-gradient via the storm-flow zone to discharge to streams or temporary springs. This has been found to be true even in karst terrains in semi-arid environments (Wilcox, et al. 2008). The storm-flow zone flows only in response to rain, and flow ceases in a matter of hours or days. The storm-flow zone is more pronounced on ridge crests and side-slopes, but merges with the water table near streams. The storm-flow zone is a temporary perched water table, typically 3 to 10 ft (1 – 3 m) deep, characterized by generally high organic content, roots and root channels, and bioturbation by worms and small fauna. A study by Driese, et al. (2001) demonstrated that the base of the storm-flow zone is marked by a low-permeability layer of accumulated clays and mineral deposits.

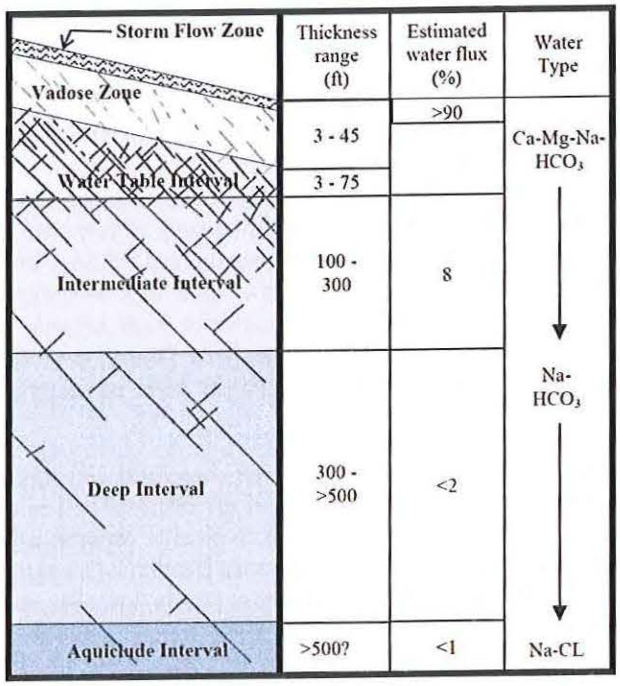
The position and drainage area of the storm-flow zone is an important consideration in landfill design, because storm-flow must be intercepted and diverted around the disposal cell in order to limit erosion of the cover and infiltration into the buried waste. This is typically accomplished through the use of upgradient French Drains and diversion ditches. Many previous Resource Conservation and Recovery Act of 1976 (RCRA) type covers at ORR were ineffective because storm-flow was not intercepted effectively and continued to cause saturation or "bath tub effect" in waste trenches due to water underflowing the caps (Melroy, et al. 1986). Construction of the EMDF would remove the storm-flow zone beneath the landfill footprint and divert shallow storm-flow around the EMDF using a relatively impervious, geomembrane-lined surface ditch in combination with French drain, both constructed on the upgradient side of the landfill.

3.3.3.1.2 Vadose Zone

The vadose zone is defined as the region of soil or bedrock in which water pressure is negative, meaning that capillarity will hold water in storage until saturation is reached. The vadose zone is the region of water table flux (rise and fall) that exists between the storm-flow zone and the saturated zone everywhere in the ORR except near perennial streams, where saturated conditions may intersect the storm-flow zone. The vadose zone is typically < 60 ft (20 m) thick beneath Pine Ridge (Solomon, et al. 1992). Water in the vadose zone migrates vertically to the water table or is taken up by plant roots and transpired (Solomon, et al. 1992; Moore 1988; Moore and Toran 1992). 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. Flow occurs in fractures and matrix pores in saprolite as pathways. The lower boundary of the vadose zone is the capillary fringe, a thin zone of near-saturation in fine-grained regolith created by capillary rise of water from the saturated zone beneath.

3.3.3.2 Saturated Zone

The saturated zone includes shallow, intermediate, and deep flow zones; the majority of groundwater flow occurs within the shallow zone. The boundaries between these levels occur at different levels in different parts of the ORR (Moore and Toran 1992) and their placement is commonly based on groundwater chemical compositions. Hydrogeochemical processes involving exchange of cations on clays and other minerals result in a change from calcium bicarbonate ($Ca\text{-}HCO_3$) to sodium bicarbonate ($Na\text{-}HCO_3$) and ultimately to a sodium chloride (Na-Cl) type water at depth. These geochemical zones reflect groundwater residence times and reduction of water flux with depth. Figure C-13 illustrates this conceptual model.



Adapted from Solomon et al. (1992)

Figure C-13. Conceptual Model of Groundwater Zones in BCV

3.3.3.2.1 Shallow Aquifer Zone

The saturated zone begins at the water table, which begins at the base of the capillary fringe and extends to depths of 75 to 100 ft (Solomon, et al. 1992). The water table is commonly found at or near the bedrock-regolith boundary. According to Solomon, et al. (1992), most fluctuation and flow occurs in the upper 3 to 15 ft of the saturated zone because of the density of open fractures and, in carbonate lithologies, the presence of cavities. Moore (1988) indicates that hydraulic conductivities in this zone are one to two orders of magnitude higher than in underlying bedrock.

The water table is 3 to 6 ft (<1-2 m) deep near perennial stream channels but may be 15 to 45 ft (5-15 m) deep beneath ridges underlain by the Rome Formation and Conasauga Group formations (Moore and Toran 1992). The depth to groundwater water at the proposed EMDF site (before construction) ranges from very near the land surface on the valley floor during wet periods to >55 ft on the flank of Pine Ridge. In dry seasons, the water table generally occurs near the regolith – bedrock contact, for which the geometric mean of depth to water in October is 12.5 ft (4.1 m) (Moore 1988). There are no known wells or boring data within the proposed EMDF footprint; however, there are wells and groundwater data in adjacent areas south and west of the site. Seasonal high groundwater 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 estimated groundwater table map is provided in Figure C-14.

The hydraulic gradient of the water table interval is generally from Pine Ridge in the north to the south west towards Bear Creek and locally towards tributaries. Hydraulic head data collected in multiport wells in Bear Creek Valley and interpreted by Dreier et al. (1993), Moore and Toran (1992), Lee and Ketelle (1989), among others, demonstrate that stratigraphy and geologic structure control valley-wide hydraulic head distributions and flow patterns. In general, recharge is topographically driven from the ridges. Hydraulic head patterns show convergent flow to the Maynardville Limestone in the valley floor indicating that it serves as the hydraulic drain for Bear Creek Valley. Flow is locally directed in both horizontal and vertical dimensions by bedding planes, much like rainwater on a street is directed by the presence of a curb. Within the Maynardville, flow is generally horizontal to the west and strike-parallel, with local upward and downward components.

Dreier et al. (1993) mapped hydraulic head distributions across EBCV, as shown in Figure C-15, that indicate an upward gradient beneath the disposal site in the Conasauga Group and probable discharge to the Maynardville Limestone.. There is an isolated high pressure pod in the Nolichucky Shale that appears to be a relic of higher density fluids flowing down dip from the S-3 Ponds. On the opposite side of the valley, the gradient is vertically downward from the Knox Aquifer to the Maynardville Limestone. The Maynardville Limestone has a conspicuously lower hydraulic head than adjacent stratigraphic units above that indicates that it, with Bear Creek, serves as the drain for the valley as a whole. Bailey and Lee (1991) modeled flow in BCV and found a similar head distribution, as shown in Figure C-16.

Vertical gradients are generally upward and flow toward the reduced hydraulic head in the Maynardville Limestone (Dreier et al. 1993). S-3 Pond (DOE 1997) and chlorinated volatile organic compound (VOC) contaminant plumes from the Boneyard/Burnyard (BYBY) 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 groundwater flows. However, flow meter surveys conducted in BCV by Moore and Young (1992) found that natural downward flows occurred in most of the 70 wells measured. Flow rates ranged from 0.01 gpm to over 1.25 gpm; induced flow rates were somewhat lower.

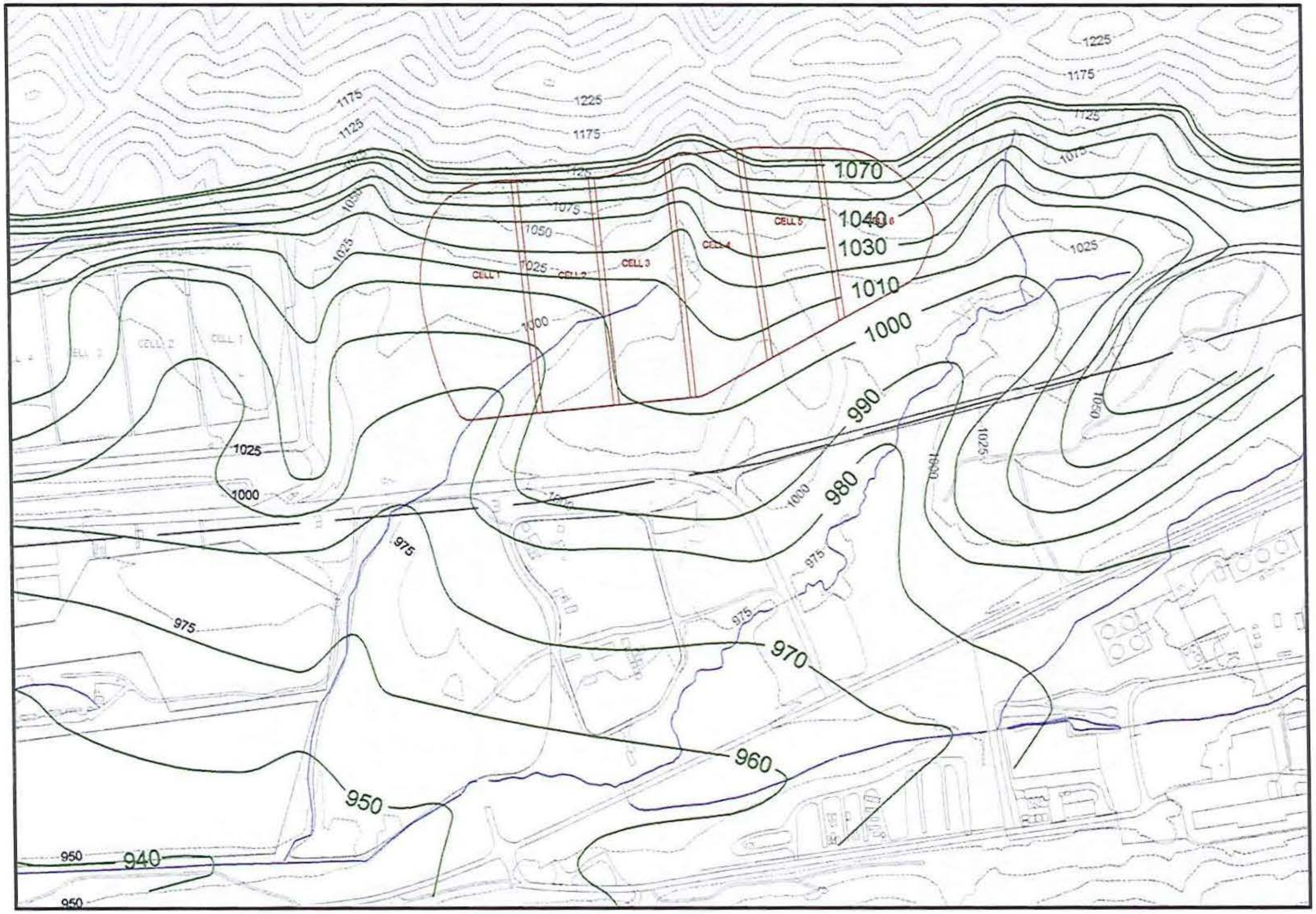
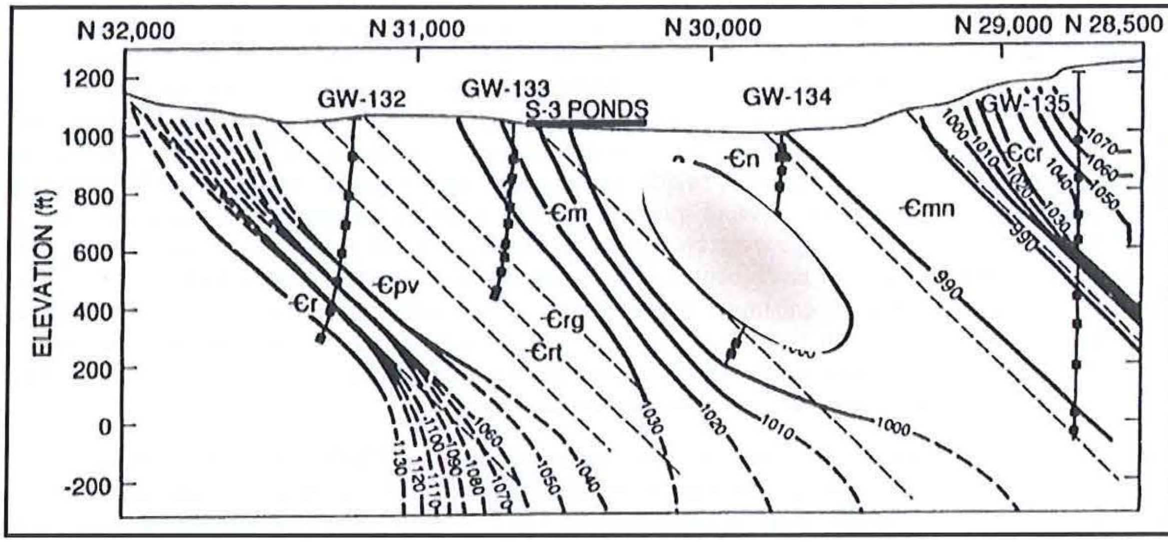
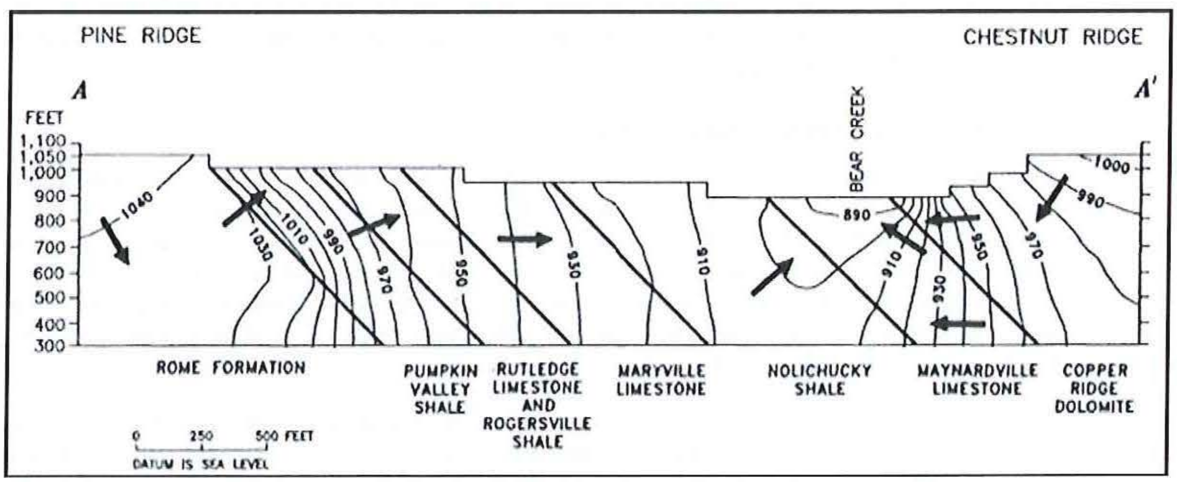


Figure C-14. Estimated High Groundwater Table Elevations for the Proposed EMDF Site



Adapted from Dreier, et al. (1993). Arrows indicate groundwater flow directions. 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 C-15. Hydraulic Head Distribution Across EBCV



Source: Bailey and Lee, 1991. Numbered contours indicate head distribution and arrows indicate flow directions. Cross-section is near the BCBG.

Figure C-16. Cross-Sectional Representation from a Computer Model of Groundwater Hydraulic Head and Flow Patterns for EBCV

BNI (1984) conducted surveys of vertical and horizontal flow in Conasauga Group rocks in the BCBG and BYBY areas and found that flow orientation and sense (upward or downward) were variable and depended on depth, lithology, and fractures and cavities. In general, vertical flow was consonant with the local water table gradient based on head measurements, and horizontal flow was toward streams. Several measurements made in wells screened in the Nolichucky Shale indicated horizontal Darcy velocities in the 10s of ft/day, although most were less than 5 ft/day.

The water table typically fluctuates with rainfall and climate, and the magnitude and speed of response is directly related to the type of pore system being monitored. At one end of the spectrum are wells completed in relatively impermeable matrix pore-dominated zones, i.e., zones with few open fractures, in which the water table elevation does not respond directly to rainfall events, but instead shows a long-term, low-amplitude rise and fall that corresponds to wet-dry seasonal changes. At the other end of the response spectrum are wells that are completed in cavities or in conduit-flow regimes, such as in the Maynardville Limestone, which typically exhibit a rapid short-lived rise in water level in response to moderate to heavy rainfall. Water level rises average over 16 ft (5.3 m). This is termed quickflow because the rise and subsequent decline to base flow levels occurs over a matter of hours to days (Shevnell, et al. 1995). Water levels in wells completed in enhanced fractures, but in not actual cavity systems, exhibit rainfall responses somewhere between these two extremes. Response to rainfall events can be seen even in relatively deep wells, indicating connectivity between shallow and deep fracture systems. However, these responses may be pressure pulse and not true groundwater movement.

Most groundwater in the shallow zone is a calcium bicarbonate ($Ca\text{-}Mg\text{-}Na\text{-}HCO_3$) type. Haase (1991) found that this water chemistry is dominant to depths of about 75 ft, but in a few wells was found to extend to about 300 ft. The pH range for this water is 6.5 to 7.5. These waters are generally saturated with respect to calcite, but are under saturated relative to dolomite. Table C-10 provides data on the geochemistry of Conasauga Group groundwater.

Shevnell (1994) indicates that shallow waters are not saturated with calcite, leading her to conclude that groundwater that is consistently under saturated with respect to calcite indicate that these waters are influenced by recharge and have relatively short residence time. Further, temporal variations between supersaturated and under-saturated conditions in some wells can be explained by diffusion of old, saturated waters from matrix pores during low-flow periods, and flushing with under-saturated waters during high-flow or quick-flow periods.

3.3.3.2.2 Intermediate and Deep Aquifer Zones

Sparse stratigraphically controlled fracture networks at intermediate to deep depths in the saturated zone probably transmit most of the water that reaches intermediate to deep zones from shallower depths along strike toward tributary streams, while the remainder flows down-dip and through fractures discharge to main valley streams, such as Bear Creek (Moore and Toran 1992). The top of the intermediate zone is marked by a change in the dominant anions from mixed-cation - HCO_3 to $Na\text{-}HCO_3$, 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).

Moore and Toran (1992) postulate that flow paths in the deeper groundwater zones are longer and less tortuous than in shallower rocks. They also indicate that very little water flows through the deeper groundwater zone, and that water flux decreases with depth. According to Solomon, et al. (1992), the deep zone hosts very little groundwater flow. This very low flux can be explained by the reduced number of open fractures and consequent reduced hydraulic conductivity and increased friction, as well as by the difference in water density.

Table C-10. Geochemical Zones in the Conasauga Group Formations

<table>
<tr><th rowspan="2">Interval or Zone</th><th colspan="3">Bear Creek Valley (Haase 1991)</th><th colspan="2">Bear Creek Valley (Bailey and Lee 1991)</th><th colspan="3">Melton Valley (Haase, et al. 1987; Nativ, et al. 1997)</th></tr>
<tr><th>Depth (ft)</th><th>Type</th><th>pH</th><th>Depth (ft)</th><th>Type</th><th>Depth (ft)</th><th>Type</th><th>pH</th></tr>
<tr><td>Shallow</td><td>75 ft</td><td>Ca, Mg-HCO_3</td><td>NA</td><td>< 50</td><td>Ca, Mg-HCO_3 or SO_4</td><td>< 75</td><td>Ca, Mg-HCO_3 or SO_4</td><td>6.5 – 7.5</td></tr>
<tr><td>Intermediate</td><td>NA</td><td>NA</td><td>NA</td><td rowspan="2">50 – 500</td><td rowspan="2">Na-HCO_3 (with some Na-Cl and Na-SO_4</td><td>75 - 275</td><td>Na-HCO_3</td><td>6.0 – 8.5</td></tr>
<tr><td>Deep</td><td>NA</td><td>NA</td><td>NA</td><td>75 - 530</td><td>Na-HCO_3 to Na-Cl</td><td>8.0 – 10.0</td></tr>
<tr><td>Brine (aquaclude)</td><td>>530</td><td>Na-Cl</td><td>NA</td><td>NA</td><td>NA</td><td>590 (GW-121)</td><td>Ca-Na-Mg-Cl + SO_4</td><td>11.6</td></tr>
</table>

The intermediate and deep aquifer zones are distinguished from the shallow zone by a change from a calcium-magnesium-bicarbonate chemistry to a chemistry dominated by sodium-bicarbonate (Na-HCO_3) ions (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 an Na-HCO_3 water type with distinct zones of Ca-Mg-Na-SO_4 water. These sulfate-rich water zones appear to be related to the presence of gypsum beds in the carbonate units.

This change in groundwater chemistry is interpreted to be the result of rock-water interactions and diagenesis of minerals. The rate at which the groundwater reaches chemical equilibrium with source minerals is important in the diagenetic evolution of Na-HCO_3, indicating that the groundwater is reaching equilibrium with the host rock. If clay alteration is an important control on groundwater geochemistry, then Na-HCO_3 type water may mark the transition between the actively circulating shallow zone and stagnating groundwater 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 groundwater 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.

3.3.3.3 Aquiclude

The aquiclude is so named because the extremely high salinity of this water indicates that little or no groundwater 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 to 10.0 range, and change from $Na-HCO_3$ as the dominant ion pair to dominance of sodium chloride (Na-Cl) below 1,150 ft. This increase occurred just below a major fracture zone. Haase (1991) noted that the deep sodium-chloride groundwater in four deep wells sampled for this study was saturated with respect to calcium and magnesium, and contained barium 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[1] 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 groundwater 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 groundwater circulation is minimal, and that deep rocks exhibit very low hydraulic conductivity values, on the order of 10^{-7} to 10^{-9} cm/s, which suggests either absence of numerous permeable fractures or absence of flow.

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 groundwater exchange may occur between water beneath the halocline and shallower groundwater 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 groundwater 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. It would require a great deal of hydraulic head or pressure 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, 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 the brine of shallow groundwater. This analogous to the fresh water sea water boundary that develops in coastal aquifers.

3.3.4 Groundwater Contaminants

No contaminated groundwater or soil is known to occur on or under the proposed EMDF area. According to the BCV RI (DOE 1997), groundwater contamination at sites near the EMDF site consists of:

- Radioactive constituents (gross α and β, ^{238}U, ^{235}U, ^{234}U, ^{232}Th, ^{230}Th, ^{228}Th, ^{213}Pb, and ^{40}K) in a shallow groundwater plume from BYBY that underlies NT-3;
- Chlorinated solvents in a plume extending down-dip in the Nolichucky from the BYBY;
- Nitrate and uranium in two shallow to deep groundwater plumes (one in the Nolichucky Shale, the other in the Maynardville Limestone) emanating from the S-3 Ponds; and
- Low concentrations of chlorinated VOCs in shallow groundwater at the Oil Landfarm and Sanitary Landfill 1.

[1] 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 diminished to undetectable concentrations if ground water migration times were very long.

The BCV RI (DOE 1997) provides greater detail on the nature and extent of contamination in EBCV prior to the remedial action that was completed at the BYBY in accordance with the BCV Phase I ROD.

Zone 3 groundwater monitoring is conducted in Picket B wells GW-704 and GW-706, and RCRA wells GW-008, near the Oil Landfarm, and GW-046, near the BCBG (DOE 2011b).

Well GW-008, the closest monitored well to the EMDF area, is screened at a depth of about 25 ft. Low (< 40 μg/L) and steady concentrations of several chlorinated VOCs, and higher variable concentration of perchloroethene, have been observed since monitoring began in 1999 (DOE 2011b). Other contaminants were not reported from GW-008. Well GW-046 also exhibited variations in chlorinated and non-chlorinated VOC concentrations, but at levels an order of magnitude higher than in GW-008.

Picket wells GW-704 and GW-706 are monitored for nitrate, trichloroethene (TCE), ^{99}Tc, and uranium isotopes. Concentrations of ^{234}U and ^{238}U exhibit a declining trend such that recent concentrations are at or below 20 pCi/L. TCE and nitrate concentrations are also declining. Recent TCE concentrations are below 30 ug/L, and nitrate concentrations are below 20 mg/L. ^{99}Tc concentrations also declined. Groundwater chemical concentrations vary with precipitation.

3.4 SURFACE WATER HYDROLOGY

Surface water features relevant to the proposed EMDF site include tributaries near the site and Bear Creek. Bear Creek drains west to the Poplar Creek, and then to the Clinch River (Watts Bar Reservoir). The elevation difference between upper BCV and the Watts Bar (pool elevation 741 ft) is approximately 250 ft.

3.4.1 Water Budget

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 run-off and infiltration values. Run-off 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 run-off.

Water input is usually considered to be equal to the amount of precipitation (rain and snow), but may also include surface water and groundwater inflow from other subbasins or, because groundwater 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 (groundwater and depression storage),

P = Precipitation,

GW_{in} = Groundwater inflow,

GW_{out} = Groundwater outflow,

ET = Evapotranspiration, and

R = Runoff.

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., $\Delta S = 0$); therefore, water input and output balance (CCL 2001).

Precipitation and stream flow can be measured with relatively good accuracy. As noted in Sect. 1.4.1, mean annual precipitation is 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.

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% to 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 45% to 50% either flows out of the region in streams, is held in reservoirs, such as Melton Lake, or recharges the groundwater system. Evapotranspiration is greatest during the growing season when plants are transpiring and when warm weather increases direct evaporation rates.

Groundwater inflow is often assumed to be absent or negligible because surface water drainage divides are usually more or less coincident with groundwater drainage divides. 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 1989b), as shown in Table C-11. Preliminary WAC model recharge rates range from 7 in./yr to 8.75 in./yr.

Table C-11. Water Budget Estimates for Areas of the Oak Ridge Reservation

Hydrologic Component	DOE 1997 (BCV RI)		Golder Assoc 1989b	
	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
Groundwater Recharge	3.1 in (78.6 mm)	6.7	9.55 in (242.6 mm)	22.1
Groundwater Storage	0.59 in (15 mm)	1.3		

The BCV RI (DOE 1997) and results of groundwater tracer studies (Goldstrand and Haas 1994) suggest that the surface divide between the Bear Creek basin and the UEFPC basin may not be the same as the groundwater divide. Thus, there is a possibility of extra-basin groundwater inflow to the Bear Creek watershed.

Groundwater outflow is not directly measurable, and therefore must be estimated using flow nets or computer models. Groundwater 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; Rothchild, 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 groundwater 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 groundwater 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 (1989b) studies are from areas that are most similar to the EMDF candidate site, so that the combined percentage of subsurface flow and change in groundwater storage range between 8% and 22% of total precipitation. As noted above, change in groundwater 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.

3.4.2 North Tributaries of Bear Creek

Two small streams, tributaries of Bear Creek, are near the candidate site, as shown in Figure C-17. These are North Tributary (NT)-2 and NT-3. NT-2 is a southwest flowing first-order stream to its juncture with Bear Creek.

Both NT-2 and NT-3 are fed by seeps and springs during high base flow periods (i.e., the wet season) (Robinson and Johnson 1996). NT-2 rises as a spring on the flank of Pine Ridge, roughly at the subcrop of the boundary between the Rome Formation and Pumpkin Valley Shale. A draw/ravine to the west of NT-2 is fed by a seep at about the same position relative to slope and boundary subcrop. Several other draws/ravines that flow to NT-2 are fed by seeps.

NT-3 receives flow from draws/ravines fed by precipitation and by springs and seeps at its headwaters on the east and west side.

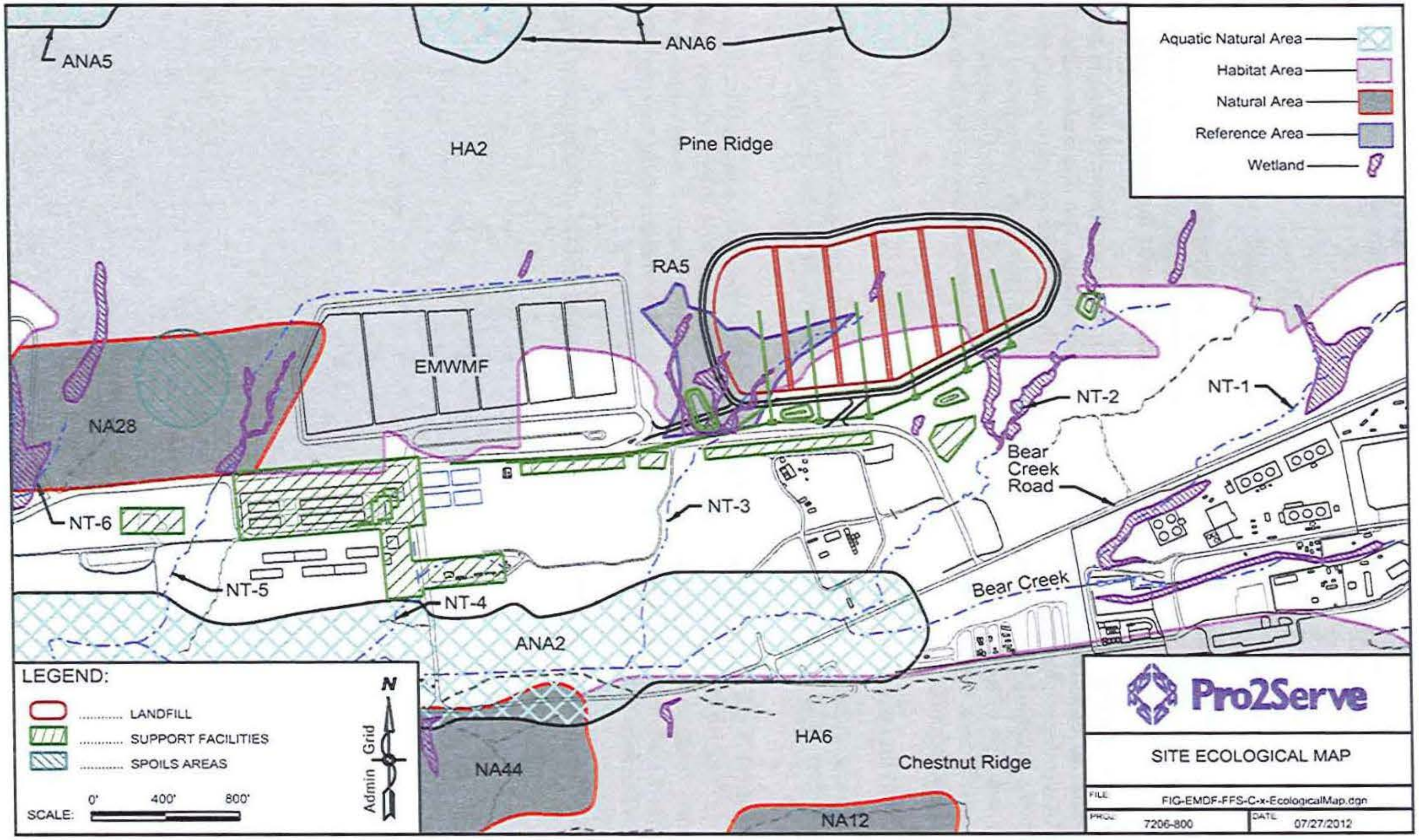


Figure C-17. Streams, Wetlands and Reference Areas in the Vicinity of the Proposed EMDF

Both NT-2 and NT-3 have small wetlands on the their main channels. The hydrology of wetlands near the Haul Road have been affected by the construction of the Haul Road. The NT-3 wetlands on the the north side of the Haul Road (Temporary Quillwort Pond) have expanded since the lower reaches were restored as a result of a flow-limiting plate that was welded across the culvert that was installed as part of NT-3 stream. This allowed water to accumulate on the north side of the Haul Road, and may have unintentionally contributed to wetlands enlargement.

3.4.2.1 Stream Flow Characteristics

During seasonal high water table conditions, the sources of the tributaries are springs and seeps that discharge from the contact of the Rome and Pumpkin Valley formations and groundwater seepage. Both NT-2 and NT-3 are intermittent streams (Robinson and Johnson 1996; Robinson and Reavis, 1996), meaning that they are dry during the annual dry season (August through October). However, in the BCV RI (DOE 1997) it was noted that NT-2 maintained continuous flow at a downstream weir from March 1994 through January 1995, i.e., for a period overlapping the USGS study period. Flow is continuous during the wet season (November through April). Portions of Bear Creek are also largely dry during the fall dry season above NT-8, about 1.3 mi to the west of NT-3.

Flow in NT-2 during a one week wet season measurement period in March 1994 was approximately 0.16 ft^3/s both at its confluence with Bear Creek and at a point roughly 1,800 ft upstream (Robinson and Reavis, 1996). During this time, NT-2 also had dry reaches. Springs and seeps were found by Robinson and Johnson (1996) to be dry during the late summer and early fall dry season, coincident with lack of base flow in the streams.

Flow in NT-3 during the same measurement period ranged from 0.2 to 0.4 ft^3/s in the upstream segments to 1.16 ft^3/s at its confluence with Bear Creek (Robinson and Reavis, 1996). NT-3 had no dry reaches during this time.

Both streams are expected to flow during the dry season, and experience flow increases during the wet season, for a short period after heavy or prolonged rainfall events. However, flow will rapidly recede as surface flow and storm flow ceases.

3.4.2.2 Gaining and Losing Reaches

Both NT-2 and NT-3 exhibit gaining and losing reaches during high base flow conditions. During high base flow conditions, the upper reaches of the tributaries gain flow, but the lower reaches may either have no gain or may be losing flow. Under low-flow conditions the tributaries can be dry throughout their length.

3.4.2.3 Tributary Chemistry Indicators

Ranges of values for four stream chemistry indicator parameters are provided in Table C-12. In general, low base flow measurements were collected from standing pools in otherwise dry streams, as the high temperatures suggest. The pH ranges from slightly acidic to slightly alkaline, and does not appear to vary with the distance from source. Specific conductivity tends to increase linearly from source to confluence at Bear Creek; the highest values occur at the mouth of each stream during both high- and low-flow periods. Temperature during high base flow is in the range that would be expected for the time of year. High base flow water temperatures tend to decrease downstream. Dissolved oxygen concentrations are highly variable.

No chemistry parameter measurements were recorded for wetlands on NT-2 and NT-3.

Table C-12. Summarized Water Chemistry Parameters for NT-2 and NT-3

Stream	Measurement period	Type	pH	Specific Conductivity (μ S/cm)	Temperature (°C)	Dissolved Oxygen (mg/L)
NT-2	High base flow	Stream (18 sites)	5.9 – 7.9	27 - 902	8.0 – 12.0	9.8 – 11.0[a]
		Spring (1 site)	7.2	29	12.0	NA
		Seeps (13 sites)	5.1 – 7.5	25 – 88[b]	8 0 – 12.0	2.4 – 10.8
	Low base flow [c]	Stream (7 sites)	6.9 – 7.9	77 – 2,030	18.0 – 22.5	6.5 – 8.2[d]
NT-3	High base flow	Stream (12 sites)	5.4 – 8.1	39 – 760	8.5 – 14.5	NA
		Spring (1 site)	6.6	62	12.0	8.8
		Seeps (3 sites)	5.4 – 6.4	41 - 66	9.5 – 12.5	5.0 – 9.5
	Low base flow [c]	Stream (5 sites)	7.4 – 7.6	73 - 642	19 – 20.5	NA
		Spring (1 site)	7.1	84	18.5	7.4
		Seeps (1 site)	6.9	92	17.5	8.2

Source: (Robinson and Johnson 1996). Data collected during March and September, 1994.
[a] Four measurements at downstream end.
[b] Eight measurements
[c] Low base flow measurements are assumed to be from isolated pools with little or no flow, since both streams are indicated to be dry during the low base flow period.
[d] Five measurements, from near head to near confluence

3.4.2.4 Tributary Contaminants

Surface water samples were collected in March 2010 at several locations in NT-3 as part of the on-going Water Resources Restoration Program to measure the uranium isotopic composition, nitrate, ^{99}Tc, and VOCs (DOE 2011b). These contaminants are associated with releases from the BYBY, Hazardous Chemical Disposal Area, Sanitary Landfill, Oil Landfarm that leach to NT-3, and a nitrate plume from the S-3 Ponds that has migrated in the Nolichucky Shale to discharge to surface water. As reported in DOE (2011b), 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 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, then began to increase again. Continuous flow-paced sampling was resumed at NT-3 because the uranium levels exceeded the 4.3 kg/yr flux standard set in the ROD. Water in NT-3 currently meets ambient water quality criteria (AWQC). Biological monitoring indicates that benthic diversity remains low and that there are fewer pollution-intolerant benthic taxa than in nearby reference streams. Fish communities in NT-3 exhibit slightly lower or similar total richness as compared to reference streams.

3.4.3 Bear Creek

Bear Creek flows west in BCV from its head waters near the S-3 Ponds to ultimately discharge to East Fork Poplar Creek near ETTP. Bear Creek is located south of the proposed EMDF site and is briefly discussed here because it receives waters from NT-2 and NT-3, and because it is the surface expression of the BCV drainage system.

The local base level for BCV is the Bear Creek flow system. This system is a 3-dimensional system in which the complex conduit system in the Maynardville and Bear Creek function as an integrated drain for the valley. At any given time, flow will occur in at least some level in the Maynardville Limestone conduits, and in Bear Creek where it lies on the Nolichucky or is not locally connected to the cavity system. The upper reaches of Bear Creek go dry and lose flow to the subsurface during low flow periods. As flow increases, more of the Maynardville cavity system will be recruited to handle the flow, until flow volumes are sufficient to cause open flow in Bear Creek. The BCV drain can be viewed as a series of stacked conduits, of which the open stream channel is simply the uppermost. It therefore is a hydraulic boundary for the majority of groundwater and surface water flow.

3.4.3.1 Stream Flow Characteristics

Daily flows at Bear Creek kilometer (BCK) 11.54, just downstream of the confluence of NT-3 with Bear Creek, were obtained from the Oak Ridge Environmental Information System database for the period from 2006 through 2011. The average daily flow is 0.55 ft^3/s, the median daily flow is 0.18 ft^3/s, and the range is from no flow (dry) in summer to 32 ft^3/s in the winter-spring wet season.

3.4.3.2 Gaining and Losing Reaches

The upper reaches of Bear Creek may be gaining, losing, or neutral, depending on high and low base flow conditions (Robinson and Reavis 1996). Under high flow conditions, Bear Creek is a losing stream at the confluence with NT-2 but becomes gaining as it passes the BYBY to its confluence with NT-3. It then becomes a losing stream as it passes Sanitary Landfill 1.

Robinson and Reavis (1996) found that under low base flow conditions, many reaches of Bear Creek above the water gap in Pine Ridge were losing or dry. This is particularly true of the reaches above the confluence of NT-4, although there is a slight gain inflow below the confluence with NT-3, even though no flow was recorded in NT-3 itself. This is interpreted, as noted above, to be the result of discharge through cavity systems underlying the tributary.

3.4.3.3 Bear Creek Water Chemistry

Table C-13 provides a summary of Bear Creek water chemistry indicators. The pH of water in the upper reaches of Bear Creek averages close to 8 standard unit (S.U.), 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 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 decreased downstream, and the exception, BCK 12.34, is near the former S-3 Ponds and likely to be affected by S-3 contaminants.

Table C-13. Summary of Bear Creek Water Chemistry Indicators

Station*	N	Period	pH (S.U.)	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

3.4.3.4 Bear Creek Contaminants

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. The uranium flux goal set by the Phase I ROD is ≤34 kg/yr at the integration point (BCK 9.2) and ≤27.2 kg/yr 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. 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 former burial grounds area.

Nitrate and cadmium contaminants emanating from the former S-3 Ponds have formed two groundwater plumes in EBCV, and some of this contaminated groundwater is discharged to the upper reaches of Bear Creek (DOE 2011b; 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 2011b). Nitrate concentrations decrease downstream from the S-3 Ponds area.

Cadmium concentrations significantly exceed the 0.25 µg/L AWQC at BCK12.34 during the years 2001 – 2010, but meet the AWQC at BCK 9.2 (DOE 2011b).

Southworth, et al. (1992) noted that reductions in Bear Creek contaminant loads occurred after waste stopped being placed, and the results of remedial effectiveness sampling since 1999 confirm this trend (DOE 2011b). However, uranium continues to exceed the ROD goal.

3.5 CONCEPTUAL FLOW MODEL

The conceptual model developed here is based on a three-porosity system in Conasauga Group units at the EMDF site. This system is composed of:

- Matrix pores in clastic saprolite
- Fractures in saprolite, unweathered clastics, and unweathered carbonates
- Cavity systems in carbonate

Groundwater in saprolite matrix and fractures and bedrock fractures in Conasauga Group units flows with the strike-parallel gradient in each unit to the nearest tributary. The high density of fractures in Conasauga rocks and saprolite defines a flow system that, at a large scale, behaves similarly to a heterogeneous matrix system in which it is the aggregate or bulk characteristics that control groundwater flow. The majority of flow from ridge flanks is directed towards the valley axis by the north tributaries and vertically upward from deeper groundwater to discharge into the Bear Creek - Maynardville Limestone drainage system by the pressure head from surrounding ridges. A small amount of diffuse flow from soils and sediments may also contribute to stream flow.

Worthington and Ford (2009) describe a process whereby dissolution along fractures in carbonate aquifers self-organizes groundwater flow into networks consisting of one or more trunk conduits, smaller tributary conduits, and fractures not yet solution-enhanced as illustrated conceptually in Figure C-18. This concept is supported by White and White (2005, 2003), who note that groundwater flow in carbonate aquifers focus into a few localized pathways at an early stage of development. This focusing is more efficient in areas of higher gradients (White and White 2003). In this concept, the trunk conduit or pathway forms along some preferred path, such as a fracture, and becomes dominant when it achieves break-through at a larger conduit or stream. At this point, flow in the trunk conduit becomes turbulent, further increasing conduit size and permeability in a positive-feedback process.

Over time, the network of conduits becomes increasingly widespread, complex, and finer as dissolution continues to develop the tributary system, presumably, to match the amount of water that must flow through the system. The concept is roughly analogous to development of surface streams, but results in finer conduits in headwaters areas than would be found in surface stream systems because no overland flow can occur in subsurface systems. Unorganized wide-area flow may occur locally, but is not a major flow pathway.

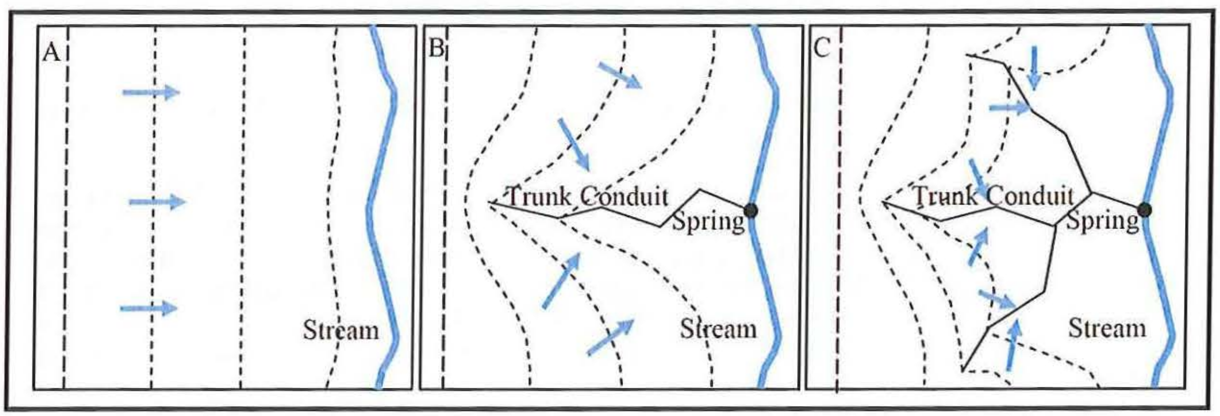


Figure C-18. Conceptualization of Development of Self-Organized Permeability in Carbonate Aquifer

The larger-aperture conduits occupy a relatively small fraction of the bulk volume of the aquifer, but because of their large size and integration, carry most of the water. However, although cavities, presumably capable of conduit flow, have been documented in the Nolichucky and Maryville formations, it is by no means clear that these convey the majority of groundwater flow, but it is likely that they convey much of the strike-parallel flow.

It can be argued that this model of self-organized permeability is not suitable for a mixed carbonate-clastic bedrock that is structurally tilted at 45° from horizontal, because clastic rocks, such as shale and siltstone, do not dissolve, and because the tilted beds present barriers to flow. However, the model can be fitted to the proposed EMDF site by substituting fractures in clastic rocks for conduits while still including conduits in carbonate rocks, and by recognizing that the dominant cross-strata fractures or joints that are exploited by NT-2 and NT-3 also function as subsurface drains. The strong anisotropy of saprolite and bedrock hydraulic conductivity will result in a more rectilinear groundwater drainage system than the surface water drainage area exhibits, but the drainage areas should be roughly the same.

The valley drain is a complex three-dimensional system in which Bear Creek and strike-parallel underflow and overflow conduits in the Maynardville Limestone function together. Bear Creek flows more or less continuously over non-karst bedrock, but loses flow to subsurface conduits where it crosses karstic rocks. Underflow conduits in the Maynardville Limestone continuously convey base flow, while overflow conduits and Bear Creek carry high flows during the wet season and heavy rainfall events. Figure C-19 is a graphical representation of this conceptual model. Water readily moves in and out of the Bear Creek channel and stacked subsurface conduits. This is demonstrated by the numerous losing and gaining reaches in Bear Creek. The amount of water in the system dictates which conduits are recruited to conduct flow, as demonstrated by the documented occurrence of quickflow in the Maynardville, and by the fact large segments of the stream go dry in summer, but flow continuously during the winter wet season. The shape of the shallow BYBY alpha plume in groundwater, as reported in (DOE 1997), and modeling conducted as part of this RI/FS (see Appendix F) support this concept.

3.6 ECOLOGICAL SETTING

The proposed EMDF site is characterized by upland deciduous hardwood forests, intermittent streams, springs, and seeps, and small upland wetlands. A number of areas on the ORR have been identified as Natural Areas, Aquatic Natural Areas (ANAs), Reference Areas (RAs), Aquatic RAs, Special Management Zones, Conservation Easement Areas, Cooperative Management Areas, Habitat Areas, and Potential Habitat Areas. Two of these, RA-5 and ANA-2, will be or could be impacted by construction and operation of the proposed EMDF. Figure C-17 shows these features.

3.6.1 Wetlands

Two wetlands, one near NT-2 and one near NT-3, are within the conceptual landfill footprint and are likely to be impacted by landfill construction.

NT-2 receives flow from five small draws/ravines, and four of these host forested wetlands in broad level bottoms upstream and downstream of the Haul Road. One wetland area on the north side of the Haul Road covering approximately 1 acre has been identified along the main channel of NT-2, as well as along a draw/ravine that enters from the north (Rosensteel and Trettin 1993). It is likely that this northern draw/ravine and associated wetland would be affected by EMDF construction. No status species have been reported in this wetland area (Parr 2012; Rosensteel and Trettin, 1993; Cunningham and Pounds 1991).

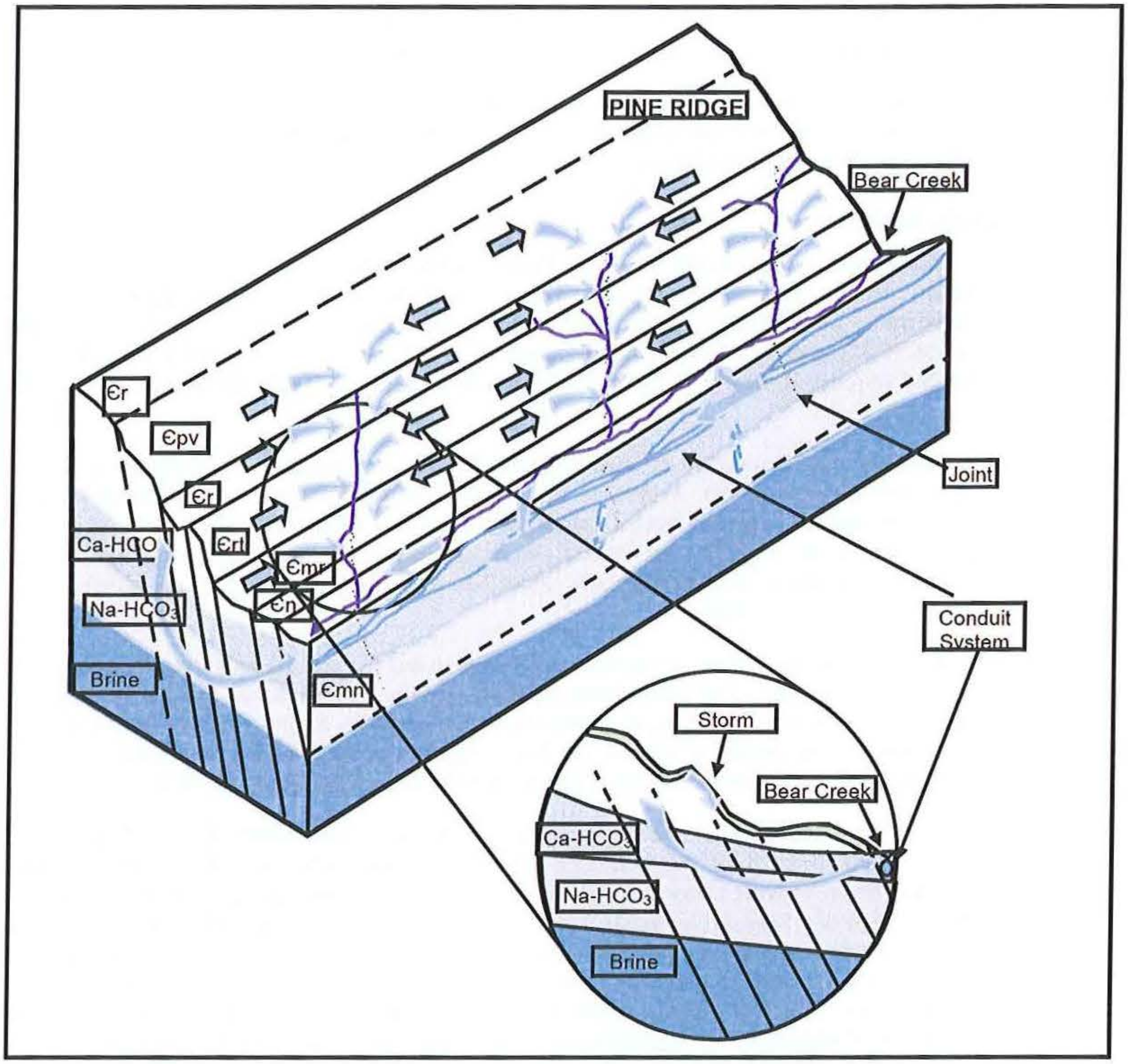


Figure C-19. Block diagram Illustrating Conceptual Groundwater Flow Model for the Proposed EMDF Site

RA-5 encompasses the Quillwort Temporary Pond wetland on NT-3 where two draws/ravines join the main stream channel immediately north of the Haul Road. This wetland appears to have been formed, in part, by a partial restrictor plate installed over the culvert before it passes under the Haul Road. This wetland has an estimated gross area of approximately 1 acre (Rosensteel and Trettin 1993). The two small draws/ravines are classed as forested wetlands in tributary bottoms with dense understory, while the center channel wetland is classed as 'forested wetland in depression at tributary head' (Rosensteel and Trettin 1993). RA-5 is known to contain clammy hedge hyssop (*Gratiola neglecta*) and Carolina quillwort (*Isoetes caroliniana* [A.A. Eaton] Luebke; this name is considered by the Interagency Taxonomic Information System to be synonymous with *Isoetes valida* (Engelmann) Clute, strong quillwort). None of these is a federal- or state-listed threatened or endangered species, nor are they sensitive species in Tennessee (TDEC 2008). RA-5 may be an important amphibian breeding ground

(Parr, pers. comm., 2012). However, Baranski (2009) ranked the ORR natural areas and reference areas on several factors, and found that RA-5 ranked among the lowest priority sites.

NT-3 also has a small (0.1 acre) wetland in its headwaters, which is classed as emergent wetland at narrow sloped headwall spring. Robinson and Johnson (1996) noted that all upland wetland sites were dry during the September 1994 measurement period.

3.6.2 Aquatic Resources

Bear Creek is designated as Oak Ridge Research Park Aquatic Natural Area 2 (Parr 2012; Baranski 2009). 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), and because the large segments of Bear Creek and its tributaries are commonly dry during the late summer and early fall months (Robinson and Reavis, 1996; Robinson and Johnson 1995).

In general, the diversity and abundance of aquatic fauna increase with distance from the contaminated headwaters (Southworth, et al. 1992). 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, dragon flies and damselflies, stoneflies, crickets and grasshoppers, alderflies and fishflies, caddisflies, butterflies and moths, beetles, true flies, and true bugs.

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 and are increasingly more common downstream. Southworth, et al. (1992) notes that mayflies, highly sensitive to heavy metal pollution, are almost totally absent in all but the lower reaches of Bear Creek. Upstream areas are 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 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. Four fish species predominate in the upper reaches of Bear Creek (above kilometer 11) include 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 Highway 95.

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.

No federal- or state-listed threatened or endangered aquatic species have been observed in Bear Creek or its tributaries (Southworth, et al. 1992).

3.6.3 Other Status Species

No surveys of terrestrial animals have been conducted at or near the EMDF site. 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 A11, Y-12 meteorological tower), and did not document any threatened or endangered terrestrial vertebrate species. They observed four then-protected bird species at sites on Chestnut Ridge along ST-2 and Walker Branch. The yellow bellied sapsucker (*Sphyrapicus varius* L. 1766), 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* Wilson 1810) 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 (*Accipter striatus* Vieillot 1807), 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 (*A. cooperii* Bonaparte 1828) 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 (*Circus cyaneus* L. 1766); state-listed as in need of management, but not federally listed have been observed on the ORR, but should not pose a concern at the EMDF site because the disturbed area is small relative to the available undeveloped areas.

3.6.4 Other Natural Resources

Approximately half of the proposed EMDF is within the ORERP. The EMDF will impact primarily forested terrain.

3.7 CULTURAL RESOURCES

There are no known archeological or historical resources in or near the proposed EMDF site (DOE 1999; DuVall 1996; Fielder, et al. 1977). Two former residences or farms were located near the confluence of NT-3 with Bear Creek, approximately 1,000 ft south of the proposed EMDF site. These were inspected (DuVall 1996) and reported to contain only scattered remnants of building debris (bricks, stones). Neither of these sites are within or near the anticipated impact areas for the EMDF.

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APPENDIX D

ALTERNATIVES RISK ASSESSMENT
AND
FUGITIVE EMISSION MODELING

CONTENTS

FIGURES

TABLES

ACRONYMS

ANL	Argonne National Laboratory
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
FEMA	Federal Emergency Management Agency
ILCR	Incremental Lifetime Cancer Risk
LLW	low-level (radioactive) waste
MEI	maximally exposed individual
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
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
WAC	Waste Acceptance Criteria
Y-12	Y-12 National Security Complex

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.

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 Sect. 2.1 through Sect. 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. Parameters for evaluating transportation risk in the two cases, 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

The proposed EMDF site that is evaluated in the On-site Disposal Alternative is located immediately east of the EMWMF in East Bear Creek Valley (EBCV). 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 the on-site disposal facility. A single route was modeled that represented on-site transport for both the On-site Disposal Alternative and Off-site Disposal Alternative. 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 sites to EMDF for the On-site Disposal Alternative or from any of the three 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 National Security Complex (Y-12), and ETTP to the new EBCV site 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) in Nevada for disposal. Low-level (radioactive) 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, be unloaded and then trucked from there to the NNSS disposal facility outside of Las Vegas, NV. 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, UT for disposal at Energy*Solutions* disposal facility.

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)
- 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, AZ 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, UT (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 D-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.

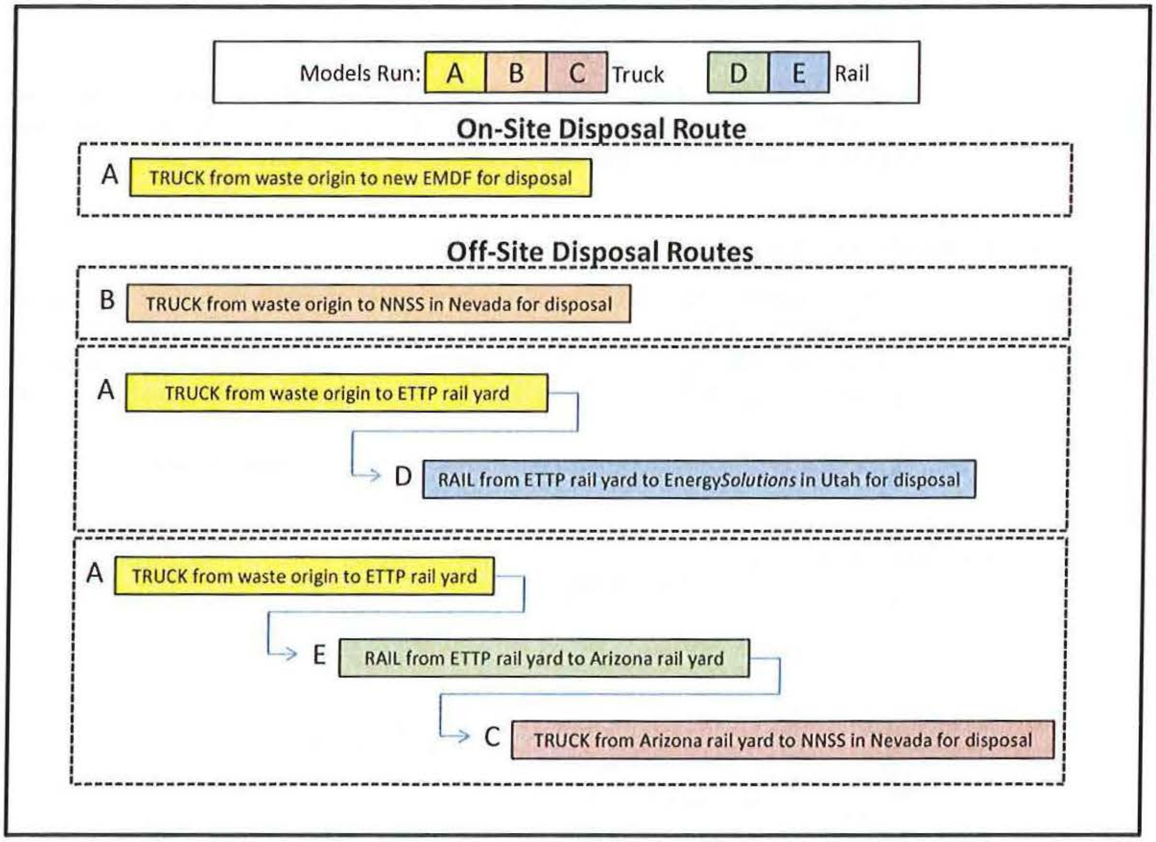

Figure D–1. Transportation Routes Assessed in On-site and Off-site Disposal Alternatives

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 Sect. 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.

2.2 TRANSPORTATION RISK MODELING

Assessing risk encountered through the transportation of waste involves multiple pathways and multiple receptors. Figure D-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.

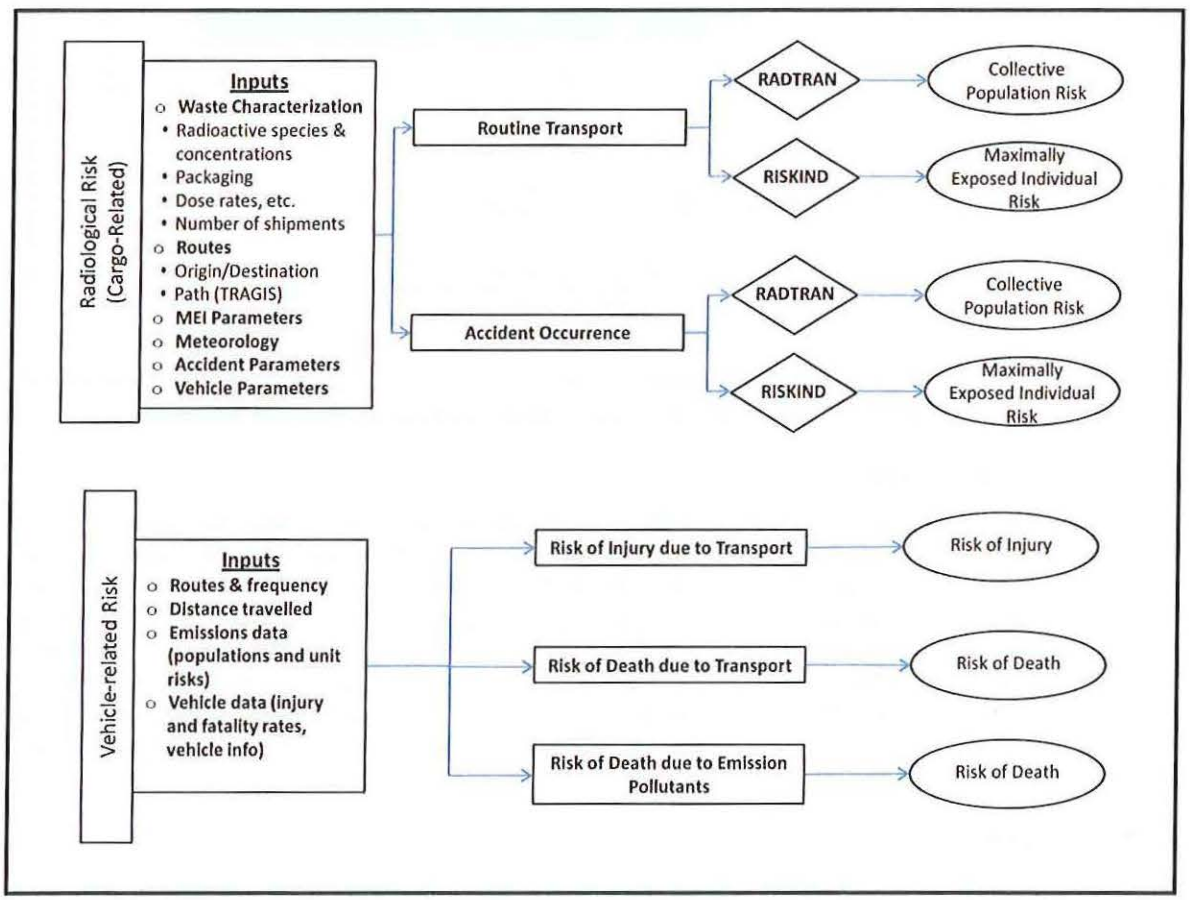

Figure D–2. Approach to Determining Transportation Risk

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 D-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 Sect. 2.1 and 2.3 and Figure D-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 D-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.

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 new EMDF (drivers, resident along route)
- Truck travel from waste origin to NNSS or from Kingman, AZ to NNSS (drivers, person in traffic, resident along route, truck inspector, and person at service station)
- Rail travel from ETTP rail to either Clive, UT or Kingman, AZ (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 D–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 of 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 new EMDF, and this is sufficiently representative whether the waste is generated at ORNL, ETTP, or Y-12.
- It is estimated that 183,426 shipments of waste will be made.
- The MEIs include the driver of the truck and a resident/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 11 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 D-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 Sect. 2.1.4 and given in Table D-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 9200 m^3/year is assumed. This is the average breathing rate based on the default breathing rate of 8000 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 D-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 D-1.
- Mixed waste (LLW/RCRA) is transferred to Energy*Solutions* in Clive, UT for disposal.
- LLW and LLW/TSCA waste is transferred to NNSS for disposal.
- Classified waste is trucked to NNSS for disposal.
- 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, AZ): 179,136
  - On-site transport (intermodals) to ETTP rail yard (and further transporting to Clive, UT): 3,534
  - Off-site transport (truckloads: some trucks carry two intermodals [debris], some trucks carry one intermodal [soil], due to weight limitations) from Kingman, AZ to NNSS: 110,880
  - Off-site transport of classified waste from ETTP to NNSS: 378
- 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 (six intermodals per rail car based on carrying soil or eight intermodals per rail car based on carrying debris) from ETTP rail yard to Clive, UT: 486
  - Off-site rail transport (six intermodals per rail car based on carrying soil or eight intermodals per rail car based on carrying debris) from ETTP rail yard to Kingman, AZ: 24,168
- A rail car is assumed to hold six intermodals, stacked two high. This makes the rail car dimension 12-ft×8-ft ×60-ft long. Shipping car holds 66 yd^3 of waste. Waste is assumed to have a density of 1.5 g/cm^3, approximately that of soil. (For radionuclide exposure modeling, six intermodals of soil were assumed for assumed for all rail shipments. The weight of six intermodals of soil is approximately equivalent to eight intermodals of debris.)
- 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 D-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 hear 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 to 2010 was calculated to escalate the population densities input to the RADTRAN model.

- Numbers of persons during stops were assumed as: 10 (5 to 20 m) at rest/refuel stops, 10 (5 to 100 m) in traffic jams, and 1 (1 to 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. Handlers are assumed to be under dose-tracking/limit program and not analyzed.
- For MEI exposures, routine stops are assumed to produce a 10 to 15-min 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 D-2.
- Routine and accident scenarios are evaluated for MEIs and collective populations.

Table D-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 D–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 hr Long-term 50 yr	Short-term 2 hr Long-term 50 yr
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* that is aerosolized)	0.05	0.05
Respirable fraction	(fraction of *aerosolized fraction* that can be 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 D-3 and D–4 summarize the results for this assessment, 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 D-3), and multiplied by the number of shipments to calculate risk based on all shipments of all waste for each given alternative for the lifecycle of the project, and therefore account for cumulative exposures over thousands or hundreds of thousands of shipments (see Table D-4). As expected, on-site transport of waste carries a significantly lower risk of cancer illnesses and fatalities than off-site transport of waste.

Table D-5 summarizes the risk rates for injuries and fatalities expected from vehicular operation due to exposure to emissions and expected traffic accidents for both 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.

Table D–3. Transportation Risk Assessment, Cancer Risk Due to Radiological Exposures for Single Shipment

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		Off-Site Total	
	Fatal	Non-fatal	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	9.50E-06	1.27E-05
Resident Along Route	2.40E-08	3.20E-08	2.40E-08	3.20E-08	7.20E-08	9.60E-08	4.80E-08	6.40E-08	1.44E-07	1.92E-07
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	4.34E-08	5.79E-08
Resident Along Route	3.06E-09	4.08E-09	3.06E-09	4.08E-09	1.28E-08	1.70E-08	9.72E-09	1.30E-08	2.56E-08	3.41E-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	1.93E-05	2.57E-05
On-Link	a	a	1.06E-05	1.42E-05	8.79E-07	1.17E-06	3.27E-07	4.36E-07	1.18E-05	1.58E-05
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	9.04E-06	1.21E-05
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	6.60E-06	8.80E-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	7.25E-09	9.67E-09

[a] No on-link analysis for on-site; all travel is on non-public road.

Table D-4. Transportation Risk Assessment, Cancer Risk Due to Radiological Exposures for Multiple (All) Shipments

Receptor/Scenario	On-site Disposal Alternative		Off-site Disposal Alternative (see assumptions Sect. 2.3 for explanation of number of shipments)							
	Truck to EMDF		Truck to NNSS		Truck to ETTP Rail to Kingman, AZ Truck Kingman to NNSS		Truck to ETTP Rail to Clive, UT		Off-Site Total	
	Number of shipments = 183,426		Number of shipments = 378		Number of shipments = 179,136 (to ETTP rail) 24,168 (rail to Kingman) 110,880 (Kingman to NNSS)		Number of shipments = 3,534 (to ETTP rail) 486 (rail to Clive)			
	Fatal	Non-fatal	Fatal	Non-fatal	Fatal	Non-fatal	Fatal	Non-fatal	Fatal	Non-fatal
MEIs										
			Routine Travel							
Driver (Truck) or Crew Member (Rail)	9.14E-03	1.22E-02	3.40E-03	4.54E-03	5.29E-02	7.06E-02	1.78E-04	2.37E-04	5.65E-02	7.53E-02
Resident Along Route	4.40E-03	5.87E-03	9.07E-06	1.21E-05	7.54E-03	1.01E-02	9.65E-05	1.29E-04	7.65E-03	1.02E-02
			Accidents							
Driver (Truck) or Crew Member (Rail)	1.41E-03	1.88E-03	2.90E-06	3.87E-06	2.38E-03	3.17E-03	3.02E-05	4.03E-05	2.42E-03	3.22E-03
Resident Along Route	5.61E-04	7.48E-04	1.16E-06	1.54E-06	1.05E-03	1.40E-03	1.41E-05	1.87E-05	1.06E-03	1.42E-03
Collective Population										
			Routine Travel							
Crew	7.79E-03	1.04E-02	7.21E-03	9.62E-03	1.88E-02	2.50E-02	1.50E-04	2.00E-04	2.61E-02	3.49E-02
On-Link	a	a	4.01E-03	5.35E-03	7.03E-02	9.38E-02	2.25E-04	3.00E-04	7.46E-02	9.94E-02
Off-Link	7.18E-05	9.57E-05	2.93E-04	3.90E-04	1.19E-01	1.58E-01	1.75E-03	2.34E-03	1.21E-01	1.61E-01
Handlers	1.08E-01	1.44E-01	2.23E-04	2.98E-04	2.22E-01	2.97E-01	3.12E-03	4.15E-03	2.26E-01	3.01E-01
			Accidents							
Societal Accident Exposure	2.93E-08	3.90E-08	7.69E-07	1.03E-06	1.57E-04	2.09E-04	5.40E-07	7.20E-07	1.58E-04	2.11E-04

[a] No on-link analysis for on-site; all travel is on non-public road.

Table D–5. Transportation Risk Assessment, Injury and Fatality Risk Due to Vehicle-related Incidents

Scenario	Emissions	Vehicle Travel	
	Fatal	Fatal	Non-Fatal
On-site Disposal Alternative			
Truck to EMDF	**1.15E-02**	**2.59E-02**	**8.96E-01**
Off-site Disposal Alternative			
Truck to NNSS	9.26E-02	2.55E-02	4.42E-01
Truck to ETTP; Rail to Clive, UT	4.28E-02	2.04E-02	6.53E-02
Truck to ETTP; Rail to Kingman, AZ; Truck to NNSS	8.19E+00	1.55E+00	1.49E+01
Off-site Total	**8.32E+00**	**1.59E+00**	**1.59E+01**

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, AZ, 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 D-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 for accident scenarios since the rail route also has a trucking leg from Kingman to NNSS. However, large differences are seen in the risk to drivers, crew, and on-link populations during routine travel due to the much larger number of shipments by truck.

Table D-7 summarizes the same comparison, in terms of vehicular risk. As expected, vehicle-related risks are significantly higher when all the waste is trucked versus when rail transport is used where possible.

Table D–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				
Driver (Truck) or Crew Member (Rail)	1.61E+00	2.15E+00	5.29E-02	7.06E-02
Resident Along Route	4.30E-03	5.73E-03	7.54E-03	1.01E-02
Accident				
Driver (Truck) or Crew Member (Rail)	1.38E-03	1.83E-03	2.38E-03	3.17E-03
Resident Along Route	5.48E-04	7.31E-04	1.05E-03	1.40E-03
Collective Population				
Routine Travel				
Crew	3.42E+00	4.56E+00	1.88E-02	2.50E-02
On-Link	1.90E+00	2.54E+00	7.03E-02	9.38E-02
Off-Link	1.39E-01	1.85E-01	1.19E-01	1.58E-01
Handlers	1.06E-01	1.41E-01	2.22E-01	2.97E-01
Accident				
Societal Accident Exposure	3.64E-04	4.86E-04	1.57E-04	2.09E-04

Table D–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	4.39E+01	1.21E+01	2.10E+02
Truck and Rail Transport			
Truck to ETTP; Rail to Kingman, AZ; Truck to NNSS	8.19E+00	1.55E+00	1.49E+01

3. NATURAL PHENOMENA

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}/yr (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, and therefore only the radioactive portion of the waste is considered in the assessment.

3.1 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 ~ 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 in. is assumed.

Mass-weighted averages were used as input to the RESRAD model and are given in Table D-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.

3.2 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.

3.3 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 groundwater 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 lifecycle of 23 years) for the disposal facility results in a maximum total aggregate risk of 3.71×10^{-7}.

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 placed the location of interest at approximately 1350 m horizontally distant from the proposed EMDF site in EBCV. 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 Highway 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

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 D-8. Methods used for calculating emission rates were those presented in AP-42 (EPA 1995).

Table D-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 mi/hr • Mean vehicle speed of 7.1 mi/hr (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 Sect. 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

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 $\mu g/m^3$.

4.2 RESULTS

The column on the far right of Table D–9 lists the final 24-hr 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, fall below the PM_{10} limit of 150 $\mu g/m^3$ specified in the NAAQS.

Table D-9. East Bear Creek Valley 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 ($g/s\text{-}m^2$)	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	13.00	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	86.00	
	Spoils Footprint	Unloading Dump Truck	0.0024	1.34	0.17	45.1	45.1	8.30E-05	13.67	
		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	24.32	133
	Haul	Hauling to Spoils	9.43 *	9.43 *	1.19	1563.6	157.0	4.84E-06	60.33	
	Spoils Footprint	Unloading Scraper	3.33 *	4.78 *	0.60	49.4	49.4	2.47E-04	48.67	
		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	25.33	102
		Loading into Dump Truck	0.0088							
	Haul	Hauling to Spoils	8.05 *	8.05 *	1.01	1563.6	157.0	4.13E-06	51.33	
	Spoils Footprint	Unloading Dump Truck	5.58	5.59	0.70	40.2	40.2	4.35E-04	24.96	
		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	60.66	144
	Stockpile Footprint	Unloading at Stockpile	0.029	0.044	0.01	38.7	38.7	3.70E-06	0.45	
		Loading at Stockpile	0.015							
	Haul	Hauling from Stockpile to Cell	1.66	1.66	0.21	61.0	7.3	4.69E-04	17.67	
	Fill Footprint	Unloading at Cell	4.43	6.66	0.84	61.6	61.6	2.21E-04	66.33	
		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 E

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

CONTENTS

TABLES

ACRONYMS

ALARA	as low as reasonably achievable
ARAP	Aquatic Resource Alteration Permit
ARAR	applicable or relevant and appropriate requirement
BMP	best management practice
CAA	Clean Air Act of 1970
CFR	Code of Federal Regulations
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
DOE	Department of Energy
DOT	U.S. Department of Transportation
EMDF	Environmental Management Disposal Facility
EMWMF	Environmental Management Waste Management Facility
EPA	Environmental Protection Agency
FR	Federal Register
FML	flexible membrane
GCL	geosynthetic clay liner
LLW	low-level (radioactive) waste
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NT	Northern Tributary
ORR	Oak Ridge Reservation
OSHA	Occupational Safety and Health Administration
PCB	polychlorinated biphenyl
PPE	personal protective equipment
RCRA	Resource Conservation and Recovery Act of 1976
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
TBC	to be considered
TDEC	Tennessee Department of Environment and Conservation
TSCA	Toxic Substances Control Act of 1976
U.S.	United States
WAC	Waste Acceptance Criteria

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).

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) Sect. 121(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 (40 *Code of Federal Regulations* [*CFR*] 300.430 [f][1][ii][B]). Inherent in the interpretation of ARARs is the assumption 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 United States (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 the federal and state chemical-, location-, and action-specific ARARs for the On-site Disposal Alternative for construction and operation of an additional CERCLA waste disposal facility referred to as the Environmental Management Disposal Facility (EMDF), and the Off- site Disposal Alternative for transport of CERCLA waste to an approved off-site facility.

ARARs include only federal and state environmental or facility siting laws/regulations designed to protect the environment; 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 through Sect. 300.150 of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), independent of the ARARs process; therefore, neither the regulations promulgated by OSHA nor DOE Orders related to occupational safety are addressed as ARARs. These regulations would appear in 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 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).
- In addition to ARARs, other advisories, criteria or guidance may be considered for a particular release. The to be considered (TBC) category consists of advisories, criteria, or guidance that were developed by the EPA, other federal agencies, or states that may be useful in developing CERCLA remedies per 40 *CFR* 300.400(g)(3).

CERCLA on-site remedial response actions must comply only with the substantive requirements of a regulation to obtain federal, state, or local permits (CERCLA Sect. 121[e]). To ensure that CERCLA response actions proceed as rapidly as possible, EPA has 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 (DOE 1992) participants have agreed that the DOE Oak Ridge Office 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 actions, Table E-1 lists the chemical-specific ARARs/TBCs; Table E-2 lists the location-specific ARARs/TBCs; and Table E-3 lists the action-specific ARARs/TBCs.

Table E-4 provides the action-specific ARARs/TBCs for the Off-Site 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 would comply with all ARARs with the exception of the following two requirements for which a waiver would be requested:

1. The Toxic Substances Control Act of 1976 (TSCA) hydrologic conditions requirement that there be no hydraulic connection between the site and standing or flowing surface water and a 50-ft vertical separation be maintained between the bottom of the landfill liner system or natural in-place soil barrier and the historic high water table (40 *CFR* 761.75 [b] [3])

2. The Tennessee Department of Environment and Conservation (TDEC) hydrological conditions requirement for land disposal of radioactive waste that the hydrogeologic unit used for disposal shall not discharge groundwater to the surface within the disposal site (TDEC 1200-2-11-.17[1][h]).

Both waivers would need to be incorporated into the Record of Decision (ROD) if the On-site Disposal Alternative is the selected remedy. As described in Sect. 3 of this appendix, a waiver for these requirements would be requested based on equivalent protectiveness.

2. CERCLA ON-SITE CONSIDERATIONS

CERCLA Section 121(e) exempts on-site CERCLA activities from administrative permitting requirements. 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 and associated sites 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 Sect. 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 developing 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).

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 the precedent set with approval of the EMWMF. 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." 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. WAIVER OF TSCA AND TDEC HYDROLOGIC CONDITIONS ARARS

CERCLA Section 121(d)(4) allows for waivers of ARARs under certain circumstances for on-site actions. 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]). In addition, a TDEC hydrologic conditions requirement for land disposal of radioactive waste specifies the hydrogeologic unit used for disposal shall not discharge groundwater to the surface within the disposal site (TDEC 1200-2-11-.17[1][h]). Construction of a disposal facility at the EMDF site evaluated under the On-site Disposal Alternative would not meet these TSCA and TDEC requirements.

If on-site disposal is the selected remedy, waivers from the hydrologic conditions requirements would be requested on the basis of "equivalent protectiveness."

TSCA requirement 40 *CFR* 761.75(b)(3): An "equivalent protectiveness" waiver of the TSCA 50-ft groundwater buffer requirement would be requested on the basis that implementation of the more stringent leachate collection requirements under Resource Conservation and Recovery Act of 1976 (RCRA) result in a facility that meets or exceeds the protectiveness anticipated under TSCA. The provision for a waiver under CERCLA based on protectiveness parallels TSCA regulations at 40 CFR 761.5(c)(4) allowing the EPA TSCA administrator to waive the requirement if protectiveness can be demonstrated.

The TSCA requirement for minimum depth to the water table does not provide a true performance standard that can be evaluated. For example, gravel and highly fractured rock can have a hydraulic conductivity of as low as 1×10^{-1} cm/sec, compared to a conductivity of up to 1×10^{-7} cm/sec for clay. For a continuous 50-ft layer, the range of time for permeation could be anywhere from 4.2 hrs (gravel) to 482 years (clay). A RCRA landfill would use a multiple liner system that could incorporate flexible membranes (FMLs), geosynthetic clay liners (GCLs) and low permeability clay. The range of hydraulic conductivities for these materials range from $<1\times10^{-7}$ cm/sec for low permeability clay, 5×10^{-9} cm/sec for GCLs; and between 1×10^{-11} and 1×10^{-13} cm/sec for FMLs depending on the type of materials used. In addition to a leachate collection/detection system, RCRA landfill design typically uses a 3-ft thick clay foundation layer and a 10-ft clay geologic buffer to isolate the disposal cell from the groundwater table. Consistent with DOE O 435.1, the compliance period for facility performance assessment is 1,000 years. As shown in Appendix F of this RI/FS, peak risks beyond 1,000 years are considered for development of preliminary WAC. However, groundwater modeling results beyond 1,000 years after facility closure are less reliable than those within the 1,000-year timeframe.

There is precedence for waiver of the TSCA 50-ft groundwater buffer requirement. It is commonly waived in the southeast because of high groundwater tables; EPA-Region 4 has waived this requirement in the past, including granting a waiver for the EMWMF.

TDEC requirement TDEC 1200-2-11-.17(1)(h): As discussed in Chapter 6 of this RI/FS, the EMDF would be constructed over part of Northern Tributary (NT)-3. This tributary to Bear Creek is fed by springs and seeps that are hydraulically connected to the site and discharge groundwater to the surface within the disposal site. The conceptual design includes an extensive underdrain system, shallow upgradient French drain, and upgradient geomembrane-lined diversion ditch, and a landfill liner composed of multiple impermeable layers, which are designed to mitigate the hydrologic conditions at the site and provide "equivalent protectiveness". Upgradient storm water would be diverted around the landfill in a geomembrane-lined ditch. The shallow upgradient French drain would intercept and divert shallow perched groundwater flowing within the stormflow zone away from the buried waste. The landfill would be constructed over a portion of NT-3 and flow would be rerouted west of the new facility and rejoin the existing NT-3 channel south of the Haul Road. In addition, construction of the landfill would eliminate percolation of surface water into the ground within the footprint of the landfill. Collectively, these design features would lower the groundwater table beneath the landfill and would reduce groundwater fluctuations. The underdrain system would provide a pathway for upgradient and/or upwelling seeps and springs to flow beneath the landfill, while maintaining at least a 10-ft thick geologic buffer below the liner system.[1] The underdrain system would provide a "preferred pathway" for groundwater and could be used as a tertiary leak detection and removal system for the landfill.

[1] The EMWMF design complies with the TDEC solid waste requirement for a 10-ft geologic buffer (TDEC 1200-1-7-.04[4][a][2]) per a TDEC request. Consistent with this agreement, the conceptual design for the proposed EMDF includes a 10 ft geologic buffer.

4. 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, groundwater, soil, and air) for specific hazardous substances, pollutants, or contaminants. Because there is no particular operable unit or medium being remediated, there are no chemical-specific ARARs for cleanup levels for the alternatives. There are, however, chemical-specific ARARs limiting exposure to radioactivity identified for the On-site Disposal Alternative (see Table E-1) that are discussed below.

4.1 RADIATION PROTECTION

The radiation dose to members of the public must not exceed 100-mrem/yr 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.

The TDEC performance standard specifies that concentrations of radioactive material which may be released to the general environment in groundwater, surface water, air, soil, plants, or animals must not exceed annual dose limits. The release of radioactivity in effluents to the general environment must also be maintained at ALARA levels.

5. LOCATION-SPECIFIC ARARS/TBCS

Location-specific requirements (see Table E-2) establish restrictions on permissible concentrations of hazardous substances or requirements for how activities will be conducted because they will take place in special locations (e.g., wetlands, floodplains, critical habitats, historic districts, streams). The location-specific ARARs discussed here are based on the siting of the proposed EMDF in East Bear Creek Valley immediately east of EMWMF. Additional location-specific considerations (i.e., siting requirements) are addressed as action-specific requirements in Chapter 6 of this Appendix. The Off-site Disposal and No-Action Alternatives would not impact any special locations.

5.1 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 C 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, the extent of wetlands impact would be determined based on wetlands survey and other detailed design considerations. Compensatory mitigation in the form of wetland restoration, creation, or enhancement may be required.

The conceptual design footprint of the EMDF, leachate storage tanks, contact water basins, leachate collection and treatment facility, access roads, and sediment basins are not within the 100- or 500-year floodplain of Bear Creek. Regulations regarding potential impacts on floodplains would be applicable if construction could impact the floodplain. Construction activities at the EMDF site would involve some disturbance of wetlands and aquatic resources.

5.2 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, 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 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.

5.3 ENDANGERED, THREATENED, OR RARE SPECIES

As described in Appendix C, the EMDF site is not known to contain plants that are threatened or endangered, in need of management, or species of concern (Baranski 2009). For the On-site Disposal Alternative, a biologic and wetlands survey would be conducted, and any rare plants within the area would be protected and preserved per the Tennessee Rare Plant Protection and Conservation Act of 1985. In addition, the Tennessee dace (*Phoxinus tennesseensis*), which is listed as a "species in need of management" by the state of Tennessee, has been found throughout Bear Creek and several of its tributaries. Should any actions associated with the selected remedy impact any state-listed threatened or rare animal species, impacts would be considered and mitigated as appropriate in accordance with the Tennessee Nongame and Endangered or Threatened Wildlife Species Conservation Act.

5.4 CULTURAL RESOURCES

There are no known significant historical or archaeological resources within the EMDF footprint, support facilities, or roadways (see Appendix C). 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.

6. 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 ORR.

This facility would be designed to manage low-level (radioactive) waste, RCRA 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, Sect. 2.1.3), including a minimal volume of disposal facility operations waste, would be shipped to an off-site commercial facility for disposal. ARARs for off-site shipment are addressed in Chapter 7 of this Appendix.

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- 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 Table E-3) address:

- General construction standards – site preparation, excavation activities, etc.
- Waste management
- Disposal site suitability requirements
- Wastewater treatment facility operation and discharge
- Design, construction, and operation of a mixed (RCRA hazardous, TSCA chemical and low-level radioactive) waste landfill
- Closure
- Post closure care
- Off-site Transportation and Disposal (for the small portion of CERCLA waste that will not meet the on-site disposal facility WAC)

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, subsequent management will be in accordance with the on-site disposal facility's WAC attainment plan, a post-ROD primary document. Facility operations could also be shut down temporarily, necessitating waste accumulation. Storage, accumulation, and transportation requirements have been included as ARARs for the on-site disposal facility as appropriate to address these contingencies.

6.1 GENERAL CONSTRUCTION STANDARDS – SITE PREPARATION, EXCAVATION ACTIVITIES, ETC.

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 E-3, 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.

6.2 WASTE MANAGEMENT

Table E-3 lists ARARs and TBC guidance for characterization and management of different types of waste streams.

6.2.1 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 [PPE], 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 Order/Manual 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, low-level (radioactive) waste (LLW), or mixed waste as appropriate.

6.2.2 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.

6.2.3 Waste Segregation

TSCA waste must be segregated from incompatible wastes during management and storage. LLW should be segregated from mixed waste.

6.2.4 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.

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).

Per DOE TBC guidance, 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.

6.3 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, areas subject to seismic activity, geologic processes, or hydrogeology that adversely affect the facility's stability or ability to meet performance standards. These site conditions, if present, must not preclude design and construction of the facility so that the performance standards will be met. Performance standards for the facility include the requirement to achieve long-term stability of the disposal. TDEC requires that the facility site must be capable of being characterized, modeled, analyzed, and monitored and specifies a pre-operational monitoring program be conducted.

As noted in Chapter 3 of this Appendix, a waiver of two hydrologic condition requirements would be requested on the basis of equivalent protectiveness of landfill design. TDEC Rule 1200-2-11-.17(1)(h) requires that "the hydrogeologic unit used for disposal shall not discharge groundwater to the surface within the disposal site", e.g., that there be no streams, springs, or seeps at the site. The proposed EMDF would be built over the upper reaches of Bear Creek tributary NT-3, which is fed by springs and seeps during the wet season.

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 location would not meet the TSCA hydrologic requirement.

With the exception of these requirements, implementation of the On-site Disposal Alternative would meet all CERCLA ARARs. In addition, the risk assessment and preliminary WAC analyses (see Appendix D and Appendix F, 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.

6.4 WASTEWATER TREATMENT FACILITY OPERATION AND DISCHARGE

Wastewater collected during excavation, dewatering, or decontamination activities as well as leachate and contact water collected during EMDF operation would be treated at the planned on-site wastewater treatment facility to be constructed and operated at the EMDF site prior to discharge to Bear Creek. Wastewater would receive the degree of treatment or effluent reduction necessary to comply with TDEC water quality standards and radionuclide air emissions will comply with CAA requirements. Until the new treatment facility is operational, wastewater may be transported to an existing on-site wastewater treatment plant for treatment and subsequent discharge via a permitted outfall.

6.5 DESIGN, CONSTRUCTION, AND OPERATION OF A MIXED (RCRA HAZARDOUS, TSCA CHEMICAL AND LOW-LEVEL RADIOACTIVE) WASTE LANDFILL

Table E-3 lists RCRA, TSCA, TDEC Radiation Protection, and DOE 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 groundwater 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 administrative for most CERCLA response actions have 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 E-3.

RCRA regulations require that the landfill design must prevent leachate generation and release of hazardous constituents to groundwater; 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. Response action plans for leaks must be in place.

TDEC Radiation Protection requirements that are relevant and appropriate include that the facility design must consider long-term isolation, compliance with performance objectives, and avoidance of site degradation through erosion. Low-level waste must be placed to maintain package integrity and prevent void spaces, and a buffer zone of land must be maintained beneath the disposal unit and between the unit and disposal boundary. Closure and stabilization measures must be carried out as each disposal unit is filled and covered. A monitoring system to detect releases of radioactivity before they leave the site boundary must be conducted throughout operations.

DOE provides TBC guidance for the facility to be designed, constructed, and operated to consider the effects of natural phenomena needed to ensure facility performance. The facility should have control and stabilization features for long-term management of uranium, thorium and their decay products.

6.6 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.

TDEC provides similar requirements for closure of an LLW disposal facility. 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 chemical-waste landfill should parallel closure requirements under RCRA.

6.7 POSTCLOSURE 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. Per RCRA, post-closure care must begin after closure and must continue for 30 years. 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 maintenance, maintenance and operation of the leachate collection system as long as leachate is being generated.

RCRA and TSCA provide requirements for construction of groundwater monitoring wells. RCRA specifies groundwater monitoring program requirements, sample collection, and detection monitoring.

TDEC Radiation Protection has relevant and appropriate requirements for a monitoring system. The disposal facility must have plans for corrective measures that would be taken if monitoring detects migration of radionuclides. Institutional controls include, at a minimum, administrative restrictions for sale and use of property and securing the area to prevent human contact with hazardous substances.

6.8 OFF-SITE TRANSPORTATION AND DISPOSAL

ARARs for off-site transportation and disposal of hazardous waste, radioactive waste, LLW, PCB waste, and hazardous waste are listed in Table E-4 and discussed below in Chapter 7.

7. OFF-SITE DISPOSAL ALTERNATIVE ARARS/TBCS

Table E-4 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. 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 E-3 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. Pretransport requirements reference the DOT regulations under 49 *CFR* 172, 173, 178, and 179.

CERCLA Sect. 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. Per DOE Manual 435.1-1(I)(2)(F)(4), 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 E–1. Chemical-specific ARARs and TBC Guidance for the On-site Disposal Alternative

Medium/Action	Requirements	Prerequisite/Condition	Citation(s)
Releases of radionuclides in the environment	Exposure to individual members of the public from radiation shall not exceed a total EDE of 0.1 rem/year (100 mrem/year), exclusive of the dose contributions from background radiation, any medical administration the individual has received, or voluntary participation in medical/research programs.	Activities causing direct exposure to radiation or the release of radionuclides into the environment – **relevant and appropriate**	10 *CFR* 20.1301(a)(1)
	Shall use, to the extent practicable, procedures and engineering controls based on sound radiation protection principles to achieve occupational doses and doses to members of the public that are ALARA.		10 *CFR* 20.1101(b)
	Concentrations of radioactive material which may be released to the general environment in groundwater, surface water, air, soil, plants or animals must not result in an annual dose exceeding an equivalent of 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ. Reasonable effort shall be made to maintain releases of radioactivity in effluents to the general environment ALARA.		TDEC 1200-2-11-.16(2) 10 *CFR* 61.41

ALARA = as low as reasonably achievable
ARAR = applicable or relevant and appropriate requirement
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR = Code of Federal Regulations
EDE = effective dose equivalent
mrem = millirem
TBC = to be considered
TDEC = Tennessee Department of Environment and Conservation

Table E–2. Location-specific ARARs and TBC Guidance for the On-site Disposal Alternative

Location Characteristic(s)	Requirements	Prerequisite	Citation(s)
	Floodplains/Wetlands		
Presence of floodplain as defined in 10 *CFR* 1022.4(i) or within "lowland and relatively flat areas adjoining inland and coastal waters and other flood-prone areas such as offshore islands, including at a minimum, that area subject to a one percent or greater chance of flooding in a given year" (EO 11988, Sect. 6[c], and TDEC 1200-1-7).	Action shall be taken to reduce the risk of flood loss; minimize the impact of floods on human safety, health, and welfare; and restore and preserve the natural and beneficial values of floodplains. Measures to mitigate adverse effects of actions in a floodplain include, but are not limited to: minimum grading requirements, runoff controls, design and construction constraints, and protection of ecology-sensitive areas as provided in 10 *CFR* 1022.12(a)(3). The potential effects of actions in floodplains shall be evaluated and consideration of flood hazards and floodplain management ensured. If action is taken in floodplains, alternatives that avoid adverse effects and incompatible development and minimize potential harms shall be considered.	Federal actions potentially impacting or taking place within floodplains that involve: • acquiring, managing, and disposing of lands and facilities; • providing federally undertaken, financed, or assisted construction and improvements; and • conducting federal activities and programs affecting land use – **applicable**	EO 11988 (May 24, 1977); 10 *CFR* 1022
Presence of wetlands as defined 10 *CFR* 1022.4(v), and TDEC 1200-01-07.01	Avoid or minimize adverse impacts on wetlands and act to preserve and enhance their natural and beneficial values. Measures to mitigate adverse effects of actions in a wetland include, but are not limited to: minimum grading requirements, runoff controls, design and construction constraints, and protection of ecology-sensitive areas as provided in 10 *CFR* 1022.13(a)(3). New construction in wetlands areas should be particularly avoided unless there are no practicable alternatives. Wetlands protection considerations shall be incorporated into planning, regulating, and decision-looking processes.	Federal actions potentially impacting or taking place within wetlands that involve: • acquiring, managing, and disposing of lands and facilities; • providing federally undertaken, financed, or assisted construction and improvements; and • conducting federal activities and programs affecting land use – **applicable**	10 *CFR* 1022.3(a); 10 *CFR* 1022.4; TDEC 1200-01-07.01

Table E–2. Location-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Location Characteristic(s)	Requirements	Prerequisite	Citation(s)
	Potential effects of any new construction in wetlands that are not in a floodplain shall be evaluated. Identify, evaluate, and, as appropriate, implement alternative actions that may avoid or mitigate adverse impacts on wetlands.		10 *CFR* 1022.3(c); 10 *CFR* 1022.3(d)
Presence of jurisdictional wetlands as defined in 40 *CFR* 230.3(t) and 33 *CFR* 328.3(b)	Action to avoid degradation or destruction of wetlands must be taken to the extent possible. Discharges for which there is a practicable alternative with less adverse impacts or those which would cause or contribute to significant degradation are prohibited. If adverse impacts are unavoidable, action must be taken to enhance, restore or create alternative wetlands.	Action involving discharge of dredge or fill material into wetlands – **applicable**	Clean Water Act (33 USC 1251 et seq.), Section 404; 40 *CFR* 230
Aquatic Resources			
Within an area encompassing or affecting "waters of the State" as defined in TCA 69-3-103(33)	Must comply with the substantive requirements of the ARAP for erosion and sediment control to prevent pollution and protect sensitive resources and downstream waters. Discharge of "substances" that "will result or will likely result in harm, potential harm or detriment to the health of animals, birds, fish, or aquatic life" is prohibited.	Action involving the discharge of any pollutants; altering properties of any waters of the state as defined in TCA 69-3-103(33), including alteration of wet weather conveyances, bank stabilization, debris removal, and sand and gravel dredging; – **applicable**	TCA 69-3-108 (b)(1)(j)
Action potentially altering the properties of any "Waters of the State"	Erosion and sediment control requirements include, but are not limited to the following. • Limit clearing, grubbing, and other disturbances in areas in or immediately adjacent to Waters of the State to the minimum necessary to accomplish the proposed activity. • Unnecessary vegetation removal is prohibited and all disturbed areas must be properly stabilized and revegetated as soon as practicable. • Limit excavation, dredging, bank reshaping, or grading to the minimum necessary to install	Action potentially altering the properties of any "waters of the State" – **applicable**	TDEC Aquatic Resource Alteration General Permit Program Requirements

Table E–2. Location-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Location Characteristic(s)	Requirements	Prerequisite	Citation(s)
	authorized structures, accommodate stabilization, or prepare banks for revegetation. • Maintain the erosion and sedimentation control measures throughout the construction period. • Upon achievement of final grade, stabilize and revegetate, within 30 days, all disturbed areas by sodding, seeding, or mulching, or using appropriate native riparian species.		
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 661 et seq.)
Location encompassing aquatic ecosystem with dependent fish, wildlife, other aquatic life, or habitat or as defined in 40 *CFR* 230.3(c)	Degradation or destruction of aquatic ecosystems must be avoided to the extent possible. Discharges that cause or contribute to significant degradation of the water of such ecosystems are prohibited.	Action involving the discharge of dredge or fill material into aquatic ecosystem – **applicable**	Clean Water Act (33 USC 1251 et seq.), Section 404; 40 *CFR* 230
	Except as provided under Section 404(b)2 of the CWA, no discharge of dredged or fill material into an aquatic ecosystem is permitted if there is a practicable alternative that would have less adverse impact. No discharge of dredged or fill material shall be permitted unless appropriate and practicable steps per 40 *CFR* 230.70 et seq. are taken to 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) 40 *CFR* 230.10(d)

Table E–2. Location-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Location Characteristic(s)	Requirements	Prerequisite	Citation(s)
	Endangered, Threatened, or Rare Species		
Presence of Tennessee state-listed endangered or threatened animal species as created and amended pursuant to TCA 70-8-105 and listed in TWRCP 94-17	No person may take, harass, or destroy wildlife listed as threatened or endangered or otherwise violate the terms of TCA 70-8-105(c) or destroy knowingly the habitat of such species without due consideration of alternatives for the welfare of state-listed or federally-listed endangered species.	Action impacting such species – **applicable**	Tennessee Nongame and Endangered or Threatened Wildlife Species Conservation Act (TCA 70-8-101 et seq.); TWRCP 94-17
Presence of Tennessee-listed endangered or rare plant species as listed in TDEC 0400-6-2-.04	Protected species may not be uprooted, dug, taken, removed, damaged or destroyed, possessed, or otherwise disturbed for any purpose.	Action impacting plant species determined by the Commissioner (of TDEC) to be in jeopardy, including, but not limited to, "endangered species" pursuant to the federal Endangered Species Act – **relevant and appropriate**	Tennessee Rare Plant Protection and Conservation Act of 1985 TCA 70-8-309(a) TWRCP 94-16(II)(1)(a) TWRCP 94-17(II)
Presence of Tennessee state-listed wildlife species "in need of management" as listed in TWRCP 94-16	No person may 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.	Action impacting such species – **applicable**	TCA 70-8-104(b); TWRCP 94-16
Presence of Tennessee nongame species (Tennessee dace) as defined in TCA 70-8-103	May not take (i.e., harass, hunt, capture, kill or attempt to kill), possess, transport, export, or process nongame wildlife species.	Action impacting Tennessee nongame species, including wildlife species which are "in need of management" (as listed in TWRCP 94-16 and 94-17) – **applicable**	TCA 70-8-104(c)
	May not knowingly destroy the habitat of such wildlife species.		TWRCP 94-16(II)(1)(a) and TWRCP 94-17(II)
	Upon good cause shown and where necessary to protect human health or safety, endangered or threatened species may be removed, captured, or destroyed.		TCA 70-8-106(e) TWRCP 94 – 16(II)(1)(c)

Table E–2. Location-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Location Characteristic(s)	Requirements	Prerequisite	Citation(s)
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 take.	Action impacting such species – **applicable**	16 U.S.C. §1536(a)(2)–Sect. 7(a)(2)
Cultural Resources			
Presence of archaeological resources on public land	Steps must be taken to consider the historical, architectural, or archaeological significance of sites, structures, and objects and to consult with the State Historic Preservation Officer. Steps must be taken to protect archaeological resources and sites.	Action that would impact any resource discovered during remedial activities – **applicable**	National Historic Preservation Act Sections 106 and 110 (16 USC 470 et. seq.) EO 11593, 36 *CFR* 800 Archaeological Resources Protection Act (16 USC 470aa-11); 43 *CFR* 7.8 and 7.9) 43 *CFR* 7.5(b)(1)
Presence of archaeological or historic resources	A survey of affected areas for resources and data must be conducted and steps taken to recover, protect, and preserve data or request DOI do so. The state archaeologist and secretary of interior must be advised of the presence of the data.	Action involving alteration of terrain that might cause irreparable loss or destruction of any discovered significant scientific, prehistoric, historic, or archaeological resources – **applicable**	Archaeological and Historic Preservation Act (16 USC 469 a-c)
Presence of archaeological resources	May not excavate, remove, damage, or otherwise alter or deface such resource unless by permit or exception.	Action that would impact archaeological resources on public land – **applicable**	43 *CFR* 7.4(a)

Table E–2. Location-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Location Characteristic(s)	Requirements	Prerequisite	Citation(s)
Presence of human remains, funerary objects, sacred objects, or objects of cultural patrimony for Native Americans	If an inadvertent discovery is made in connection with an on-going activity, activity must stop in the area of the discovery and reasonable effort be made to secure and protect the objects discovered.	Objects that are in federal possession or control or that are excavated intentionally or discovered inadvertently on federal lands or under federal control – **applicable**	Native American Graves Protection and Repatriation Act (25 USC 3001-3013); 43 *CFR* 10.4(c)
	Notification and consultation procedures are required for off-site activities and recommended for on-site activities.		43 *CFR* 10.3, 10.4, and 10.6
	Disposition of all inadvertently discovered items must be carried out in prescribed procedures.		
	Must consult with Indian tribe likely to be affiliated with the objects to determine further disposition.		43 *CFR* 10.5(b).

ARAP = Aquatic Resource Alteration Permit
ARAR = applicable or relevant and appropriate requirement
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR = Code of Federal Regulations
CWA = Clean Water Act of 1972
NPDES = National Pollution Discharge Elimination System
ORR = Oak Ridge Reservation
ROD = Record of Decision
TBC = to be considered
TCA = Tennessee Code Annotated
TDEC = Tennessee Department of Environment and Conservation
TWRCP = Tennessee Wildlife Resources Commission Proclamation
USC = United States Code

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative

Action	Requirements	Prerequisite	Citation(s)
General Construction Standards–Site Preparation, Excavation Activities, etc.			
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:	Fugitive emissions from land-disturbing activities (e.g., demolition of existing buildings or structures, construction operations, grading of roads, or clearing of land) – **applicable**	TDEC Chap. 1200-3-8-.01(1)
	• use, where possible, of water or chemicals for control of dust from construction operation, grading of roads, or the clearing of land; and		TDEC Chap. 1200-3-8-.01(1)(a)
	• application of asphalt, oil, water, or suitable chemicals on dirt roads, materials stockpiles, and other surfaces that can create airborne dusts.		TDEC Chap. 1200-3-8-.01(1)(b)
	Shall not cause or allow fugitive dust to be emitted in such a manner as to exceed 5 min/h or 20 min/d beyond property boundary lines on which emission originates.		TDEC Chap. 1200-3-8-.01(2)
Activities causing radionuclide emissions	Exposures to the public from all radiation sources released into atmosphere from DOE facility shall not cause EDE > 10 mrem (0.1 mSv) per year.	Radionuclide emissions from point sources, as well as diffuse or fugitive emissions, at a DOE facility – **applicable**	40 *CFR* 61.92; TDEC Chap. 1200-3-11-.08(6)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
Activities causing storm water runoff	Implement good construction management techniques (including sediment and erosion controls, vegetative controls, and structural controls) in accordance with the substantive requirements of *General Permit No. TNR10-0000, Appendix F* to ensure water discharge:	Storm water runoff discharges from land disturbed by construction activity– disturbance of ≥1 acre total – **applicable**	TCA 69-3-108(j) TDEC 1200-4-10-.03(2)(a)
	• does not violate water quality criteria as stated in TDEC 1200-4-3, including but not limited to prevention of discharges that cause a condition in which visible solids, bottom deposits, or turbidity impairs the usefulness of water of the state for any of the uses designated for that water body by TDEC 1200-4-4, and		*Tennessee General Permit No. TNR10-0000* Section 4.3.2(a)
	• does not violate other conditions detailed in *General Permit No. TNR10-0000.*		
	• does not contain distinctly visible floating scum, oil, or other matter.		*Tennessee General Permit No. TNR10-0000* Section 4.3.2(b)
Activities causing storm water runoff	• does not cause an objectionable color contrast in the receiving stream.	Storm water discharges from construction activities — **applicable**	*Tennessee General Permit No. TNR10-0000* Section 4.3.2(c)
	• muddy water to be pumped from excavation and work areas must be held in settling basins or filtered or chemically treated prior to its discharge into surface waters. Water must be discharged through a pipe, well-grassed or lined channel or other equivalent means so that the discharge does not cause erosion and sedimentation.		*Tennessee General Permit No. TNR10-0000* Section 3.5.3.3

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	Shall develop and maintain a site-specific storm water pollution prevention plan (SWPPP) or equivalent document which includes a description of all potential sources of pollution, describe practices to be used to reduce pollutants in storm water discharges and assure compliance with substantive requirements of General Permit No. TNR10-0000.	Storm water discharges associated with industrial activities at a landfill – **applicable**	*Tennessee General Permit No. TNR10-0000* Section 1.4.2 Tennessee Erosion and Sediment Control Handbook (guidance)
	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.		*Tennessee General Permit No. TNR10-0000* Section 4.3.2(d)
	The following conditions apply to all land disturbance work:	Storm water discharges from construction activities — **applicable**	TDEC 1200-4-10-.04(7)(b)(2)(iv)
	• Sediment should be removed from sediment traps, silt fences, sedimentation ponds, and other sediment controls as necessary, and must be removed when design capacity has been reduced by 50%.		*Tennessee General Permit No. TNR10-0000* Section 3.5.3.1(e)
	• clearing and grubbing must be held to the minimum necessary for grading and equipment operation.		*Tennessee General Permit No. TNR10-0000* Section 3.5.3.1(i)
	• construction must be sequenced to minimize the exposure time of graded or denuded areas.		*Tennessee General Permit No. TNR10-0000* Section 3.5.3.1(j)
Activities causing storm water runoff	• construction must be phased for projects in which over 50 acres of soil will be disturbed. Areas of the completed phase must be stabilized within 15 days (in accordance with Section 3.5.3.2 *Tennessee General Permit No. TNR10-0000*). No more than 50 acres of active soil disturbance is allowed at any time during the construction project.	Storm water discharges from construction activities — **applicable**	*Tennessee General Permit No. TNR10-0000* Section 3.5.3.1(k)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	• erosion prevention and sediment control measures must be in place and functional before earth moving operations begin, and must be constructed and maintained throughout the construction period.		*Tennessee General Permit No. TNR10-0000* Section 3.5.3.1(l)
	• pre-construction vegetative ground cover shall not be destroyed, removed or disturbed more than 10 days prior to grading or earth moving unless the area is seeded and/or mulched or other temporary cover is installed.		*Tennessee General Permit No. TNR10-0000* Section 3.5.3.1(h)
	• permanent stabilization with perennial vegetation (using native herbaceous and woody plants where practicable) or other permanently stable, non eroding surface shall replace any temporary measures as soon as practicable.		*Tennessee General Permit No. TNR10-0000* Section 3.5.3.2
	• erosion prevention and sediment control measures shall be designed according to the size and slope of disturbed drainage areas with the goal of detaining runoff and trapping sediment.		*Tennessee General Permit No. TNR10-0000* Section 3.5.3.3
	• discharges from sediment basins and traps must be through a pipe, well-grassed or lined channel or other equivalent means so that the discharge does not cause erosion and sedimentation.		*Tennessee General Permit No. TNR10-0000* Section 3.5.3.3

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
Waste Management			
Characterization of solid waste (all primary and secondary wastes)	Must determine if that waste is hazardous waste or if waste is excluded under 40 *CFR* 261.4(b); and Must determine if waste is listed under 40 *CFR* Part 261, or	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 1200-1-11-.03(l)(b)(l) 40 *CFR* 262.11(b) TDEC 1200-1-11-.03(1)(b)(2)
	Must characterize waste by using prescribed testing methods or applying generator knowledge based on information regarding material or processes used. If waste is determined to be hazardous, it must be managed in accordance with pertinent provisions of 40 *CFR* 261-268.		40 *CFR* 262.11(c) and (d) TDEC 1200-1-11- .03(l)(b)(3)
	Must refer to Parts 261, 262, 264, 265, 266, 268, and 273 of Title 40 for possible exclusions or restrictions pertaining to management of the specific waste.	Generation of solid waste which is determined to be hazardous – **applicable**	40 *CFR* 262.11(d); TDEC Chap. 1200-1-11-.03(1)(b)(4)
Characterization of hazardous waste (all primary and secondary wastes)	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 pertinent sections of 40 *CFR* 264 to 268.	Generation of RCRA hazardous waste (including RCRA characteristic hazardous waste that is not D001 non-wastewater treated by CMBST, RORGS, or POLYM of Sect. 268.42, Table 1) for storage, treatment or disposal – **applicable**	40 *CFR* 264.13(a)(1) TDEC 1200-1-11-.06(2)(d)(1)
	Must determine the underlying hazardous constituents (as defined in 40 *CFR* 268.2[i]) in the waste.		40 *CFR* 268.9(a); TDEC Chap. 1200-1-11-.10(1)(i)(1)
	Must determine if the waste is restricted from land disposal under 40 *CFR* 268 et seq. by testing in accordance with prescribed methods or use of generator knowledge of waste.		40 *CFR* 268.7 TDEC 1200-1-11-.10(1)(g)(1)(i)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	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 Chap. 1200-1-11-.10(1)(i)(1)
Characterization of LLW (e.g., contaminated PPE, equipment, wastewater)	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 or 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:		DOE M 435.1-1(IV)(I)(2)
	• physical and chemical characteristics;		DOE M 435.1-1(IV)(I)(2)(a)
	• volume, including the waste and any stabilization or absorbent media;		DOE M 435.1-1(IV)(I)(2)(b)
	• weight of the container and contents;		DOE M 435.1-1(IV)(I)(2)(c)
	• identities, activities, and concentrations of major radionuclides;		DOE M 435.1-1(IV)(I)(2)(d)
	• characterization date;		DOE M 435.1-1(IV)(I)(2)(e)
	• generating source; and		DOE M 435.1-1(IV)(I)(2)(f)
	• any other information that might be needed to prepare and maintain the disposal facility performance assessment or demonstrate compliance with performance objectives.		DOE M 435.1-1(IV)(I)(2)(g)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
Temporary storage of hazardous waste in containers (e.g., PPE, rags, etc.)	A generator may accumulate hazardous waste at the facility provided that:	Accumulation of RCRA hazardous waste on site as defined in 40 *CFR* 260.10 – **applicable**	40 *CFR* 262.34(a) TDEC 1200-1-11-.03(4)(e)
	• waste is placed in containers that comply with 40 *CFR* 265.171-173 (Subpart 1); and • the date upon which accumulation begins is clearly marked and visible for inspection on each container; • container is marked with the words "hazardous waste," and		40 *CFR* 262.34(a)(1)(i) TDEC 1200-1-11 -.03(4)(e)(2)(i)(I) 40 *CFR* 262.34(a)(2) TDEC 1200-1-11 -.03(4)(e)(2)(ii) 40 *CFR* 262.34(a)(3) TDEC 1200-1-11 -.03(4)(e)(2)(iv)
	• container may be marked with other words that identify the contents.	Accumulation of 55 gal or less the contents of RCRA hazardous waste at or near any point of generation – **applicable**	40 *CFR* 262.34(c)(1) TDEC 1200-1-11 -.03(4)(e)(5)
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 1200-1-11-.05(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 1200-1-11-.05(9)(c)
	Keep containers closed during storage, except to add/remove waste;		40 *CFR* 264.173(a) TDEC 1200 -1-11-.05(9)(d)(1)
	Open, handle and store containers in a manner that will not cause containers to rupture or leak.		40 *CFR* 264.173(b) TDEC 1200-1-11-.05(9)(d)(2)
Design and operation of a RCRA container storage 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 of RCRA hazardous waste in containers that do not contain free liquids – **applicable**	40 *CFR* 264.175(c) TDEC 1200-1-11-.06(9)(f)(3)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	Area must have a containment system designed and operated as follows:	Storage of RCRA hazardous waste with free liquids or F020, F021, F022, F023, F026 and F027 in containers – **applicable**	40 *CFR* 264.175(a); TDEC 1200-1-11-.06(9)(f)
	• 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 1200-1-11-.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 accumulated liquids;		40 *CFR* 264.175(b)(2) TDEC 1200-1-11-.06(9)(f)(2)(ii)
	• must have sufficient capacity to contain 10% of the volume of containers or the volume of the largest container, whichever is greater;		40 *CFR* 264.175(b)(3) TDEC 1200-1-11-.06(9)(f)(2)(iii)
	• run-on into the system must be prevented unless the collection system has sufficient capacity to contain along with volume required for containers; and		40 *CFR* 264.175(b)(4) TDEC 1200-1-11-.06(9)(f)(2)(iv)
	• 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.		40 *CFR* 264.17(5)(b)(5) TDEC 1200-1-11-.06(9)(f)(2)(v)
Temporary storage of LLW (e.g., contaminated PPE, scrap metal, soil)	Ensure that radioactive waste is stored in a manner that protects the public, workers, and the environment and that the integrity of waste storage is maintained for the expected time of storage.	Management of LLW at a DOE Facility – **TBC**	DOE M 435.1-1 (IV)(N)(1)
	LLW shall not be readily capable of detonation, explosive decomposition, reaction at anticipated pressures and temperatures, or explosive reaction with water.		DOE M 435.1-1 (IV)(N)(1)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	LLW shall be stored in a location and manner that protects the integrity of waste for the expected time of storage.	Management of LLW at a DOE Facility – **TBC**	DOE M 435.1-1 (IV)(N)(3)
	LLW shall be managed to identify and segregate LLW from mixed waste.		DOE M 435.1-1 (IV)(N)(6)
Temporary storage of PCB waste (e.g., PPE, rags) in a container(s)	Container(s) shall be marked as illustrated in 40 *CFR* 761.45(a).	Storage of PCBs and PCB Items at concentrations ≥50 ppm for disposal – **applicable**	40 *CFR* 761.40(a)(1)
	Storage area must be properly marked as required by 40 *CFR* 761.40(a)(10).		40 *CFR* 761.65(c)(3)
	Any leaking PCB Items and their contents shall be transferred immediately to a properly marked non-leaking container(s).		40 *CFR* 761.65(c)(5)
	Container(s) shall be in accordance with requirements set forth in DOT HMR at 49 *CFR* 171-180.		40 *CFR* 761.65(c)(6)
	The date shall be recorded when PCB items are removed from service, and the storage shall be managed such that PCB items can be located by this date. (*Note:* Date should be marked on the container.)	PCB items (includes PCB wastes) removed from service for disposal – **applicable**	40 *CFR* 761.65(c)(8)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
Storage of PCB waste and/or PCB/radioactive waste in a RCRA-regulated container storage area	PCB storage does not have to meet storage unit requirements in 40 *CFR* 761.65(b)(1) provided that the unit:	Storage of PCBs and PCB items designated for disposal – **applicable**	40 *CFR* 761.65(b)(2)
	• is permitted by EPA under RCRA §3004, or		40 *CFR* 761.65(b)(2)(i)
	• qualifies for interim status under RCRA §3005; or		40 *CFR* 761.65(b)(2)(ii)
	• is permitted by an authorized state under RCRA §3006 and,		40 *CFR* 761.65(b)(2)(iii)
	• PCB spills cleaned up in accordance with subpart G of 40 *CFR* 761		40 *CFR* 761.65(c)(1)(iv)
Management of PCB waste (e.g., contaminated PPE, scrap metal, soil, debris, 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 PCBs are found.	Generation of PCB remediation waste as defined in 40 *CFR* 761.3 – **applicable**	40 *CFR* 761.61
Management of PCB/radioactive waste (e.g., contaminated PPE, scrap metal, soil, debris)	Any person storing such waste must do so taking into account both its PCB concentration and radioactive properties, except as provided in 40 *CFR* 761.65(a)(1), (b)(1)(ii) and (c)(6)(i).	Generation for disposal of PCB/ radioactive waste with ≥ 50 ppm PCBs – **applicable**	40 *CFR* 761.50(b)(7)(i)
Management of TSCA PCB wastes	Other wastes that are not compatible with PCBs shall be segregated from the PCBs throughout the handling and disposal process.	Management, storage of PCBs or PCB Items – **applicable**	40 *CFR* 761.75(b)(8)(i)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
Storage of PCB/radioactive waste in containers	For liquid wastes, containers must be non-leaking.	Storage of PCB/radioactive waste in containers other than those meeting DOT HMR performance standards – **applicable**	40 *CFR* 761.65(c)(6)(i)(A)
	For non-liquid wastes, containers must be designed to prevent buildup of liquids if such containers are stored in an area meeting the containment requirements of 40 *CFR* 761.65(b)(1)(ii); and		40 *CFR* 761.65(c)(6)(i)(B)
	Both liquid and non-liquid wastes containers must meet all regulations and requirements pertaining to nuclear criticality safety.		40 *CFR* 761.65(c)(6)(i)(C)
Packaging of LLW for disposal (e.g., contaminated PPE, scrap metal, debris, rags)	LLW 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 1200-2-11-.17(7)(a)(1)
	LLW 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 1200-2-11-.17(7)(a)(2)
	LLW shall contain as little free standing and noncorrosive liquid as is reasonably achievable, but in no case shall the liquid exceed 1% of the volume.	Generation of solid LLW containing liquid for disposal at a LLW disposal facility – **relevant and appropriate**	TDEC 1200-2-11-.17(7)(a)(3)
	LLW 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 1200-2-11-.17(7)(a)(4)
	LLW must not contain, or be capable of generating, quantities of toxic gases, vapor, or fumes.		TDEC 1200-2-11-.17(7)(a)(5)
	LLW must not be pyrophoric.		TDEC 1200-2-11-.17(7)(a)(6)
	LLW must have structural stability either by processing the waste or placing the waste in a container or structure that provides stability after disposal.		TDEC 1200-2-11-.17(7)(b)(1)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	LLW 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% 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 1200-2-11-.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 1200-2-11-.17(7)(b)(3)
	LLW 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 to meet the performance objectives of the disposal facility.	Generation of LLW for disposal at a DOE facility – **TBC**	DOE M 435.1-1(IV)(O)
Treatment of uranium and thorium bearing LLW	Potentially biodegradable uranium and thorium bearing LLW shall be properly conditioned so that the generation and escape of biogenic gases will not cause the emission or dose limits in DOE O 458.1 paragraph 4.h.(1) to be exceeded and that bio-degradation within the facility will not result in premature structural failure.	Placement of potentially biodegradable contaminated wastes in a long-term management facility – **TBC**	DOE O 458.1(4)(h)(1)(d)(3)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
Disposal of LLW (e.g., debris, scrap metal, soil)	LLW shall be certified as meeting waste acceptance requirements before it is transferred to the receiving facility.	Generation of LLW for disposal – **TBC**	DOE M 435.1-1(IV)(J)(2)
Exposure to any member of the public from the disposal of LLW	Assure that exposure to any member of the public to radioactive waste from the handling, transportation, and disposal of LLW does not exceed an EDE of 25 mrem/year from all pathways		DOE O 435.1 Chap. 4
Exposure from the disposal of LLW	Not cause radon-222 flux rates to exceed 20 pCi (0.7 Bq) m-2 sec-1 averaged over the surface area overlaying waste, including the covering or other confinement structures, wherever radium-226 wastes are accepted for storage or disposal		DOE O 458.1(4)(f)(2)
Disposal of RCRA hazardous waste in a land-based unit	RCRA-restricted waste 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.	Land disposal, as defined in 40 *CFR* 268.2, of RCRA restricted waste – **applicable**	40 *CFR* 268.40 TDEC 1200-1-11-.10(3)(a)
	Hazardous waste must be treated in accordance with the alternative treatment standards of 40 *CFR* 268.49(c), or according to the Universal Treatment Standards specified in 40 *CFR* 268.48 applicable to the listed and/or characteristic waste contaminating the soil, prior to land disposal.	Land disposal, as defined in 40 *CFR* 268.2, of restricted hazardous soil – **applicable**	40 *CFR* 268.49(b) TDEC 1200-1-11-.10(3)(j)(2)
	Hazardous waste may be land disposed if it meets the requirements in the table "Alternative Treatment Standards for Hazardous Debris" at 40 *CFR* 268.45 before land disposal or the debris is treated to the waste-specific treatment standard provided in 40 *CFR* 268.40 for the waste contaminating the debris.	Land disposal, as defined in 40 *CFR* 268.2, of restricted RCRA hazardous debris – **applicable**	40 *CFR* 268.45(a) TDEC 1200-1-11-.06(10)(3)(f)(1)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	Disposal of hazardous waste is 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* 268.40 or are D003 reactive cyanide.	Land disposal, as defined in 40 *CFR* 268.2, or restricted RCRA characteristically hazardous waste – **applicable**	40 *CFR* 268.1(c)(4)(iv) TDEC 1200-1-11-.06(10)(1)(3)(iv)(IV)
Disposal requirements for particular RCRA waste forms and types	Ignitable or reactive RCRA waste must not be placed in a landfill unless the waste and the landfill meet applicable provisions of 40 *CFR* Part 268; and • the resulting waste, mixture or dissolution of material no longer is reactive or ignitable; and	Disposal of ignitable or reactive RCRA waste – **applicable**	40 *CFR* 264.312(a) TDEC 1200-1-11-.06(14)(m)(1)
	• 40 *CFR* 264.17(b) is complied with (see below).		
	Ignitable or reactive RCRA waste may be landfilled without meeting 40 *CFR* 264.312(a), provided wastes are disposed of in such a way that they are protected from any materials or conditions which may cause them to ignite;	Disposal of ignitable or reactive RCRA waste (except for prohibited wastes which remain subject to treatment standards in 40 *CFR* 268.40 *et seq.*) – **applicable**	40 *CFR* 264.312(b) TDEC 1200-1-11-.06(14)(m)(2)
	Must be disposed of in non-leaking containers which are carefully handled and placed so as to avoid heat, sparks, rupture, or any other condition that might cause ignition of the wastes;		
	Must be covered daily with soil or other non-combustible material to minimize the potential of ignition;		
	Must not be disposed of in cells that contain or will contain other wastes which may generate heat sufficient to cause ignition of the waste.		
	Incompatible wastes must not be placed into a RCRA landfill 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)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
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; • produce uncontrolled toxic fumes or gases which threaten human health or the environment; • damage the structural integrity of the device or facility.	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)
Disposal of bulk or non-containerized liquids in a RCRA landfill	May not dispose of bulk or non-containerized liquid hazardous waste or hazardous waste containing free liquids in any landfill.	Placement of bulk or non-containerized RCRA hazardous waste – **applicable**	40 *CFR* 264.314(b) TDEC 1200-1-11-.06(14)(o)(4)
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(d) TDEC 1200-1-11-.06(14)(o)(4)
	Sorbents used to treat free liquids to be disposed of in landfills must be non-biodegradable as described in 264.315(e)(1).		40 *CFR* 264.314(e) TDEC 1200-1-11-.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 1200-1-11.06(14)(p)
Disposal of PCB/radioactive waste	Any person disposing of such waste must do so taking into account both its PCB concentration and its radioactive properties.	Disposal of PCB/ radioactive waste (e.g., contaminated PPE, scrap metal, soil, debris) with ≥ 50 ppm PCBs – **applicable**	40 *CFR* 761.50(b)(7)(ii)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	If, after taking into account only the PCB properties in the waste, it meets requirements for disposal in a facility permitted, licensed, or registered by a state as a municipal or non-municipal nonhazardous waste landfill, the person may dispose of such waste without regard to the PCBs, based on its radioactive properties alone, in accordance with applicable requirements.		
Disposal of bulk PCB remediation waste	Bulk PCB remediation waste shall be disposed of: • in a hazardous waste landfill permitted by EPA under §3004 of RCRA, • in a hazardous waste landfill permitted by a State authorized under §3006 of RCRA, or • in a PCB disposal facility approved under 40 *CFR* 761.60.	Bulk PCB remediation waste (as defined in 40 *CFR* 761.3) which has been de-watered and with a PCB concentration ≥50 ppm – **applicable**	40 *CFR* 761.61(a)(5)(i)(B)(2)(iii)
Performance-based disposal of PCB remediation waste	May dispose of non-liquid PCB remediation waste by one of the following methods:	Disposal of non-liquid PCB remediation waste as defined in 40 *CFR* 761.3 – **applicable**	40 *CFR* 761.61(b)(2)
	• in a high-temperature incinerator approved under Section 761.70(b),		40 *CFR* 761.61(b)(2)(i)
	• by an alternate disposal method approved under Section 761.60(e),		
	• in a chemical waste landfill approved under Section 761.75,		

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	• in a facility with a coordinated approval issued under Section 761.77, or		
	• through decontamination in accordance with Section 761.79.		40 *CFR* 761.61(b)(2)(ii)
Disposal of PCB cleanup wastes (PPE, rags, non-liquid cleaning materials)	Non-liquid PCB cleanup waste shall be disposed of either: • in a facility permitted, licensed or registered by a State to manage municipal solid waste under 40 *CFR* 258 or non-municipal, nonhazardous waste subject to 40 *CFR* 257.5 thru 257.30; or • in a RCRA Subtitle C landfill permitted by a State to accept PCB waste, or • in an approved PCB disposal facility, or • through decontamination under 40 *CFR* 761.79(b) or (c).	Generation of non-liquid PCBs at any concentration during and from the cleanup of PCB remediation waste – **applicable**	40 *CFR* 761.6 1 (a)(5)(v)(A)
Disposal of PCB cleaning solvents abrasives, and equipment	PCB cleaning solvents abrasives and equipment may be reused after decontamination in accordance with 40 *CFR* 761.79.	Generation of PCB wastes from the cleanup of PCB remediation waste – **applicable**	40 *CFR* 761.6 1 (a)(5)(v)(B)
Disposal of PCB bulk product waste *(e.g., debris or scrap metal with PCB painted surfaces)*	May dispose of PCB bulk product waste by one of the following methods:	Disposal of PCB bulk product waste as defined in 40 *CFR* 761.3 – **applicable**	40 *CFR* 761.62(a)
	• in an incinerator approved under Section 761.70;		40 *CFR* 761.62(a)(1)
	• in a chemical waste landfill approved under Section 761.75;		40 *CFR* 761.62(a)(2)
	• in a hazardous waste landfill permitted by EPA under 3004 of RCRA or by authorized state under 3006 of RCRA;		40 *CFR* 761.62(a)(3)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	• under alternate disposal approved under section 761.60(e);		40 *CFR* 761.62(a)(4)
	• in accordance with decontamination provisions of 761.79;		40 *CFR* 761.62(a)(5)
	• in accordance with thermal decontamination provisions of 761.79(e)(6) for metal surfaces in contact with PCBs.		40 *CFR* 761.62(a)(6)
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)
	Other wastes that are not compatible with PCBs shall be segregated from the PCBs throughout the handling and disposal process.		
Disposal of PCB liquids (*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.	Disposal of PCB container with liquid PCB between 50 ppm and 500 ppm – **applicable**	40 *CFR* 761.75(b)(8)(ii)
	May be disposed of if container is surrounded by an amount of inert sorbent material capable of absorbing all of the liquid contents of the container.		

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
Disposal Site Suitability Requirements			
Siting of a RCRA landfill	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 can demonstrated that procedures are in effect which will cause the waste to be removed safely, before flood waters can reach the facility.	Construction of a RCRA hazardous waste landfill – **applicable**	40 *CFR* 264.18(b)(1) TDEC 1200-1-11-.06(2)(i)
	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.		40 *CFR* 264.18(a)(1)
Siting of a TSCA landfill	The bottom of the landfill shall be above the historical high groundwater table as provided below. Floodplains, shorelands, and groundwater recharge areas shall be avoided. There shall be no hydraulic connection between the site and standing or flowing surface water. The site shall have monitoring wells and leachate collection. 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.	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	Construction of a TSCA chemical waste landfill – **applicable**	
	Floodplains, shore lands and groundwater recharge areas shall be avoided.		
	A TSCA landfill shall provide diversion structures capable of diverting all surface water runoff from a 24-hr, 25-year storm.	Construction of a TSCA chemical waste landfill (above the 100-year floodwater elevation) – **applicable**	40 *CFR* 761.75(b)(4)(ii)
	The landfill site shall be located in an area of low to moderate relief to minimize erosion and to help prevent landslides or slumping.	Construction of a TSCA chemical waste landfill – **applicable**	40 *CFR* 761.75(b)(5)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
Siting of a LLW disposal facility	LLW disposal sites shall be capable of being characterized, modeled, analyzed, and monitored.	Land disposal of LLW – **relevant and appropriate**	TDEC 1200-2-11-.17(1)(b)
	LLW disposal sites 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.		TDEC 1200-2-11-.17(1)(c)
	Areas must be avoided having known natural resources which, if exploited, would result in failure of the cell to meet performance objectives.		TDEC 1200-2-11-.17(1)(d)
	Disposal site must be generally well drained and free of areas of flooding and frequent ponding.		TDEC 1200-2-11-.17(1)(e)
	Waste disposal shall not take place in a 100-year floodplain or wetland.		
	Upstream drainage areas must be minimized to decrease the amount of runoff which could erode or inundate the disposal unit.		TDEC 1200-2-11-.17(1)(f)
	The disposal site must provide sufficient depth to the water table that groundwater intrusion, perennial or otherwise, into the waste will not occur.		TDEC 1200-2-11-.17(1)(g)
Siting of a LLW disposal facility	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 1200-2-11-.16 being met, wastes may disposed of below the water table. In no case will waste disposal be permitted in the zone of fluctuation of the water table.	Land disposal of LLW – **relevant and appropriate**	

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	The hydrogeologic unit used for disposal shall not discharge groundwater to the surface within the disposal site.		TDEC 1200-2-11-.17(1)(h)
	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.		TDEC 1200-2-11.17(1)(i)
	Areas must be avoided where surface geologic processes such as mass wasting, erosion, slumping, landslides, 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.		TDEC 1200-2-11-.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.		TDEC 1200-2-11-.17(1)(k)
	A preoperational monitoring program must be conducted to provide basic environmental data on the disposal site characteristics.		TDEC 1200-2-11-.17(4)(a)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
Wastewater Treatment Facility Operation and Discharge			
Point source discharge of radionuclides into the air from a DOE facility	Emissions of radionuclides to the ambient air shall not exceed those amounts that would cause any member of the public to receive in any year an EDE of 10 mrem/yr.	Radionuclide emissions from point sources, as well as diffuse or fugitive emissions, 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 dose equivalent in excess of 1% of the standard. All radionuclides which could contribute greater than 10% of the potential effective dose equivalent for a release point shall be measured.		40 *CFR* 61.93(b)(4)(i)
Transport to wastewater treatment facility	All tank systems, conveyance systems, and ancillary equipment used to store or transport waste to an on-site NPDES-permitted wastewater treatment facility are exempt from the requirements of RCRA Subtitle C standards.	On-site wastewater treatment units that are subject to regulation under Sect. 402 or Sect. 307(b) of CWA (NPDES-permitted) – **applicable**	40 *CFR* 270.1(c)(2)(v); TDEC Chap. 1200-1-11-.07(1)(b)(4)(iv)
Treatment of collected leachate	Are not prohibited from land disposal if such wastes are managed in a treatment system that subsequently discharges to waters of the United States pursuant to a permit issued under Sect. 402 of 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.	Restricted RCRA characteristically hazardous waste intended for disposal – **applicable**	40 *CFR* 268.1(c)(4)(i); TDEC Chap. 1200-1-11-.10(1)(a)(3)(iv)(I)
Discharge of contaminated storm water	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 of 1977 at TSCA 69-3-103(30).	Point Source discharge(s) of pollutants into surface water – **applicable**	TDEC 1200-4-3-.05(6)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
Design, Construction, and Operation of a Mixed (RCRA hazardous, TSCA chemical and low-level radioactive) Waste Landfill			
Security System	Operators 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(5)(b) and (c).	Operation of a RCRA landfill – **applicable**	40 *CFR* 264.14 TDEC 1200-1-11.06(2)(e)
Security System	Unless a natural barrier adequately deters access by the general public, either warning signs and fencing must be installed and maintained or requirements of 40 *CFR* 61.154(c)(1) and (2) must be met.	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)
	Warning signs must be displayed at all entrances and at intervals of 330 ft or less along the property line of the site.		40 *CFR* 61.154(b)(1)
	The warning signs must: • be posted in a manner and location that a person can easily ready the legend;		40 *CFR* 61.154(b)(1)(i)
	• conform to the requirements of (20 in. × 14 in.) upright format signs in 29 *CFR* 1901.145(d)(4); and		40 *CFR* 61.154(b)(1)(ii)
	• display the legend in the lower panel with letter sizes and styles of a visibility at least equal to those specified in 40 *CFR* 61.154(b)(1)(iii).		40 *CFR* 61.154(b)(1)(iii)
	The perimeter of the disposal site must be fenced in a manner adequate to deter access by the general public.		40 *CFR* 61.154(b)(2)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
Security System	A 6-ft woven mesh fence, wall or similar device shall be placed around the site to prevent unauthorized access.	Construction of a TSCA chemical waste landfill – **applicable**	40 *CFR* 761.75(b)(9)(i)
	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.		40 *CFR* 761.75(b)(9)(ii)
	Site shall be operated and maintained to prevent hazardous conditions resulting from spilled liquids and windblown materials.		40 *CFR* 761.75(b)(9)(iii)
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 landfill – **applicable**	40 *CFR* 264.15(a) TDEC 1200-1-11-.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 1200-1-11-.06(2)(f)(3)
Personnel training	Operators must ensure personnel are adequately trained in hazardous waste, emergency response, monitoring equipment maintenance, alarm systems procedures, etc.	Operation of a RCRA landfill – **applicable**	40 *CFR* 264.16 TDEC 1200-1-11-.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.	Operation of a RCRA landfill – **applicable**	40 *CFR* 264.19 TDEC 1200-1-11-.06(2)(j)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
Contingency plan	Operators must have 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.	Operation of a RCRA landfill – **applicable**	40 *CFR* 264.51 TDEC 1200-1-11-.06(4)(b)
	Operators must have at least one emergency coordinator on the facility premises or on call responsible for coordinating emergency response measures in accordance with 40 *CFR* 264.56.		40 *CFR* 264.55 TDEC 1200-1-11-.06(4)(f)
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 1200-1-11-.06(3)
Inventory requirements	The location, dimensions, contents, and location of each cell must be recorded in reference to permanently surveyed benchmarks.	Operation of a RCRA landfill – **applicable**	40 *CFR* 264.309 TDEC 1200-1-11-.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)
Inventory requirements	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.	Land disposal of LLW – **relevant and appropriate**	TDEC 1200-2-11-.17(3)(g)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
Surface water monitoring	The groundwater 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)
	Any surface watercourse designated by EPA shall be sampled at least monthly when the landfill is being used for disposal operations, and for a time period specified by the EPA on a frequency of no less than once every six months after final closure of the disposal area.	Operation of a TSCA chemical waste landfill – **applicable**	40 *CFR* 761.75(b)(6)(i)(B) & (C)
	As a minimum, all samples shall be analyzed for the following parameters: • PCBs • PH • specific conductance • chlorinated organics		40 *CFR* 761.75 (b)(6)(iii)
	Sampling methods and analytical procedures for these parameters shall comply with those specified in 40 *CFR* Part 136, as amended in 41 Federal Register 52779 on December 1, 1976.		

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
Liner and leachate collection system design for a RCRA landfill	The owner must install two or more liners and a leachate collection and removal system above and between such liners.	Construction of a RCRA landfill – **applicable**	40 *CFR* 264.301(c) TDEC 1200-1-11-.06(14)(b)(3)(i)(I)
	The liner system must include: • 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 postclosure period; and		40 *CFR* 264.301(c)(1)(i); TDEC 1200-1-11-.06(14)(b)(3)(i)(I)I
	• a composite bottom liner consisting of at least two components:		TDEC 1200-1-11-.06(14)(3)(i)(I)II
	– upper component must be designed and constructed of materials to prevent migration of hazardous constituents into this component during the active life and postclosure period; and		
Liner and leachate collection system design for a RCRA landfill	– lower component designed and constructed of materials to minimize the migration of hazardous constituents if a breach in the upper component were to occur;	Construction of a RCRA landfill – **applicable**	
	– constructed of at least 3 ft of compacted soil material with a hydraulic conductivity of no more than 1×10^{-7} cm/second		

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	• liners must comply with paragraphs (a)(1)(i), (ii), and (iii) of TDEC 1200-1-11-.06(14)(b)(3)(i) (I)III		TDEC 1200-1-11-.06(14)(b)(3)(i) (I)III
	The liner must be:		40 CFR 264.301(a)(1)
	• 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 are exposed, climatic conditions, or stress from installation or daily operation;		TDEC 1200-1-11-.06(14))(b)(1)(i)(I) 40 *CFR* 264.301(a)(1)(i)
	• 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		40 *CFR* 264.301(a)(1)(ii) TDEC 1200-1-11-.06(14)(b)(1)(i)(II)
	• installed to cover all areas likely to be in contact with the waste or leachate		40 *CFR* 264.301(a)(1)(iii) TDEC 1200-1-11-.06(14)(b)(1)(i) (III)
Top leachate collection and removal system	The top leachate collection and removal system of a RCRA landfill 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; and	Construction of a RCRA landfill – **applicable**	40 *CFR* 264.301(c)(2) TDEC 1200-1-11-.06(14)(b)(1) (ii)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	Leachate collection system must be constructed of materials that are:		TDEC 1200-1-11-.06(14)(b)(1) (ii)(I)
	• chemically resistant to waste managed in landfill and leachate generated; and		TDEC 1200-1-11-.06(14)(b)(1) (ii)(I)I
	• sufficient strength and thickness to prevent collapse under pressures exerted by overlying wastes, waste cover materials, and by any equipment used		TDEC 1200-1-11-.06(14)(b)(1) (ii)(I)II
Bottom leachate collection and removal system/leak detection system	Leachate collection and removal system must be capable of detecting, collecting, and removing leachate from all areas of the landfill during active life and the post-closure care period. Requirements for a leak detection system are satisfied by installation of a system that is:	Construction of a RCRA landfill – **applicable**	40 *CFR* 264.301(c)(3) TDEC 1200-1-11-.06(14)(b)(3) (iii)
	• constructed with a bottom slope of 1% or more;		40 *CFR* 264.301(c)(3)(i) TDEC 1200-1-11-.06(14)(b)(3)(iii)(I)
	• constructed of granular drainage materials with a hydraulic conductivity of 1×10^{-2} cm/second and a thickness of 12 in. or more or synthetic or geonet drainage materials with a transmissivity of 3×10^{-5} m^2/sec;		40 *CFR* 264.301(c)(3)(ii) TDEC 1200-1-11-.06(14))(b)(3)(iii)(II)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	• constructed of materials that are chemically resistant to waste managed and expected leachate to be generated, and structurally sufficient to resist pressures exerted by waste, cover, and equipment used at the landfill;		40 *CFR* 264.301(c)(3)(iii) TDEC 1200-1-11-.06(14)(b)(3) (iii)(III)
	• designed and operated to minimize clogging during the active life of the facility and postclosure care period; and		40 *CFR* 264.301(c)(3)(iv) TDEC 1200-1-11-.06(14)(b)(3) (iii)(IV)
	• constructed with sumps and liquid removal methods (e.g., pumps) adequate to prevent the backup of liquids into the drainage layer and capable of measuring and recording the volume of liquids present in the sump and liquids present in the sump and of liquids removed.		40 *CFR* 264.301(c)(3)(v) TDEC 1200-1-11-.06(14)(b)(3) (iii)(V)
	Operators 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 1200-1-11-06(14)(b)(3)(iv)
	If the leak detection system is located below the seasonal high water table, a demonstration must be made that the system will not be adversely affected by groundwater	Construction of a RCRA landfill – **applicable**	40 *CFR* 264.301(c)(5) TDEC 1200-1-11-.06(14)(b)(3)(v)
Leachate collection monitoring system for TSCA landfill	A leachate collection monitoring system shall be installed above the chemical waste landfill. Acceptable system includes compound leachate collection.	Construction of a TSCA chemical waste landfill – **applicable**	40 *CFR* 761.75(b)(7)
	Compound leachate collection system consists of a gravity flow drain field installed above the waste disposal facility liner and above a secondary installed liner.		40 *CFR* 761.75 (b)(7)(ii)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
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.	Construction of a RCRA landfill – **applicable**	40 *CFR* 264.301(g) TDEC 1200-1-11-.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-hr, 25-year storm event.		40 *CFR* 264.301(h) TDEC 1200-1-11-.06(14)(b)(8)
	Collection and holding facilities must be emptied or otherwise expeditiously managed after storm events to maintain design capacity of the system.	Operation of a RCRA landfill – **applicable**	40 *CFR* 264.301(i) TDEC 1200-1-11-.06(14))(b)(9)
Wind dispersal control system	Must cover or manage the landfill to control wind dispersal of particulate matter.	Operation of a RCRA landfill – **applicable**	40 *CFR* 264.301(j) TDEC 1200-1-11-.06(14)(b)(10)
	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)
	At the end of each operating day, or at least every 24-hr period while the site is in continuous operation, cover the asbestos containing waste with:		40 *CFR* 61.154(c)
	• at least 6 in. of compacted non asbestos-containing material, or		40 *CFR* 61.154(c)(1)
	• a resinous or petroleum based dust suppression agent that effectively binds dust and controls wind erosion in the manner and frequency specified by the manufacturer.		40 *CFR* 61.154(c)(2)
	RCRA landfill operators must inspect landfill weekly and after storm events to ensure proper functioning of: • run-on and runoff control systems, • wind dispersal control systems, and • leachate collection and removal systems.	Operation of a RCRA landfill – **applicable**	40 *CFR* 264.303(b)(1)-(3) TDEC 1200-1-11-.06(14)(d)(2)(i)-(iii)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	RCRA landfill operators must record the amount of liquids removed from the leak detection system sumps at least weekly during the active life and closure period.	Operation of a RCRA landfill – **applicable**	40 *CFR* 264.303(c)(1) TDEC 1200-1-11-.06(14)(d)(3)(ii)
Monitoring and inspection of liners, leak detection, run-on/ run-off systems during the active life of the facility	During construction or installation, liners and cover systems must be inspected for uniformity, damage and imperfections (e.g., holes, cracks, thin spots, etc.).	Construction of a RCRA landfill – **applicable**	40 *CFR* 264.303(a) TDEC 1200-1-11-.06(14)(d)
Post-construction inspection	Immediately after construction or installations: • synthetic liners and covers must be inspected to ensure: tight seams and joints and the absence of tears, punctures or blisters;	Construction of a RCRA landfill – **applicable**	40 *CFR* 264.303(a)(1) TDEC 1200-1-11-.06(14)(d)(1)(i)
	• soil based and mixed liners and covers must be inspected for imperfections including lenses, cracks, channels or other structural non-uniformities		40 *CFR* 264.303(a)(2) TDEC 1200-1-11-.06(14)(d)(1)(ii)
	RCRA landfill operators must inspect landfill weekly and after storm events to ensure proper functioning of:	Operation of a RCRA landfill – **applicable**	40 *CFR* 264.303(b); TDEC 1200-1-11-.06(14)(d)(2)
	• run-on and runoff control systems, • wind dispersal control systems, and • leachate collection and removal systems.		
	RCRA landfill operators must record the amount of liquids removed from the leak detection system sumps at least weekly during the active life and closure period.	Operation of a RCRA landfill – **applicable**	40 *CFR* 264.303(c)(1) TDEC 1200-1-11-.06(14)(d)(3) (ii)
Response actions for leak detection system	RCRA landfill operators 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 1200-1-11-.06(14)(e)(1)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	RCRA landfill operators 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 1200-1-11- .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 or closure; and		40 *CFR* 264.304(b)(4) TDEC 1200-1-11-.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 1200-1-11-.06(14)(e)(2) (v)
	RCRA landfill operators must assess the source and amounts of the liquids by source;	Leak and/or remediation determinations required – **applicable**	40 *CFR* 264.304(c)(1) TDEC 1200-1-11-.06(14)(c)(3) (i)
Response actions for leak detection system	Conduct analysis of the liquids to identify sources and possible location of the leaks; and	Leak and/or remediation determinations required – **applicable**	
	Assess seriousness of leaks in terms of potential for escaping into the environment; or		40 *CFR* 264.304(c)(2)
	Document why such assessments are not needed.		TDEC 1200-1-11-.06(14)(e)(3) (ii)
Liner design requirements for a TSCA landfill	TSCA chemical waste landfills 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:	Construction of a TSCA chemical waste landfill – **applicable**	40 *CFR* 761.75(b)(1)
	• In place soil thickness, 4-ft or compacted soil liner thickness, 3-ft;		40 *CFR* 761.75(b)(1)(i)
	• Permeability (cm sec), equal to or less than 1×10^{-7};		40 *CFR* 761.75(b)(1)(ii)
	• percent soil passing No. 200 sieve > 30;		40 *CFR* 761.75(b)(1)(iii)
	• Liquid limit, > 30; and		40 *CFR* 761.75(b)(1)(iv)
	• Plasticity Index > 15; or		40 *CFR* 761.75(b)(1)(v)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	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.		40 *CFR* 761.75(b)(2)
	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.		
Performance objectives for LLW disposal facility	A land disposal facility must be sited, designed, operated, closed and controlled after closure so that reasonable assurance exists that exposures to humans are within limits established in the performance objectives in 1200-2-11-.16(2) and (5).	Operation and Closure of LLW disposal facility – **relevant and appropriate**	TDEC 1200-2-11-.16(1)
LLW disposal site stability	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.	Operation and Closure of LLW disposal facility – **relevant and appropriate**	TDEC 1200-2-11-.16(5)
LLW disposal facility design	Land disposal site design features must be directed toward long-term isolation and avoidance of the need for continuing active maintenance after site closure.	Land disposal of LLW – **relevant and appropriate**	TDEC 1200-2-11-.17(2)(a)
	The disposal site design and operation must be compatible with the disposal site closure and stabilization plan and lead to disposal site closure that assures compliance with the performance objectives.		TDEC 1200-2-11-.17(2)(b)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	The disposal site design must compliment and improve, where appropriate, the ability of the disposal site's natural characteristics to assure that the performance objectives are met.		TDEC 1200-2-11-.17(2)(c)
	Surface features must direct surface water drainage away from disposal units at velocities and gradients which will not result in erosion that will require on-going active maintenance in the future.	Construction of LLW disposal facility – **relevant and appropriate**	TDEC 1200-2-11-.17(2)(e)
LLW disposal operations	Wastes must be emplaced in a manner that maintains the package integrity during emplacement, and minimizes the void spaces to be filled.	Operation of LLW disposal facility – **relevant and appropriate**	TDEC 1200-2-11-.17(3) (d)
	A buffer zone of land must be maintained between the disposal unit and disposal boundary and beneath the disposed waste.		TDEC 1200-2-11-.17(3) (h)
	The buffer zone shall be of adequate dimensions to carry out environmental monitoring activities.		
	Void spaces between waste packages must be filled with earth or other material to reduce future subsidence within the disposal unit.		TDEC 1200-2-11-.17(3)(e)
	Closure and stabilization measures must be carried out as each disposal unit is filled and covered.		TDEC 1200-2-11-.17(3)(i)
	Active waste disposal operations must not have an adverse effect on completed closure and stabilization measures.		TDEC 1200-2-11-.17(3)(j)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
Monitoring of LLW disposal facility	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.	Operation of LLW disposal facility – **relevant and appropriate**	TDEC 1200-2-11-.17(4)(c)
Facility design, construction	Systems structures and components must be designed, constructed and operated to withstand the effects of natural phenomena as necessary to ensure confinement of hazardous material, the operation of essential facilities, and the protection of government property.	Construction of new non-nuclear facility under DOE-STD-1027-92 – **TBC**	DOE O 420.1
Control and stabilization	Control and stabilization features shall be designed to: • provide to the extent reasonably achievable an effective life of 1,000 years with a minimum of at least 200 years; and	Long-term management of uranium, thorium, and their decay products – **TBC**	DOE O 458.1(4)(h)(1)(d)(1)(a)
	• Limit Rn-222 emanation to the atmosphere from the wastes to less than an annual average release rate of 20 pCi/m2/s and prevent increase in the annual average Rn-222 concentration at or above any location outside the boundary of the contaminated area by more than 0.5 pCi/L.		DOE O 458.1(4)(h)(1)(d)(1)(b)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	Closure		
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.	Closure of RCRA landfill – **applicable**	40 *CFR* 264.114 TDEC 1200-1-11-.06(7)(e)
Closure of RCRA landfill	Must close the a RCRA landfill unit in a manner that: • minimizes the need for further maintenance, and • 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 ground or surface waters or to the atmosphere, and • complies with the closure requirements of 40 *CFR* 265.310.	Closure of a RCR.A hazardous waste management facility – **applicable**	40 *CFR* 265.111 TDEC 1200-1-11-.05(7)(b)
Closure of RCRA landfill	Must cover the landfill or cell with a final cover designed and constructed to: • provide long-term minimization of migration of liquids through the closed landfill; • function with minimum maintenance; • promote drainage and minimize erosion or abrasion of the cover; • accommodate settling and subsidence so that the cover's integrity is maintained; and • have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present.	Closure of a RCR.A hazardous waste management facility – **applicable**	40 *CFR* 265.310(a) TDEC 1200-1-11-.05(14)(k)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
Closure of a LLW disposal facility	Covers must be designed to minimize 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.	Land disposal of LLW – **relevant and appropriate**	TDEC 1200-2-11-.17(2)(d)
Closure of an inactive asbestos waste disposal site	Either discharge no visible emissions to the outside air; or Cover the asbestos-containing waste 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; or	Disposal of asbestos containing waste material – **applicable**	40 *CFR* 61.151 (a)(1) 40 *CFR* 61.151(a)(2)
	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)
	Maintain warning signs and fencing (if installed as specified in 40 *CFR* 61.154(b).		40 *CFR* 6 1. 151 (b)(1)
Clean closure of RCRA container storage area	Must close the facility in a manner that: • minimizes the need for further maintenance; • controls, minimizes or eliminates, to the extent necessary to protect human health and environment, postclosure escape of hazardous waste, hazardous constituents, contaminated run-off or hazardous waste decomposition products to ground or surface waters or to the atmosphere; and • complies with closure requirements of 40 *CFR* 264.178.	Management of RCRA hazardous waste in containers – **applicable**	40 *CFR* 264.111 TDEC 1200-1-11-.06(7)(b)
	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.		40 *CFR* 264.178 TDEC 1200-1-11-.06(9)(i)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
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 groundwater monitoring well(s)	Shall be accomplished by a licensed driller	Permanent plugging and abandonment of a well – **relevant and appropriate**	TDEC 1200-4-9-.16(2)
	Shall be completely filled and sealed in such a manner that vertical movement of fluid either into or between formation(s) containing underground source of drinking water through the bore hole is not allowed.		TDEC 1200-4-6-.09(6)(d)
	Shall be performed in accordance with the provisions for Seals at TDEC 1200-4-6-.09(6)(e), (f), and (g), for Fill Materials at 1200-4-6-.09(6)(h) and (i), for Temporary Bridges at 1200- 4--6-.09(6)(j), for Placement of Sealing Materials at 1200-4- 6-.09(7)(a) and (b), and Special Conditions at 1200-4-6- .09(8)(a) and (b), as appropriate.		
Postclosure Care			
Post-closure plan	Must have a written post-closure plan which identifies planned monitoring activities and frequency at which they will be performed for groundwater monitoring, containment systems and cap maintenance.	Closure of a RCRA landfill – **applicable**	40 C*FR* 264.118 TDEC 1200-1-11-.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.	Closure of a RCRA landfill – **applicable**	40 *CFR* 264.119(a) TDEC 1200-1-11-.06(7)(j)
	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 .	Closure of a RCRA landfill – **applicable**	40 *CFR* 264.119(b) TDEC 1200-1-11-.06(7)(j)(2)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
Survey plat	Must submit to the local zoning authority or the authority with jurisdiction over local land use, a survey plot applicable 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 1200-1-11-.06(7)(g)
	Within 60 days of closure 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 that:	Closure of an asbestos containing waste disposal site – **applicable**	40 *CFR* 61.151(e)
	• the land has been used for disposal of asbestos-containing waste; • survey plat and record of location and quantity of waste disposed within the site required in 40 *CFR* 61.154(f) have been filed; and • the site is subject to 40 *CFR* Part 61 subpart M.		

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
Duration	Postclosure 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 1200-1-11-.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.	Closure of a RCRA landfill – **applicable**	40 *CFR* 264.117(c) TDEC 1200-1-11-.06(7)(h)(3)
General post-closure care	Owner or operator must:	Closure of a RCRA landfill – **applicable**	40 *CFR* 264.310(b) TDEC 1200-1-11-.06(14)(k)
	• maintain the effectiveness and integrity of the final cover including making repairs to the cap as necessary to correct effects of settling, erosion, etc.;		40 *CFR* 264.310(b)(1) TDEC 1200-1-11-.06(14)(k)(2)(i)
	• continue to operate the leachate collection and removal system until leachate is no longer detected;		40 *CFR* 264.310(b)(2) TDEC 1200-1-11-.06(14)(k)(2) (ii)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	• 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);		40 *CFR* 264.310(b)(3) TDEC 1200-1-11-.06(14)(k)(2) (iii)
	• maintain and monitor a groundwater monitoring system and comply with all other applicable provisions 40 *CFR* 264, Subpart F;		40 *CFR* 264.310(b)(4) TDEC 1200-1-11-.06(14)(k)(2) (iv)
	• prevent run-on and run-off from eroding or otherwise damaging final cover; and		40 *CFR* 264.310(b)(5) TDEC 1200-1-11-.06(14)(k)(2) (v)
	• protect and maintain surveyed benchmarks used to locate waste cells.		40 *CFR* 264.310(B)(6) TDEC 1200-1-11-.06(14)(k)(2) (vi)
Operation of leachate collection system	Must record the amount of liquids removed from the leak detection system at least monthly after the final cover is installed and thereafter as specified in 40 *CFR* 264.303(c)(2).	Closure of a RCRA landfill – **applicable**	40 *CFR* 264.303(c)(2) TDEC 1200-1-11-.06(14)(d)(3) (ii)
	Shall be monitored monthly for quantity and physicochemical characteristics of leachate produced.	Operation of a TSCA chemical waste landfill – **applicable**	40 *CFR* 761.75(b)(7)
	Water analysis shall be conducted as provided in 40 *CFR* 761.75(b)(6)(iii)(see above).		
	The leachate should be either treated to acceptable limits for discharge or disposed of by another approved method.		

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
General groundwater monitoring requirements	The groundwater monitoring system must consist of a sufficient number of wells, installed at appropriate locations and depths to yield groundwater samples from the uppermost aquifer that:	Operation of a detection monitoring program under 40 *CFR* 264.98 – **applicable**	40 *CFR* 264.97(a) TDEC 1200-1-11-.06(6)(h)(1)
	• represent the quality of background groundwater; • represent the quality of groundwater passing the point of compliance; and • allows for the detection of contamination when the hazardous waste or constituents have migrated from the waste management area to the uppermost aquifer.		
	If underlying earth materials are homogenous, impermeable, and uniformly sloping in one direction, only three sampling points shall be necessary.	Operation of TSCA chemical waste landfill groundwater monitoring program – **applicable**	40 *CFR* 761.75(b)(6)(ii)(A)
	These three points shall be equally spaced on a line through the center of the disposal area and extending from the area of highest water table elevation to the area of the lowest water table elevation.		
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 groundwater samples. The annular space above the sampling depth must be sealed to prevent contamination of groundwater and samples.	Construction of RCRA groundwater monitoring well – **applicable**	40 *CFR* 264.97(c) TDEC 1200-1-11-.06(6)(h)(3)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	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 storm water runoff.	Construction of a TSCA groundwater monitoring well – **applicable**	40 *CFR* 761.75(b)(6)(ii)(B)
Monitoring program	Groundwater monitoring program must include consistent sampling and analysis procedures that are designed to ensure monitoring results that provide a reliable indication of groundwater quality below the waste management area.	Operation of a detection monitoring program under 40 *CFR* 264.98 – **applicable**	40 *CFR* 264.97(d) TDEC 1200-1 -11-.06(6)(h)(4)
	Groundwater monitoring program must include sampling and analytical methods that are appropriate and accurately measure hazardous constituents in groundwater samples.	Operation of a detection monitoring program under 40 *CFR* 264.98 – **applicable**	40 *CFR* 264.97(e) TDEC 1200-1-11-.06(6)(h)(5)
	Groundwater monitoring program must include a determination of the groundwater surface elevation each time groundwater is sampled.	Operation of a detection monitoring program under 40 *CFR* 264.98 – **applicable**	40 *CFR* 264.97(f) TDEC 1200-1-11-.06(6)(h)(6)
Sample collection	The number and size of samples collected to establish background and measure groundwater quality at the point-of-compliance shall be appropriate for the form of statistical test employed following generally accepted statistical principles and otherwise comply with the provisions of this section.	Operation of a detection monitoring program under 40 *CFR* 264.98 – **applicable**	40 *CFR* 264.97(g) TDEC 1200-1-11-.06(6)(h)(7)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	The groundwater 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. As a minimum, all samples shall be analyzed for the following parameters: • PCBs • pH • specific conductance • chlorinated organics Sampling methods and analytical procedures for these parameters shall comply with those specified in 40 CFR Part 136, as amended in 41 Federal Register 52779 on December 1, 1976.	Operation of TSCA groundwater monitoring wells – **applicable**	40 *CFR* 761.75(b)(6)(ii)(B)
Detection monitoring	Owners or Operators of hazardous waste facilities must monitor for specified indicator parameters, waste constituents or reaction products that provide a reliable indication of the presence of hazardous constituents in groundwater.	Operation of a detection monitoring program under 40 *CFR* 264.98 – **applicable**	40 *CFR* 264.98(a) TDEC 1200-1-11-.06(6)(i)
	Must install a groundwater monitoring system at the compliance point as specified under 40 *CFR* 264.95 that complies with 264.97(a)(2), (b), and (c).		40 *CFR* 264.98(b) TDEC 1200-1-11-.06(6)(i)(2)
	Must conduct a monitoring program for each specified chemical parameter and hazardous constituent in accordance with 264.97(g).		40 *CFR* 264.98(c) TDEC 1200-1-11-.06(6)(i)(3)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
	A sequence of at least four samples from each well (background and compliance wells) must be collected at specified frequencies.		40 *CFR* 264.98(d) TDEC 1200-1-11-.06(6)(i)(4)
	Must determine the groundwater flow rate and direction in the uppermost aquifer at least annually.		40 *CFR* 264.98(e) TDEC 1200-1-11-.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 1200-1-11-.06(6)(i)(6)
	If owner/operator determines that there is statistically significant evidence of contamination at any monitoring well at the compliance point, must follow the provisions of this section.		40 *CFR* 264.98(g) TDEC 1200-1-11-.06(6)(i)(7)
Corrective measures for LLW disposal facility	Must have plans for taking corrective measures if migration of radionuclides would indicate that the performance objectives of Rules of the TDEC 1200-2-11-.16 may not be met.	Closure of an LLW landfill – **relevant and appropriate**	TDEC 1200-2-11-.17(4)(b)

Table E-3. Action-specific ARARs and TBC Guidance for the On-site Disposal Alternative (Continued)

Action	Requirements	Prerequisite	Citation(s)
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.	Closure of an LLW landfill – **relevant and appropriate**	TDEC 1200-2-11-.17(4)(d)
	The monitoring system must be capable of providing early warning of releases of radionuclides from the disposal unit before they leave the site boundary.		
Waste left in place	Institutional controls are required and shall include, at a minimum, administrative restrictions for sale and use of property and securing area to prevent human contact with hazardous substances.	Hazardous substances left in place that might pose an unreasonable threat to public health, safety, or the environment **– relevant and appropriate**	TDEC 1200-1-13-.08(10)
Off-site Transportation and Disposal- See Table E-4			

ALARA = as low as reasonably achievable
ARAR = applicable or relevant and appropriate requirement
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR = Code of Federal Regulation
DOE = U.S. Department of Energy
DOE M = DOE Manual
DOE O = DOE Order
DOT = U.S. Department of Transportation
EDE = effective dose equivalent
EMWMF = Environmental Management Waste Management Facility
EPA = U.S. Environmental Protection Agency
HMR = Hazardous Materials Regulations
HMTA = Hazardous Materials Transportation Act of 1975
ID = identification number
LLW = low-level (radioactive) waste
mrem = millirem
mSv = millisievert
ORO = Oak Ridge Operations
ORR = Oak Ridge Reservation
PCB = polychlorinated biphenyl
PPE = personal protective equipment
RCRA = Resource Conservation and Recovery Act of 1976
ROD = record of decision
TBC = to be considered
TDEC = Tennessee Department of Environment and Conservation
TSCA = Toxic Substances Control Act of 1976
WAC =waste acceptance criteria

Table E–4. Action-specific ARARs and TBC Guidance for the Off-Site Disposal Alternative

Medium/Action	Requirements	Prerequisite/Condition	Citation(s)
Transportation of hazardous materials	Hazardous material transport 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 radioactive waste	LLW shall be packaged and transported in accordance with DOE O 460.1A and DOE O 460.2.	Shipment of LLW off-site – **TBC**	DOE M 435.1-(I)(1)(E)(11)
Transportation of LLW	To the extent practical, the volume of LLW and the number of the shipments shall be minimized.	Shipment of LLW off-site – **TBC**	DOE M 435.1-1(IV)(L)(2); DOE M 435.1-1(III)(L)(2)
Transportation of PCB wastes	PCB waste transport must comply with the manifesting provisions at 40 *CFR* 761.207 through 40 *CFR* 761.218.	Relinquishment of control over PCB wastes by transporting or offering for transport – **applicable**	40 *CFR* 761.207 (a)
Transportation of hazardous waste off-site	RCRA hazardous waste transport 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. 262.40, 262.41(a) for record keeping, and Sect. 262.12 to obtain EPA ID number.	Off-site transportation of RCRA hazardous waste – **applicable**	40 *CFR* 262.10(h); TDEC 1200-1-11-.03(1)(a)(8)
	Must comply with the requirements of 40 *CFR* 263.11–263.31. A transporter who meets all applicable requirements of 49 *CFR* 171–179 and 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); TDEC 1200-1-11-.04(1)(a)(1)

Table E-4. Action-specific ARARs and TBC Guidance for the Off-Site Disposal Alternative (Continued)

Medium/Action	Requirements	Prerequisite/Condition	Citation(s)
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) TDEC 1200-1-11-.03(a)(6)
Transportation of LLW off site	LLW waste shall be packaged and transported in accordance with DOE O 1460. 1A and DOE O 460.2.	Shipment of LLW off site – **TBC**	DOE M 435.1-1(1)(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)
	Authorized limits shall be consistent with limits and guidelines established by other applicable Federal and State laws.		
Transportation to disposal facility	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; DOE O 460.1 **(TBC)**
	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
	Must be marked with hazardous waste marking, generator's name and address, and the manifest docket number.	Transportation of hazardous waste in containers of 110 gal or less – **applicable**	40 *CFR* 262.32(b)
	Shipment must be manifested according to 40 *CFR* 262 and 40 *CFR* 263.	Transportation of hazardous waste for off-site TSD – **applicable**	40 *CFR* 262 Subpart B; 40 *CFR* 263 Subpart B
	Generators must certify before the shipment that the waste meets the waste acceptance criteria of the receiving facility.	Waste shipped from one field organization to another for disposal – **TBC**	DOE O 435.1

Table E-4. Action-specific ARARs and TBC Guidance for the Off-Site Disposal Alternative (Continued)

Medium/Action	Requirements	Prerequisite/Condition	Citation(s)
	LLW must be disposed of on-site; if off-site disposal is required due to lack of capacity, disposal must be to a DOE facility.	Shipments of LLW – **TBC**	DOE O 435.1
	Off-site disposal of LLW to a commercial facility requires an exemption from the on-site disposal requirements of DOE O 435.1; requests for exemption must be approved by the DOE ORO Field Office. Must meet DOE Order and Implementing procedural requirements for off-site shipments.	Shipments of LLW – TBC	DOE M 435.1-1(I)(2)(F)(4)

ALARA = as low as reasonably achievable
ARAR = applicable or relevant and appropriate requirement
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR = *Code of Federal Regulations*
CWA = Clean Water Act of 1972
DOE = U.S. Department of Energy
DOE = U.S. Department of Transportation
gal = gallon
LLW = low-level (radioactive) waste
EDE = effective dose equivalent
FS = Feasibility Study
mrem = millirem
NPDES = National Pollution Discharge Elimination System
ORO = Oak Ridge Office
ORR = Oak Ridge Reservation
RI = Remedial Investigation
ROD = record of decision
TBC = to be considered
TDEC = Tennessee Department of Environment and Conservation

8. REFERENCES

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APPENDIX F

ON-SITE DISPOSAL FACILITY PRELIMINARY WASTE ACCEPTANCE CRITERIA

CONTENTS

FIGURES

TABLES

ACRONYMS

ASA	Auditable Safety Analysis
BCV	Bear Creek Valley
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
COC	contaminant of concern
DF	dilution factor
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
EU	Equivalent Uptake
FFA	Federal Facility Agreement
FML	flexible membrane layer
HDPE	high-density polyethylene
HELP	Hydrologic Evaluation of Landfill Performance
HI	hazard index
K_d	solid-to-liquid partition coefficient
LLW	low-level (radioactive) waste
MOC	Method of Characteristic
MSL	mean sea level
NRC	Nuclear Regulatory Commission
NT	Northern Tributary
ORR	Oak Ridge Reservation
PWAC	Preliminary Waste Acceptance Criteria
RCRA	Resource Conservation and Recovery Act of 1976
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
SOF	sum of fractions
TMR	telescopic mesh refinement
U.S.	United States
UBCV	Upper Bear Creek Valley
USGS	U.S. Geological Survey
VWSOF	volume weighted sum of fractions
WAC	waste acceptance criteria

1. INTRODUCTION

The purpose of this Appendix is to develop analytic Preliminary Waste Acceptance criteria (PWAC) to meet applicable risk and dose criteria using fate and transport analysis for a potential new Environmental Management Disposal Facility (EMDF). This analysis provides the basis for demonstrating that the On-site Disposal Alternative would be protective of human health and the environment, meet remedial action objectives, and be a viable disposal option for most future Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) waste.

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/Feasibility Study (RI/FS) evaluates a proposed EMDF site in East Bear Creek Valley (EBCV) for disposal of future CERCLA waste after the Environmental Management Waste Management Facility (EMWMF) reaches maximum capacity. The proposed EMDF site is located adjacent and east of the current EMWMF site and has similar engineering design and hydrogeologic attributes.

1.1 WAC COMPONENTS

Radiological and chemical releases from wastes disposed in the proposed EMDF and the potential risks to the public from such releases would be mitigated by disposal cell design and hydrogeologic attributes. A previously negotiated waste acceptance criteria (WAC) attainment process for the EMWMF involves the completion of four separate sets of requirements (DOE 2001a):

- Administrative WAC were derived from applicable or relevant and appropriate requirements in the EMWMF Record of Decision (ROD) (DOE 1999), and from other agreements between the DOE, the U.S. Environmental Protection Agency (EPA), and the Tennessee Department of Environment and Conservation.
- Analytic WAC were derived from the approved risk assessment model in the EMWMF RI/FS and RI/FS Addendum (DOE 1998a, DOE 1998b) for the EMWMF.
- Auditable Safety Analysis (ASA)-derived WAC were derived from facility authorization basis documentation for the EMWMF.
- Physical WAC were derived from operational constraints and contractual agreements for EMWMF operations.

The administrative WAC includes limits on disposal of greater than Class C waste and compliance with Resource Conservation and Recovery Act of 1976 (RCRA) land disposal restrictions. The administrative WAC also prohibits disposal of transuranic waste, high-level waste, spent nuclear fuel, or 11e(2) byproduct waste, and places limits on total uranium concentrations in waste separate from and in addition to analytic WAC considerations.

The ASA-derived WAC limits disposal of radionuclide based on a maximum credible release of material that would occur during an extreme wind event at the operating facility. These limits are also separate from and in addition to analytic WAC considerations.

The focus of this Appendix is the risk-based analytic PWAC for the proposed EMDF. The analytic PWAC are numerical limits developed by applying fate and transport analysis using conceptual design elements of the EMDF and risk/dose analytical approaches. As described in the WAC Attainment Plan for EMWMF (DOE/OR/01-1909&D3), the analytic WAC is the numerical concentration of a constituent in a given waste lot such that, if the waste form with this concentration occupied the entire disposal cell volume, risk or hazard index (HI) to a public receptor would be equal to specified criteria. However, it is unlikely that a single waste type will occupy the entire facility. Rather, the disposal cell will ultimately contain many waste forms, each having a specific volume of radiological and chemical contaminants. To accommodate these different waste forms, an approach to apply the contaminant-specific WAC to various waste streams was developed for the EMWMF. The sum of fractions (SOF) calculation method is used to determine whether a waste containing multiple contaminants is acceptable for disposal. The SOF calculations are specific to a single waste lot. The volume weighted sum of fractions (VWSOF) calculation method is used to account for the fact that not all waste lots will contain the same volume of waste.

The four separate WAC components and compliance process for the EMWMF are the product of formal negotiations between the Federal Facility Agreement (FFA) parties during the pre-ROD and post-ROD stages of the CERCLA process. At the RI/FS stage for a potential new facility, it is early in the conceptual design and decision making process to determine what final WAC components will be agreed to by the FFA parties. It is assumed at this stage that a similar WAC approval process would be followed for a potential new facility. It is also assumed that administrative, ASA-derived, and physical WAC components for the new facility and the WAC compliance approach, including the SOF and VWSOF calculations methodology, for the new facility would be similar to the WAC components and compliance approach for EMWMF.

The analytic PWAC would be finalized as the design for the disposal facility proceeds and final design parameters, site layout, and additional site-specific characterization data are available. It is acknowledged that the analytic PWAC results presented in this Appendix are a preliminary data set. The analytic PWAC were developed to show protectiveness and viability of land disposal at the proposed site. If on-site disposal is the selected remedy as determined by the CERCLA process, final WAC (administrative, analytic, ASA-derived, and physical) would be approved for a new facility at the selected site prior to waste receipt. The final WAC approved by the FFA parties may be similar to the WAC approved for EMWMF.

The site conceptual model and exposure pathways are discussed in Chapter 2. Preliminary WAC development and applied models are summarized in Chapter 3. Chapter 4 describes site-specific model development for the proposed EMDF site. Risk/dose modeling and calculations are discussed in Chapter 5. Chapter 6 provides analytic PWAC calculations and results and a discussion of results relative to the EMWMF WAC. Chapter 7 lists references used in the analysis. Attachment A provides supplemental modeling information.

2. SITE CONCEPTUAL MODEL AND RISK EXPOSURE PATHWAYS

The proposed EMDF would be an on-site, low-level (radioactive) 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 sites and demolition of contaminated buildings from CERCLA cleanup projects. The proposed EMDF has a conceptual design capacity of 2.5 million yd^3. Figure F-1 illustrates the site plan of the proposed EMDF.

The conceptual design of the EMDF is described in Sect. 6.2 of this RI/FS and site characteristics are described in Appendix C. Summary information about the proposed site characteristics, site conceptual model and risk exposure pathway, and receptor and risk criteria is provided below.

2.1 PROPOSED EMDF SITE DESCRIPTION

The EMDF site is located in EBCV on the ORR. The EMDF site lies on the southern slopes of Pine Ridge between Bear Creek Northern Tributary (NT)-2 and NT-3. 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 to 1,260 ft above mean sea level (MSL). The elevation of the Bear Creek Valley (BCV) floor ranges from about 940 to 1,000 ft-MSL.

The stratigraphic section exposed in BCV includes rocks ranging in age from Early Cambrian to Early Mississippian. 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 site geology is provided in Appendix C.

The early Cambrian Rome Formation, which is the oldest unit exposed in the site area, outcrops on the ridge top of Pine Ridge and dips 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 the BCV, the Conasauga Group is subdivided into six formations: Pumpkin Valley, Rutledge, Rogersville, Maryville, Nolichucky, and Maynardville. The Maynardville Formation, composed mostly of limestone, underlies the valley floor. The Knox Group of late Cambrian is composed primarily of massive, siliceous dolomite that forms the Chestnut Ridge on the south side of BCV.

Small-scale geologic features, such as fractures and solution features are a major factor in groundwater movement through the formations underlying the BCV. These bedrock features provide the pathways for groundwater flow through geologic formations, such as shales and limestones, that typically have little intrinsic permeability. Fractures are well developed in all stratigraphic units as a result of tectonic activity and geostatic relief, and are the most pervasive groundwater-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 hydraulic and dominant strike-parallel groundwater flow paths. Fracture aperture width and frequency generally decrease with depth in all formations and thus restrict the depth of active groundwater circulation. The unconsolidated materials, or regolith, overlying bedrock in the EBCV site include a mixture of residuum and bedrock remnants and weathered bedrock saprolite.

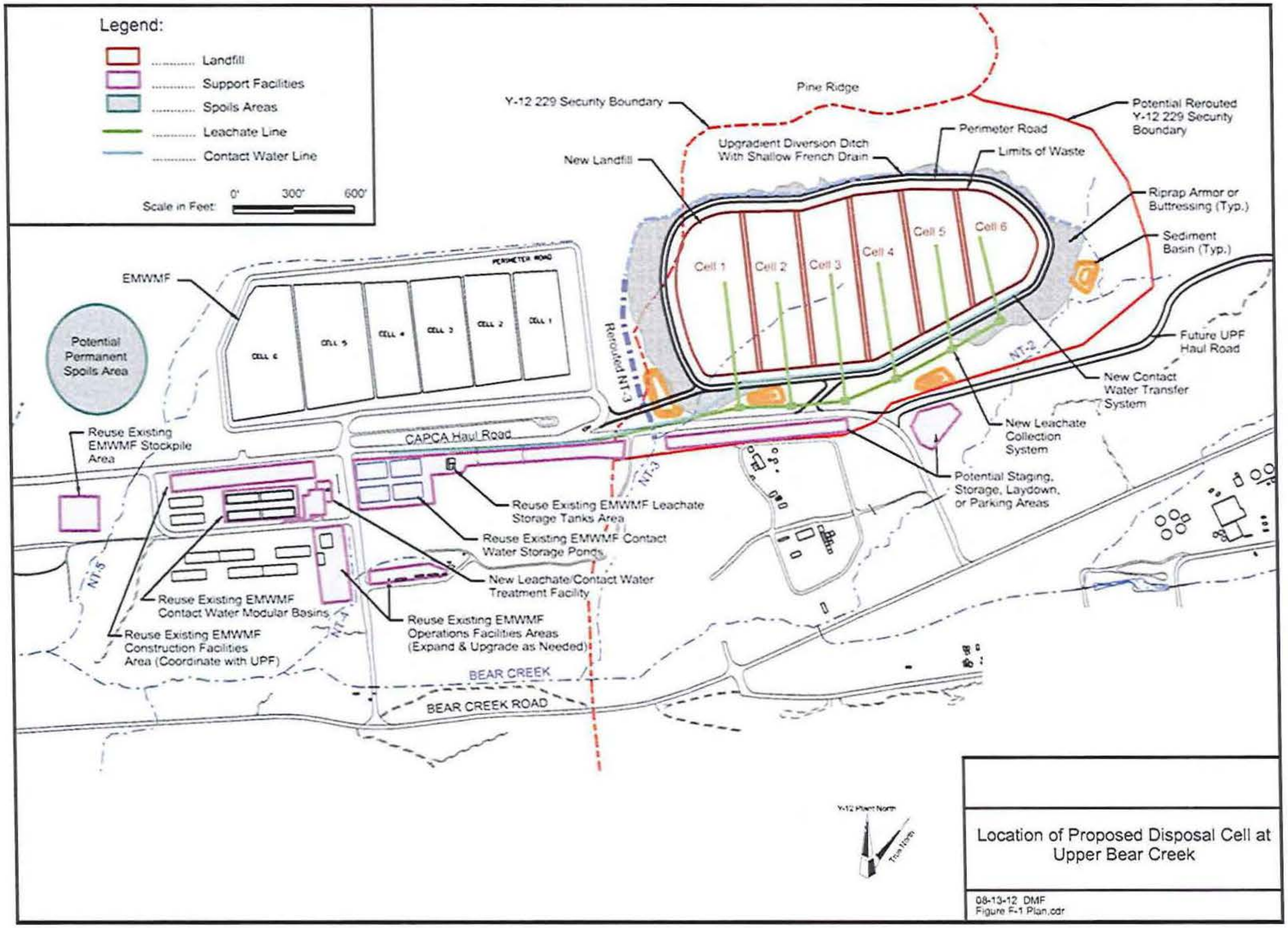


Figure F-1. Location of the Proposed EMDF Cell at Upper Bear Creek

Within BCV, the majority of groundwater flow occurs primarily within the upper 100 ft of the aquifer system (Solomon et al. 1992). The occurrence and movement of groundwater in the bedrock is closely related to the presence of bedding planes, joints, fractures, and solution cavities. In general, groundwater in the bedrock occurs under water-table conditions but becomes increasingly confined with depth. Downward recharge to the groundwater system occurs along the flanks of Pine Ridge and Chestnut Ridge.

BCV hydrogeologic units behave as an anisotropic system in all three dimensions, evidenced by the elongated drawdown along strike direction observed during pumping tests and the spatial distribution of contaminant plumes. The anisotropic nature of hydraulic conductivity associated with the bedrock underlying BCV is apparently caused by the orientation and intersection of fractures, joints, and/or bedding planes. Due to this anisotropy, groundwater flow is primarily along strike (i.e., east to west). Due to the along-strike flow directions, a large portion of the shallow groundwater discharges into the tributaries and eventually flows into Bear Creek.

Bear Creek flows southwestward from its headwaters for approximately 4.5 miles along the BCV axis, and then turns northward to flow into East Fork Poplar Creek by cutting through Pine Ridge. The drainage area of BCV is approximately 5.2 mi^2 (Robinson and Johnson 1995). Most of the tributaries of Bear Creek originate along the flanks of the Pine Ridge.

2.2 CONCEPTUAL SITE MODEL AND RISK EXPOSURE PATHWAY

Development of a conceptual site model of the site is necessary prior to evaluating the likely impact of potential contaminants that might emanate from the EMDF. A conceptual site model identifies the key elements of fate and transport, which include the media that the contaminants may move through and the receptor that could become exposed to such contaminants. In this application, the conceptual site model is a continuum flow model, meaning that flow occurs in pore, fractures, and conduits, but that at the scale of the model, these can be considered as one system, similar to a porous medium, such as sandstone. While a conceptual site model, in general, is a simplification of the fate and transport processes, it provides a visualization and general understanding that are used to develop the WAC modeling processes. See Section 3.5 of Appendix C for additional information about the conceptual site model.

Figure F-2 shows the conceptual disposal cell leachate movement and groundwater flow characteristics at the area. Exposure pathways include the migration of contaminants in groundwater and surface water from the disposal facility after the cap and liner systems have experienced some degree of failure, allowing water to percolate through the landfill. After the closure of the disposal cell and degradation of the synthetic components of the disposal cell, water is able to infiltrate the waste and leach contaminants from the wastes. Contaminants would then migrate vertically through the unsaturated zone and into the groundwater zone where they would be transported to a nearby well or discharged to surface water. Most of the groundwater flow occurs in the upper part of the soil and bedrock system and mostly discharges into surface water bodies of Bear Creek and its tributaries, as well as in conduits in the Maynardville Limestone. The modeling process calculates the risks related to exposure to contaminants for a defined hypothetical receptor. Groundwater 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. Development of the analytic PWAC is based on an evaluation of this likely exposure pathway. The location of the hypothetical receptor for the proposed EMDF used to define exposure assumptions is analogous to that used for the EMWMF analytic WAC modeling.

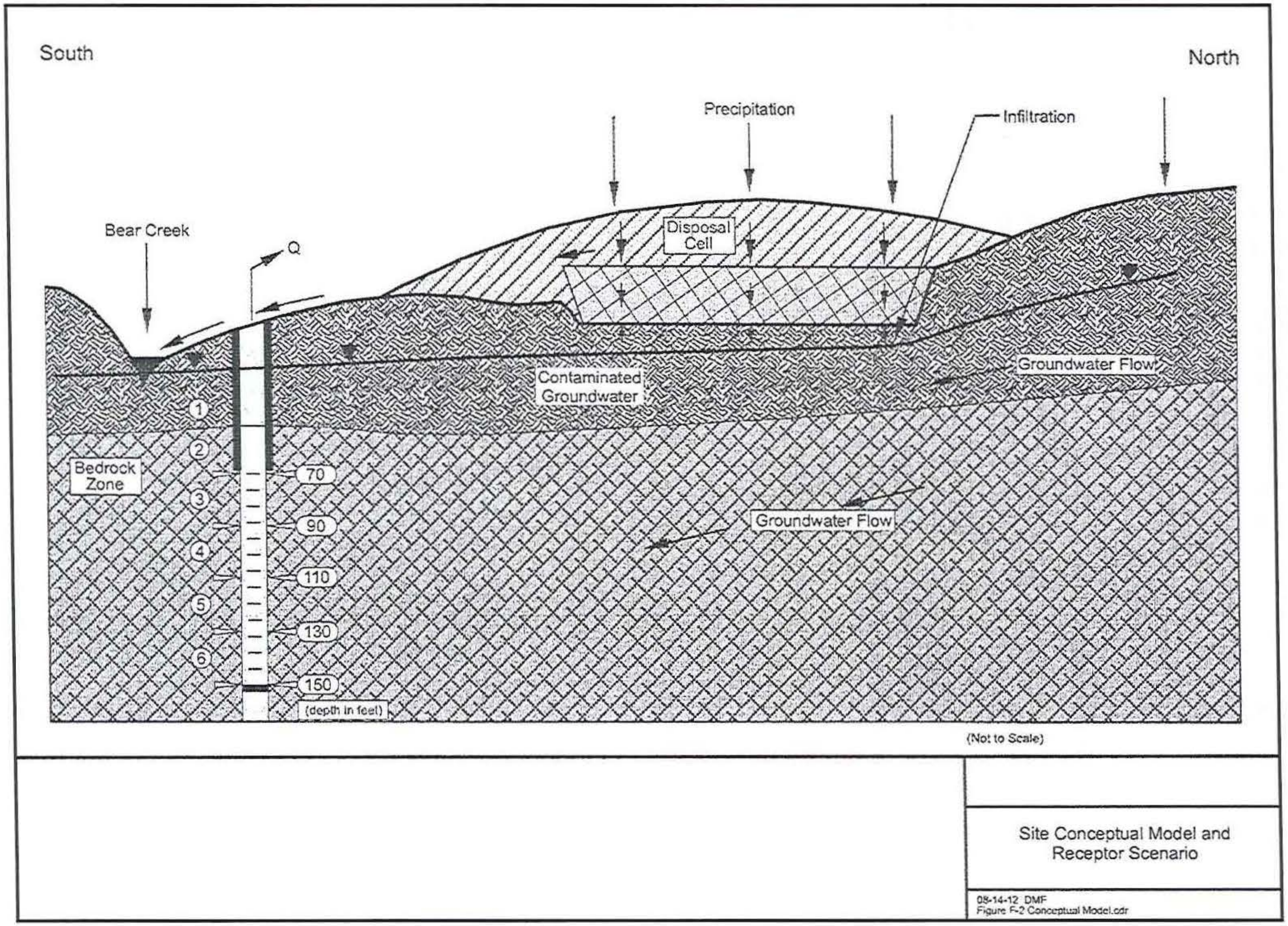


Figure F-2. Conceptual Site Model and Receptor Scenario

DOE would provide long-term care of the facility (institutional controls) such that an inadvertent intruder (e.g., someone digging into and being directly exposed to the waste after landfill closure) is not a likely risk exposure pathway. However, if it is assumed that institutional controls are lost in the future, inadvertent intruder scenarios are not considered plausible based on the conceptual design aspects of the disposal facility, including the biointrusion layer and the cap thickness. The 13-ft multi-layer cap system described in Sect. 6.2.2.4 of the RI/FS includes a 3-ft thick biointrusion layer of free-draining, coarse granular material (i.e., 4-in. to 12-in. diameter riprap) to inhibit penetration by humans, burrowing animals, and plants.

2.3 RECEPTOR AND RISK CRITERIA

For the proposed EMDF, concentration-based "analytic" PWAC were developed assuming a hypothetical resident farmer receptor. The resident farmer is assumed to live between the EMDF and Bear Creek (in the downgradient direction of general groundwater flow and discharge). The hypothetic farmer uses groundwater 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 and regulations in Tennessee, the upper, more active, weathered bedrock zone would not be used for domestic water supplies. The shallow portion of the well is cased and the well is screened in the unweathered fractured bedrock as shown in Figure F-2.

The contaminant leaching/transport analysis and exposure conceptual model is presented in Figure F-3. For the rural residential farmer there is a potential for exposure to contaminated media through the following pathways:

- Ingestion of contaminated water
- Consumption of home-grown vegetables/fruits irrigated with contaminated water
- Consumption of milk and meat from livestock fed with vegetation irrigated with the contaminated water

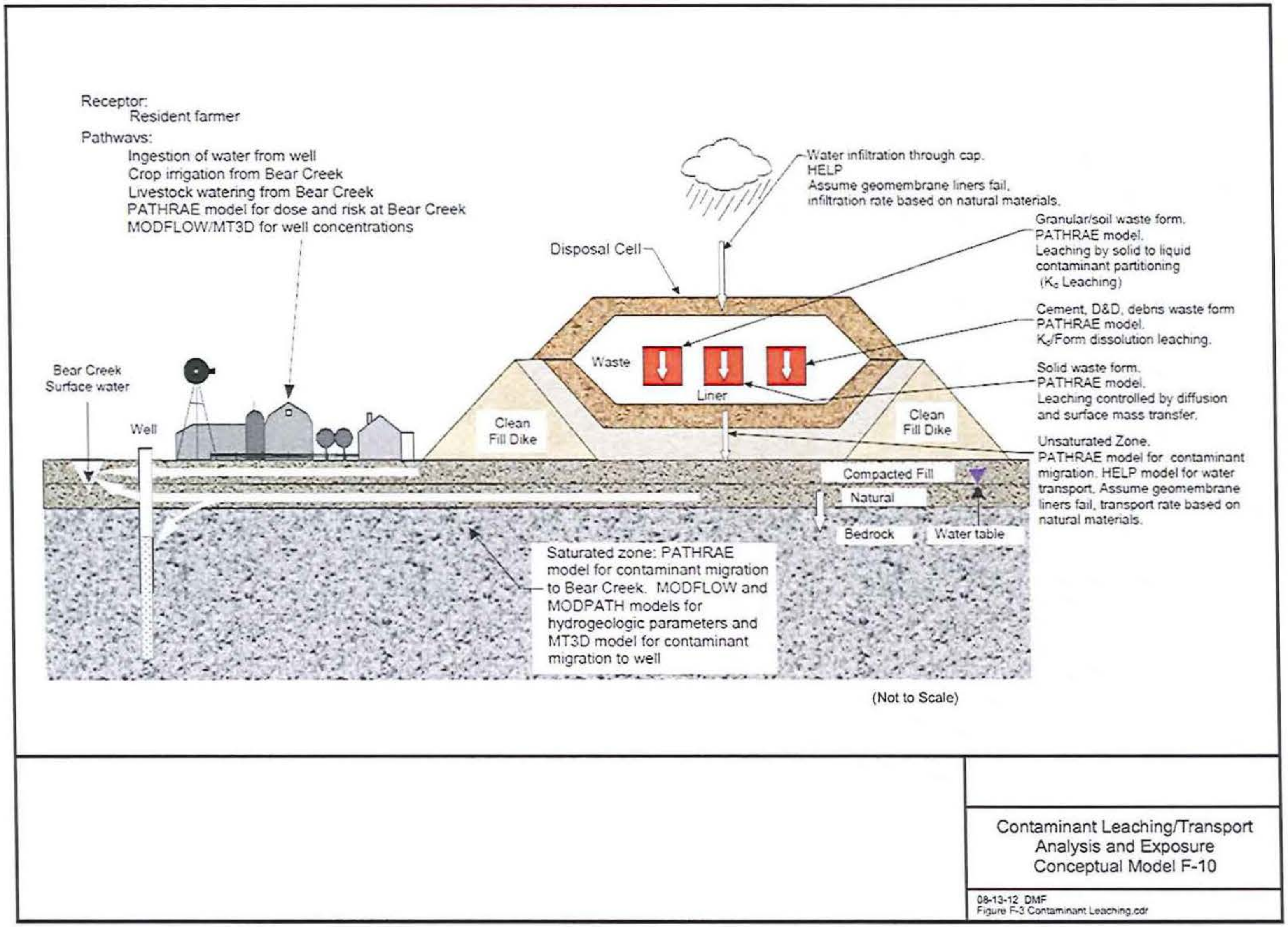


Figure F-3. Contaminant Leaching/Transport Analysis and Exposure Conceptual Model

DOE Order 435.1 (DOE 2001c) requires analysis of low-level waste disposal facilities using a performance-based approach with little to no reliance on engineered controls for a performance period of 1,000 years .

The following risk goals for the aggregate radiological and chemical impacts to the hypothetical receptor from all waste disposed in the proposed EMDF were used for development of the analytic WAC:

- An Excess Lifetime Cancer Risk (ELCR) (carcinogenic risk) $\leq 1 \times 10^{-5}$ and a hazard index (HI)[1] ≤ 1 for the first 1,000 years after closure.
- Carcinogenic risk $\leq 10^{-4}$ and HI ≤ 3 for >1,000 years to 100,000 years after closure.

These risk criteria are the same as those approved for the currently operational EMWMF. The 1,000-year compliance period is consistent with the regulatory timeframe in DOE Order 435.1. For PWAC development presented in this Appendix, peak risks beyond 1,000 years were calculated for uncertainty/sensitivity analyses to evaluate the long-term characteristics of the disposal cell design and performance. However the results of modeling beyond the 1,000-year compliance timeframe are not required by DOE Order 435.1 and are less reliable.

To calculate analytic PWAC, the proposed EMDF was conceptualized as one large waste cell containing a uniform concentration of a single contaminant. Risks were then calculated for this uniform concentration, and analytic PWAC were back-calculated from these derived risks using the appropriate risk goals listed above based upon the time of peak risk and the type of risk being calculated.

[1] The HI is a summation of the hazard quotients for all chemicals to which an individual is exposed. A HI value of 1.0 or less indicates that no adverse human health effects (non-cancer) are expected to occur.

3. PRELIMINARY WAC DEVELOPMENT AND MODELS

Information about the PWAC development steps, modeling, and calculation methods is provided in this Chapter. An overview of the process is described in Sect. 3.1 and a description of the individual models used is provided in Sect. 3.2.

3.1 OVERVIEW OF PWAC DEVELOPMENT

Linkage and application of the contaminant leaching/transport models and steps used to develop the PWAC are depicted in Figure F-4.

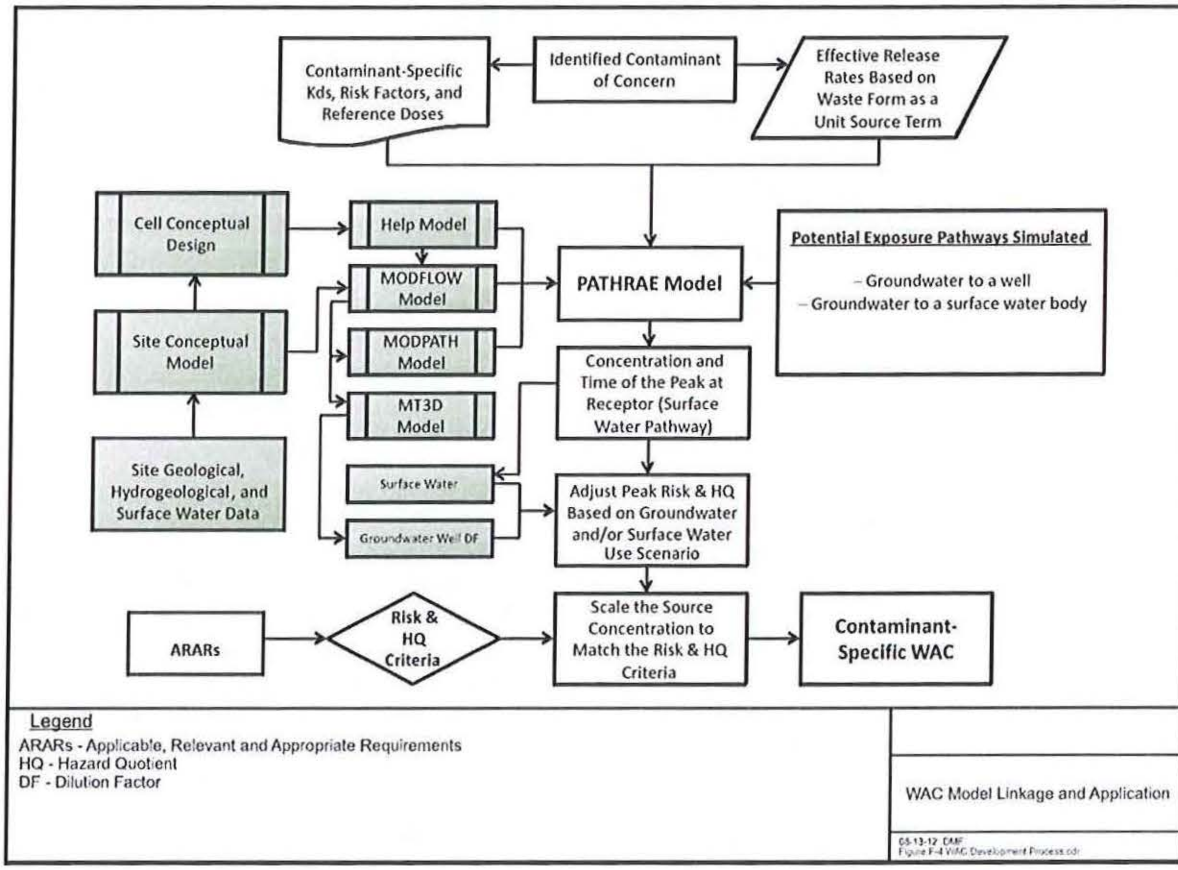


Figure F-4. WAC Model Linkage and Application

The main design and site features, calculations, and models used in these analyses were as follows:

- Determination of water infiltrating the cap, passing through the waste, and entering the vadose zone and groundwater was accomplished by mass balancing analysis of precipitation and evapotranspiration, cap drain removal of water, and hydraulic flow, with the steady-state infiltration rate conservatively taking no credit for man-made cover and liner components. The Hydrologic Evaluation of Landfill Performance (HELP) computer code (Schroeder et al. 1994) was used for these calculations.

- Solid-to-liquid partition coefficient (K_d) values of contaminants from soil were used as input to unsaturated, one-dimensional, time-dependent modeling of source leaching and contaminant transport in the waste and vadose zones to groundwater. The PATHRAE code (Rogers and Associates Engineering 1995a and b) was used for these calculations.
- Groundwater condition and flow characteristics in the disposal cell area and groundwater travel time to tributaries or Bear Creek were evaluated using the three-dimensional, finite difference, time-dependent MODFLOW (McDonald and Harbaugh 1988) and MODPATH (Pollock 1989) models, respectively.
- Discharge of groundwater to tributaries and/or Bear Creek, solute mixing with tributary/stream flow, and contaminant uptake by receptors were calculated using the PATHRAE code. Average surface water flow data were also used for these calculations.
- Groundwater dilution factors (DFs) at the receptor well location relative to source concentrations due to advection process were established using the MT3D model (Zheng 1990). Other processes, such as contaminant specific dispersion, retardation due to absorption, and degradation, were considered during PATHRAE application.
- The PATHRAE results and EPA applicable slope factors were used to calculate risk for a resident farmer (WAC receptor) using contaminated well water for domestic use and contaminated Bear Creek water for agricultural purposes.

To ensure that both carcinogenic risk and HI toxicity goals are met, separate analytic PWAC concentration limits for individual radiological and chemical constituents at the EMDF are calculated. These limits correspond to the maximum permissible concentration of the constituent that could be placed in the facility if the waste containing the single constituent were to occupy the entire disposal cell volume in a soil like matrix.

The PWAC development process used for the proposed EMDF is similar to the process used for EMWMF. The exposure pathway from disposal cell to surface water was analyzed using the PATHRAE-HAZ/RAD analytical model, a revised version of the original risk performance code (PATHRAE-EPA) developed for EPA. In addition to waste volume and waste characteristic data, PATHRAE-HAZ/RAD relies on parameter input from other models, such as HELP for infiltration rate through the landfill, MODFLOW for groundwater flow field, path, and discharge locations and rates, and MODPATH for constituent travel times and paths from specific groundwater entrance points below the cell to receptor locations. The peak contaminant concentration in the well is determined by scaling the concentrations and doses modeled for the surface water using dilution factors. The well dilution factor is the ratio of the concentration of a constituent in the well water to a unit concentration in solute seepage entering the groundwater beneath the disposal facility. The creek dilution factor is calculated using the measured surface water volume and flow rate. The well dilution factor is calculated based on an analysis performed using MODFLOW and MT3D.

The contaminant leaching/transport analysis and exposure conceptual models are depicted in Figure F-3. The contaminant movement includes the following processes:

- Infiltration of water into the waste cell
- Leaching of contaminants from the waste disposed into the underlying groundwater zone
- Transport of contamination from the site to the receptor well and discharge to surface water bodies
- Subsequent uptake by the hypothetical receptor via applicable groundwater and surface water exposure route

3.2 MODELS USED TO SUPPORT PWAC DEVELOPMENT

The relevant HELP, MODFLOW/MODPATH MT3D, and PATHRAE-HAZ/RAD models are described in following sections.

3.2.1 Hydrologic Evaluation of Landfill Performance Model

The HELP model (Schroeder et al., 1994) is used to evaluate the water budget for the proposed EMDF and estimate infiltration rates to groundwater. This information is needed for groundwater flow and fate and transport modeling as the precursor to risk/dose analysis using PATHRAE-HAZ/RAD and groundwater 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, unsaturated vertical drainage, and leakage through soil, geomembrane, or composite liners. These input data are described in Sect. 2 of Attachment A 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 help hazardous waste landfill designers and regulators evaluate 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 (McDonald and Harbaugh 1988) and MODPATH (Pollock 1989) are used to evaluate the hydrogeologic conditions and parameters at the proposed waste disposal site. The parameters estimated include groundwater flow path, travel time, groundwater velocity, and flux rate.

MODFLOW is a modular, block-centered finite-difference groundwater flow code developed by the U.S. Geological Survey (USGS). MODFLOW is capable of simulating both transient and steady-state saturated groundwater 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 towards wells, and groundwater into and 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 presentation of hydraulic properties within the MODLFOW also provides flexibility to present fracture orientation and distribution. This approach is acceptable for BCV given the large scale of the model domain, the highly fractured nature of the hydrostratigraphic units, and the degree of accuracy that is required to support the WAC analysis.

MODFLOW is widely used by the industrial, scientific, and governmental communities. The code has been rigorously tested and verified, and varieties of software tools are publicly available for graphical preprocessing and post processing. Various MODFLOW models have been developed for Oak Ridge area and used extensively for the BCV RI/FS and EMWMF modeling and performance evaluation (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 various receptors outside of the waste disposal site in groundwater is simulated by using MT3D (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, single-species contaminants in complex saturated ground-water systems. MT3D calculates concentration distributions, concentration histories at selected receptor 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 (Rogers and Associates Engineering, 1995a and b), 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 through multiple pathways, of contaminants 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 persons 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 as other pathway analysis codes, such as RESRAD (Yu et al. 1993). A benchmarking comparative study by 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.

PATHRAE-HAZ/RAD can model the movement of contaminants via groundwater to surface water. This movement results from the leaching of contaminants by precipitation that infiltrates through the cap and percolates through the waste. A one-dimensional model of this movement through a uniform medium is used. 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. 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.

Although PATHRAE-HAZ/RAD can also model movement of contaminants to a groundwater well, it uses a simple one-dimensional flow assumption that would not be representative of the complex BCV groundwater flow regime. Therefore, the contaminant movement in the aquifer system is modeled using the MODFLOW and MT3D code.

Some of the PATHRAE-HAZ/RAD input values (such as uptake and intake parameters) used for the proposed EMDF site are generic numbers obtained from literature sources, and some are measured, site-specific values (such as stream flow rates). Some key parameters were calculated using additional models and site-specific information (e.g., water infiltration rates, groundwater transport parameters, and contaminant release rates for various waste forms). Key parameters used in the PATHRAE model are summarized in Table F-1.

Table F-1. Key PATHRAE-HAZ/RAD Parameters

Physical Process	Solution Methodology	Parameters Needed
Rate of water infiltration into the waste cell	HELP model	Site-specific climatic parameters; disposal cell design parameters; vadose zone hydrological parameters
Contaminant release rates from the waste disposal forms to the surrounding backfill soils	K_d leaching mechanisms and waste diffusion processes	Site-specific and generic K_d factors for soils; generic diffusion parameters
Material retardation characteristics (i.e., the ability of a material to retard the movement of contaminants) within and away from the disposal facility	K_d equilibrium mechanisms with backfill soils, vadose zone soils, and saturated media	Site-specific and generic K_d factors for soils and saturated zone media
Groundwater transport characteristics	MODFLOW and MT3D models	Site-specific and generic hydrogeologic parameters
Groundwater interactions with surface water	MODFLOW, MODPATH, and PATHRAE model	Surface water flow parameters and MODFLOW/MODPATH results
Contaminant uptake parameters for the food chain, and the intake rates for human receptors consuming contaminated food and water	PATHRAE model	EPA and Nuclear Regulatory Commission (NRC) literature values

4. DEVELOPMENT OF SITE-SPECIFIC MODELS

Development of a site-specific HELP model, site-specific groundwater flow models, and application of the fate-transport model for the proposed EMDF site are described in the following sections.

4.1 HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE MODEL

The landfill conceptual design and HELP model simulation and results for the proposed EMDF are described below.

4.1.1 Conceptual Design of Disposal Facility

A conceptual design of the proposed on-site waste disposal facility has been developed 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 10 discrete layers incorporated into the cover design and nine layers incorporated into the basal liner design below the waste. 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.

The cell design includes the following key components:

- The total cover thickness is 13 ft and includes a 5-ft vegetation layer (a soil/rock matrix) on its top slope, underlain by a 1-ft drainage layer (graded natural materials such as sand and gravel) and a 3-ft biointrusion layer (larger rocks and boulders). Combined, these 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.
- The cover includes a geomembrane layer over a two-part 2-ft thick low-permeability clay layer. The two-part clay layer is comprised of a 1-ft thick amended clay layer 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 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. For modeling purposes, all waste is conservatively assumed to be soil-like (see Sect. 5.1 of this Appendix).
- The liner system 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 leachate detection system to confirm that the cell liner system is functioning properly and to collect leachate if the primary system fails. These drainage layers will intercept all the water migrating from the waste.

- The liner design has 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 cell. They also help prevent water from intruding into the wastes from beneath the cell. The fully designed and functional landfill system will not allow any precipitation recharging to the groundwater through the waste.

The liner and cover layers of the EMDF conceptual design are illustrated in Figure 6-6 in Chapter 6 of the RI/FS. Table F-2 summarizes the disposal cell layer profile and soil, waste, and geosynthetic material characteristics used in the HELP model.

As described in Sect. 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. A lesson learned from the EMWMF construction is that a similar landfill can be successfully constructed over tributaries in BCV. An underdrain is necessary for the proposed EMDF within the tributary channel to provide a flow path for groundwater immediately below the landfill and prevent upwelling, since tributaries are natural discharge areas for groundwater.

An extensive underdrain system would be required beneath the landfill within a portion of NT-3 and where there are draws/ravines containing springs and seeps. The intent of this underdrain system would be to intercept upwelling groundwater and prevent it from saturating the geologic buffer and liner system. The conceptual layout plan for the underdrain is shown on Figure 6-8 of this RI/FS. 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 groundwater away from the landfill. The upper portion of NT-3 would be diverted to the west of the landfill.

Table F-2. EMDF Design Profile and Material Characteristics

Layer #	Material	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 (%)
1	Top Soil/Rock Mix	1	60	4	0.437	0.105	0.047	1.70E-03		
2	Sand/Gravel	1	12	3	0.457	0.083	0.033	3.10E-03		
3	Biointrusion (rip-rap)	1	36	1	0.417	0.045	0.018	1.00E-02		
4	Drainage	2	12	21	0.397	0.032	0.013	3.00E-01	100	5
5	HDPE (FML)	4	0.06	35				2.00E-13		
6	Amended Compact Clay	3	12	16	0.427	0.418	0.367	3.50E-08		
7	Cover Compacted Clay	1	12	0	0.427	0.418	0.367	1.00E-07		
8	Contour Gravel	1	12	21	0.397	0.320	0.013	3.00E-01		
9	Waste	1	600	22	0.419	0.307	0.18	1.90E-05		
10	Protective Soil	1	12	26	0.445	0.393	0.277	1.90E-06		
11	Drainage (Leachate collection)	2	12	21	0.397	0.032	0.013	3.00E-01	100	2.5
12	HDPE (FML)	4	0.06	35				2.00E-13		
13	Geonet Leak Detection Layer	2	0.3	20	0.85	0.01	0.005	1.00E+01	100	2.5
14	HDPE (FML)	4	0.06	35				2.00E-13		
15	Compacted Clay Layer	3	36	16	0.427	0.418	0.367	1.00E-07		
16	Soil Geobuffer	1	120	26	0.445	0.393	0.277	1.90E-06		

HDPE – high density polyethylene
FML – flexible membrane 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)

4.1.2 Hydrologic Evaluation of Landfill Performance Model Simulations and Results

Performance of the EMDF cell cover/liner system is analyzed using HELP model. The performance of the system will likely undergo three stages after the closure of the EMDF.

- Fully Functional Stage – All layers are assumed to be functional and every aspect of the system performs as designed, including all design features, such as high-density polyethylene (HDPE) liners, leachate collection system, and drainage layers. HELP Model simulation result for infiltration rate to groundwater in this stage is 0.0 in. per year.
- Partially Functional Stage – The HDPE flexible membrane layer (FML) is assumed to be degraded and ineffective. The FML layers would no longer function as impermeable layers in the cover and liner systems. However, the leachate collection and removal system would still be operational. HELP Model simulation result for the infiltration rate in this stage is 0.38 in. per year.
- Long-term Performance Stage – This is a conservative worst-case scenario of the EMDF cell cover/liner system performance. All engineered features (i.e., all synthetic materials) are assumed to be degraded and ineffective. The drainage layers in the liner systems are also assumed to be ineffective due to degradation of the synthetic material and failure of the leachate collection and removal system. As a result, the liner drainage layers would become vertical percolation layers and no water would flow out these drainage layers. The remaining soil materials would maintain their properties. Using this long-term performance scenario, HELP model simulations resulted in an infiltration rate of 0.42 in. per year.

For simplified and conservative consideration, the long-term (worst case) scenario is used to develop the PWAC. This constant long-term infiltration rate is assumed as soon as the disposal cell is closed and used as an input value in subsequent modeling and calculations.

Table F-3 shows the results of HELP Model analysis for the worst case, long-term performance scenario. Section 2 of Attachment A to this Appendix provides additional detail about the HELP model.

Table F-3. HELP Model Predicted Mass Balance and Infiltration Rates for Long-term Performance (Worst Case)

Cell Layer System			Performance – Worst Case	
Cover System	Layer Performance	Top Soil/Rock Mix (5 ft)	YES	
		Sand/Gravel (1 ft)	YES	
		Bio-Intrusion Layer (3 ft Rip-rap)	YES	
		Drainage (1 ft)	YES	
		FML	Degraded	
		Amended Clay	YES	
		Compacted Clay/Contour Gravel	YES	
	Modeled Results		**Mass Balance (in/yr)**	**Mass Balance (%)**
		Precipitation	54.39	100
		Runoff	0.69	1.26
		Evapotranspiration	30.90	56.81
		Drain Collection	22.37	41.13
		Flux Rate into Waste (in/yr)	**0.42**	0.78
Waste Zone				
Liner System	Layer Performance	Soil (1 ft)	YES	
		Leachate Collection Drainage (1 ft)	Not Functional	
		FML	Degraded	
		Leak Detection Drainage Geonet	Degraded	
		FML	Degraded	
		Compacted Clay (3 ft)	YES	
	Modeled Results		**Mass Balance (in/yr)**	**Mass Balance (%)**
		Leachate Drain Collection	not applicable	
		Leak Drain Collection	not applicable	
		Flux Rate through Clay Liner (in/yr)	**0.42**	0.78

FML – flexible membrane liner

4.2 SITE-SPECIFIC GROUNDWATER FLOW MODELS

To develop required key input parameters to support analytic PWAC development and future design of a potential new disposal facility, a site-specific groundwater flow model for the Upper BCV (UBCV) Model has been developed for the proposed EMDF based on the Bear Creek regional groundwater flow model (DOE 1997) and EMWMF models (BJC 2003, DOE 1998b, and 2010).

A telescopic mesh refinement (TMR) modeling approach was used to develop the refined UBCV model from the calibrated BCV flow model constructed by 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. However, further refinements of locations of streams and waste units were made after the site-specific flow model was constructed.

4.2.1 Model Development Procedure

The UBCV model was developed in two stages. The UBCV model representing current site conditions (Year 2012) was the first stage. The current condition model was compared to existing and current site-specific data (such as stream flow and groundwater levels) and model parameters were adjusted to match model results with actual conditions. A sensitivity analysis of the current condition model was also conducted based on field data and the conceptual model. The sensitivity analysis used a strike-parallel linear high hydraulic conductivity zone in the Maynardville Formation to simulate conduit flow.

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 the disposal facility construction and closure.

The construction of the disposal cell site-specific UBCV model consisted of the following steps:

1. Establish model domain and dimension.

   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.

2. Refine for current condition (2012) model.

   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, allow for future EMDF engineering features, and to meet the need for risk/performance evaluation.

   b. The refined and improved parameters used in extensive calibrated EMWMF models were incorporated into the UBCV model.

   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. Create the EMDF (future condition) model.

   The future condition model was used for prediction and to provide required parameters of risk analysis and calculation.

   a. EMDF design and post-closure topography were incorporated into the future condition model to predict the flow condition after disposal cell construction.

   b. Parameters representing the construction/engineered features for the proposed EMDF were incorporated into the future condition model.

   c. Future landfill performance parameters, such as long-term recharge rate through waste zone, were included.

4.2.2 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 S-3 Pond 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 F-5 shows the 2012 topography and UBCV model domain. Figure F-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.

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 current (2012) topography for the current condition model 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 to 25 ft. The bottom of layer three corresponds approximately to the unweathered bedrock surface. Fractured bedrock is represented by layers 4 through 8, each of which are 20-ft thick. Layers 9, 10, and 11 are 150-, 200-, and 300-ft thick, respectively, representing less fractured and less permeable deeper bedrock. Figure F-7 shows the vertical discretization for the model along the two cross sections.

There are a total of 4,540,800 cells in the UBCV Model, of which 3,572,049 are active in groundwater flow.

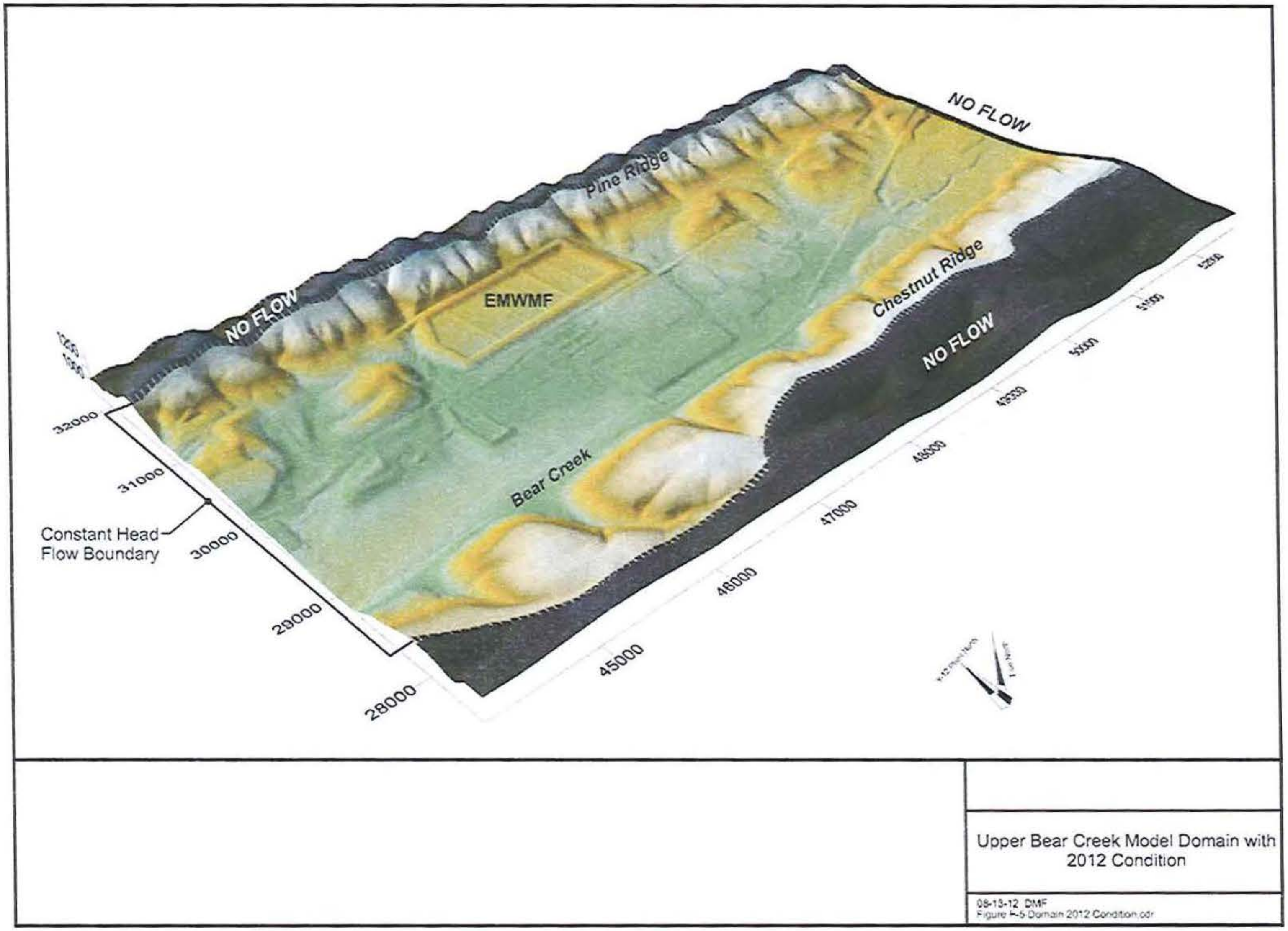
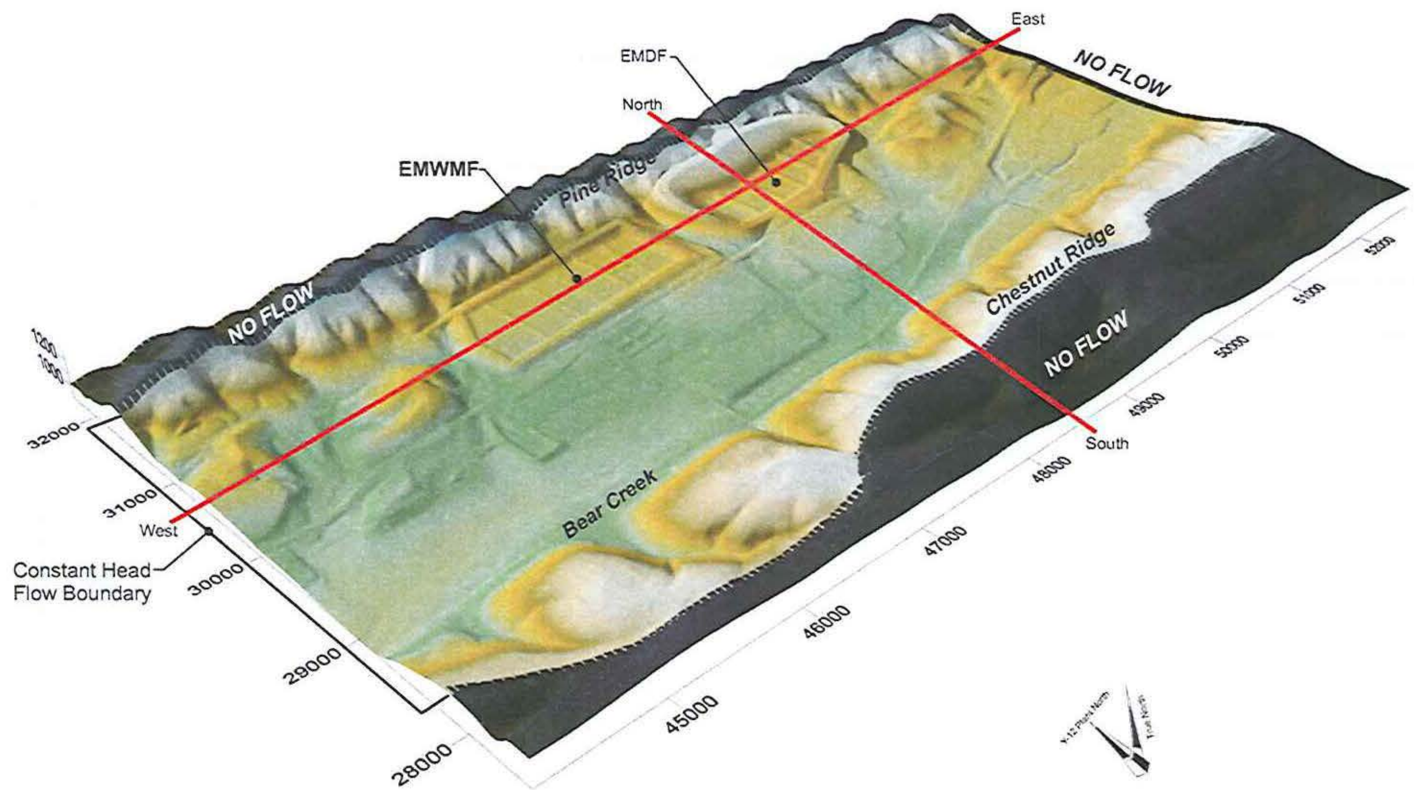


Figure F-5. Upper Bear Creek Model Domain with 2012 Condition



Upper Bear Creek
Model Domain with EMDF

08-14-12 DMF
Figure F-6 Domain-Cells.cdr

Figure F-6. Upper Bear Creek Model Domain with New Disposal Cell

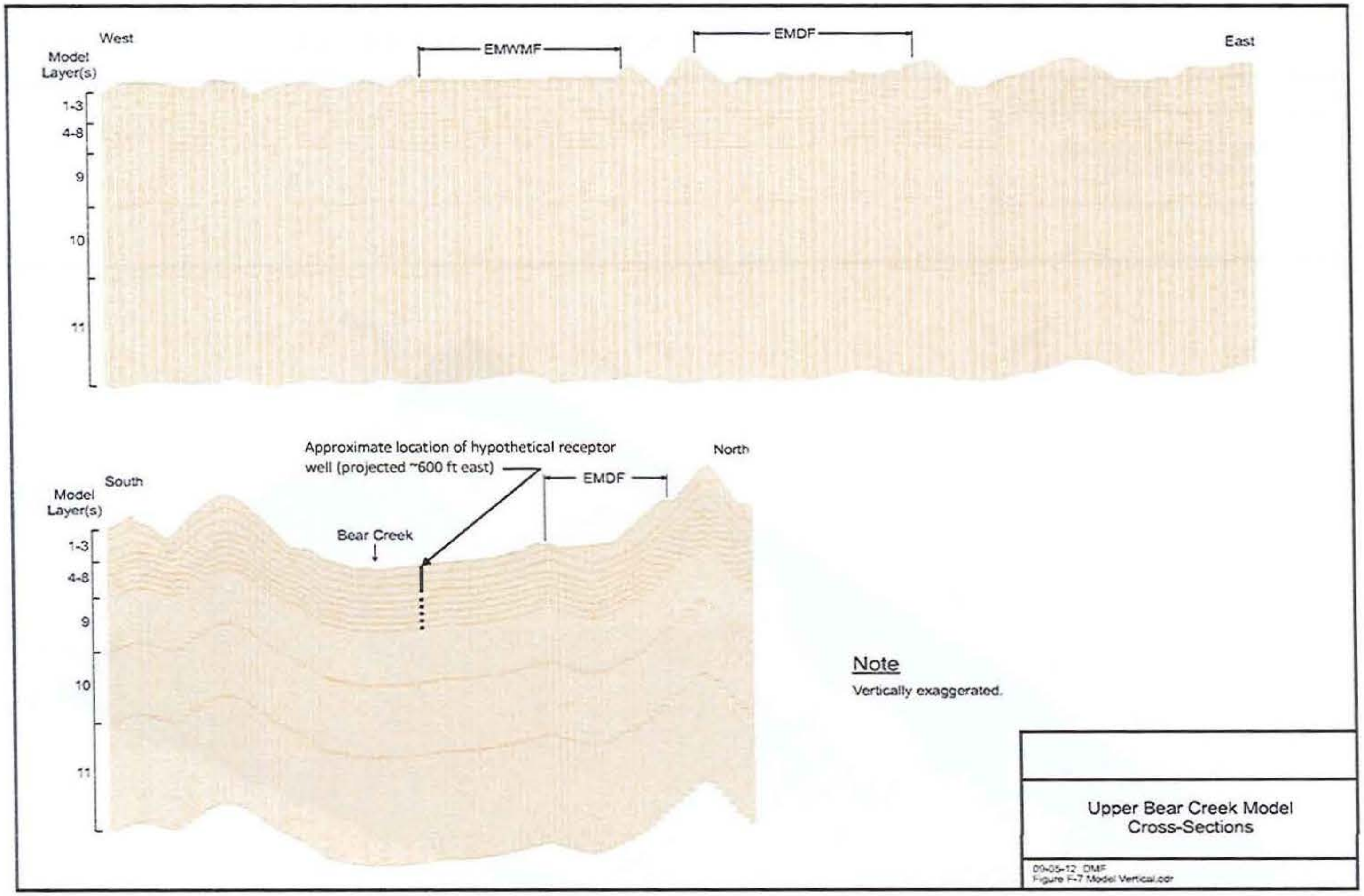


Figure F-7. Upper Bear Creek Model Cross-Sections

4.2.3 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 groundwater divide between BCV and Upper East Poplar Creek to the east (Figure F-5 and F-6). These boundaries match the natural groundwater divide. Constant head boundary conditions to the west were assumed based on a steady state simulation of the calibrated regional BCV groundwater flow model. The model boundary was established at a sufficient distance from the EMDF site to not be affected by topographic alterations associated with disposal cell development.

The base of the model is a no-flow boundary because minimal exchange of meteoric water with mineralized groundwater (i.e., brine) occurs below this depth (see Sect. 3.3.3.3 in Appendix C). 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, and French drains. The surface drainage features are represented in the model as drain cells (see Figure F-8). Drain cells allow groundwater to discharge into a surface water body. Actual stream bottom elevations were assigned in the model.

Infiltration from precipitation is assumed to be the sole source of recharge to groundwater for the site-specific UBCV model as the site is bounded on three sides by no-flow boundaries. Excluding the disposal cell area, infiltration is precipitation minus runoff and evapotranspiration and the recharge rate is a function of geologic media, surface slope, and vegetation. Five different recharge rates were assigned in the model (see Figure F-9) corresponding to (1) natural recharge to the carbonates; (2) natural recharge to the shales; (3) natural recharge to the sandstones; (4) reduced recharge through existing caps at former and operating waste disposal sites; and (5) the reduced recharge through the proposed disposal cell in a degraded state. An infiltration precipitation recharge rate of 0.42 in. per year through the proposed disposal cell cap was used in the future condition model. This value, considered to be a worst-case condition, was derived from a hydrologic analysis conducted with the HELP Model (Schroeder, et. al., 1994) as described in Sect. 4.1.2.

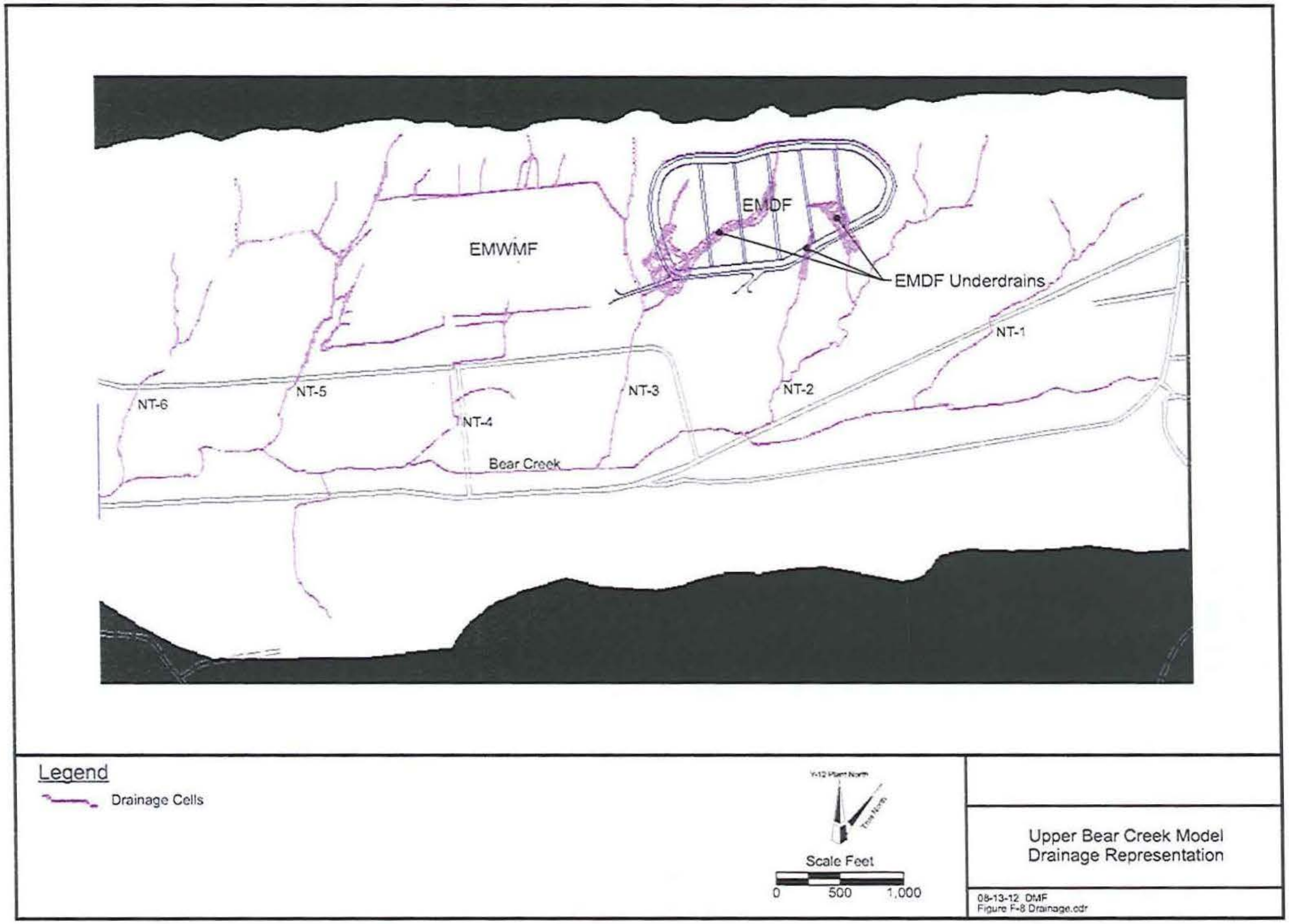


Figure F-8. Upper Bear Creek Model Drainage Representation

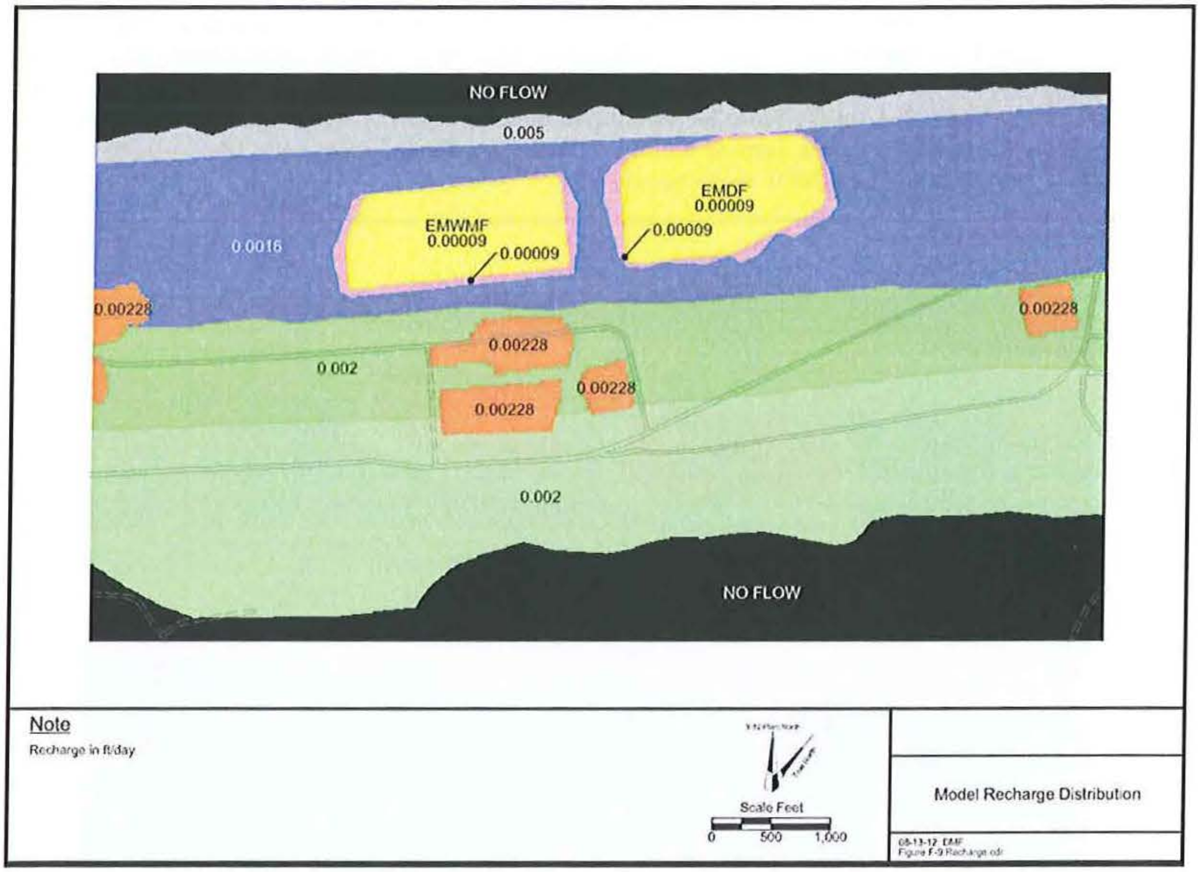


Figure F-9. Model Recharge Distribution

4.2.4 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 vs. Kx (Kz)] of five to one (for weather bedrock zone) and ten to one (for fractured bedrock zone) were used to represent the preferred fracture/bedding orientation of the natural 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.

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 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 site is modeled as a single unconfined aquifer, with 11 vertical layers to simulate the changes in hydraulic parameters with depth and the 45 degree dip is input by staggering of hydrogeologic units with depth. Model layers 1-3 represent the unconsolidated/weathered bedrock zone. Model layers 4 through 6 represent the top bedrock interval between 50 and 150 ft. Model layers 7 through 9 represent the intermediate/deep bedrock zone.

Figure F-10 shows the zones of hydraulic conductivities used to represent hydrogeologic units in Model Layer 1. Figure F-11 shows the hydraulic conductivity field in a vertical south-north cross section. Table F-4 provides a summary of model parameters for the future condition UBCV model. All parameter values shown in Table F-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.

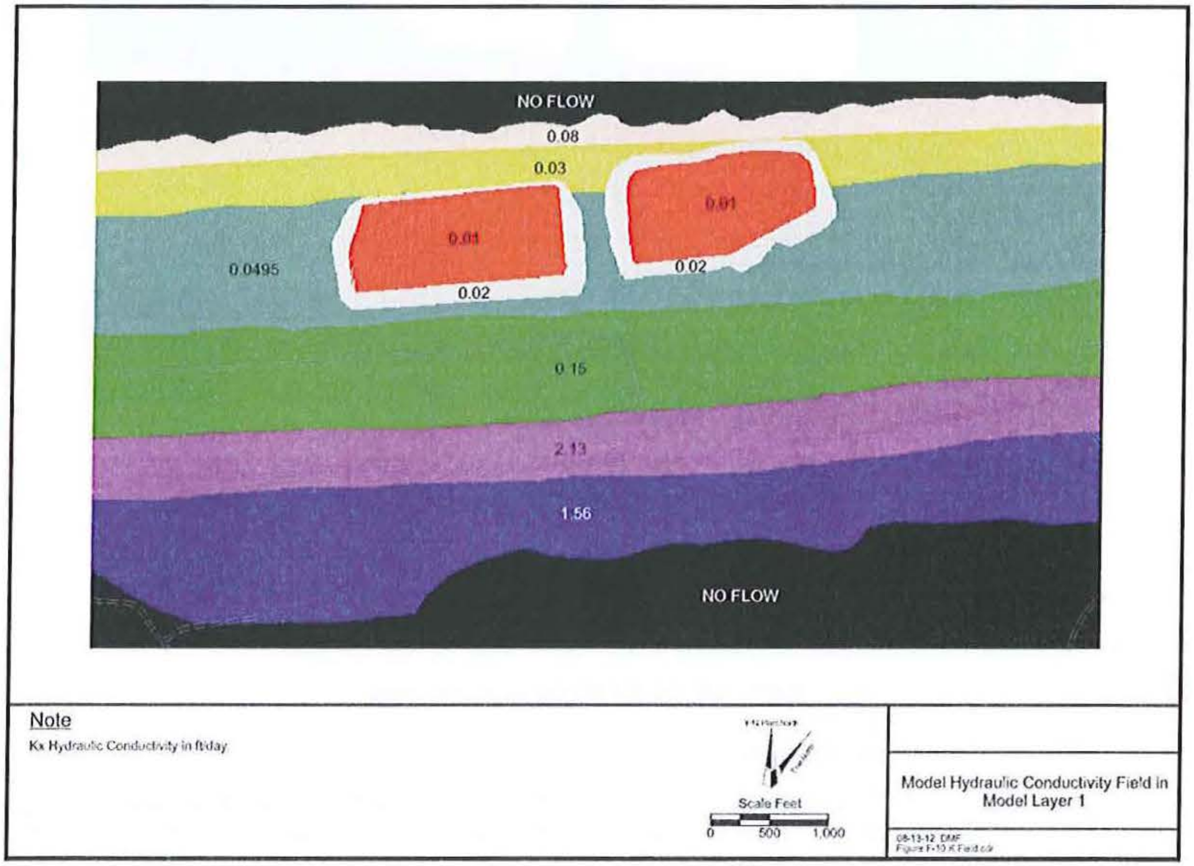


Figure F-10. Model Hydraulic Conductivity Field in Model Layer 1

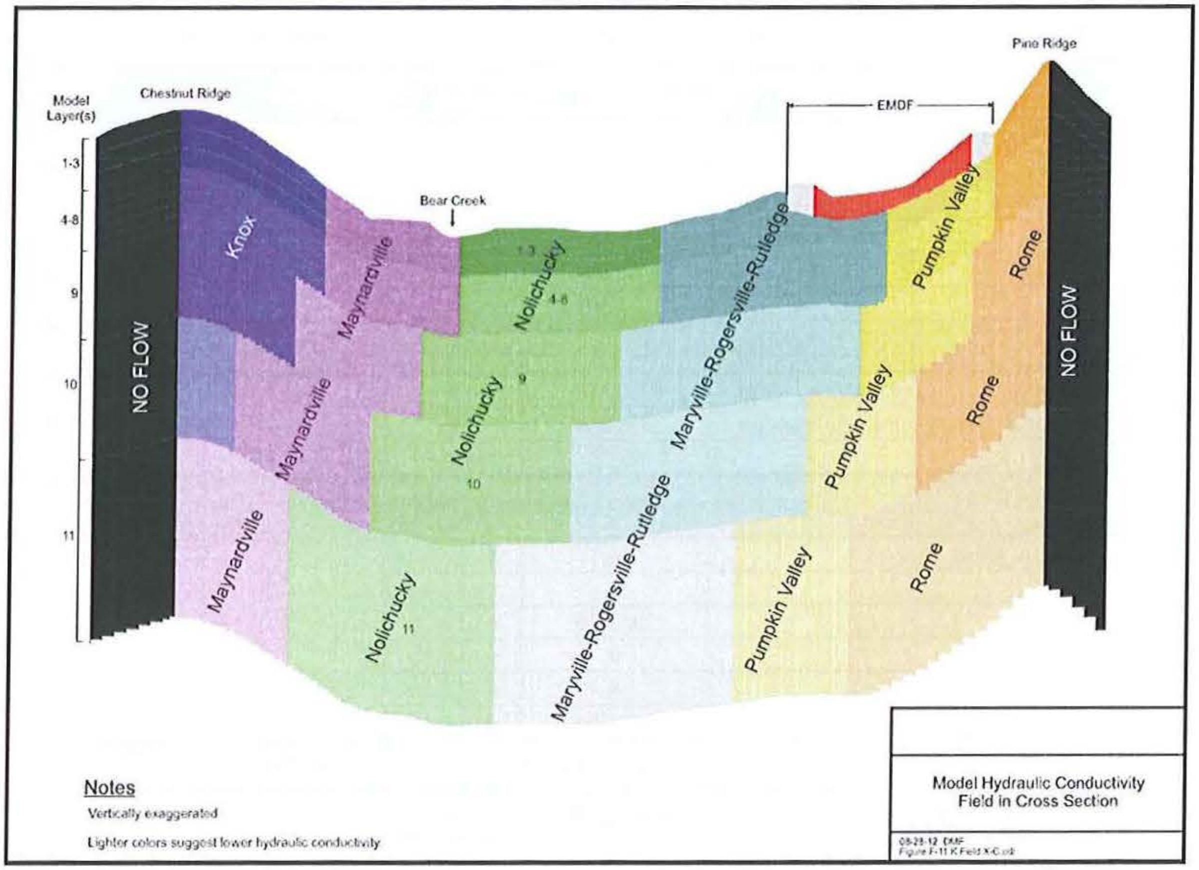


Figure F-11. Model Hydraulic Conductivity Field in Cross Section

Table F-4. UBCV Groundwater Model Parameter Summary (Future Condition)

GRID INFORMATION			
Number of Rows	860		
Number of Columns	480		
Number of Layers	11		
Total Cells	4,540,800		
Total Active Cells	3,572,049		
Percent Inactive	78.67%		
GRID DIMENSIONS			
Row Spacing - Uniform Delta-Y	10	ft	
Column Spacing Uniform Delta-X	10	ft	

Table F-4. UBCV Groundwater Model Parameter Summary (Future Condition) (Continued)

GRID DIMENSIONS (CONTINUED)					
Vertical Spacing					
Layers 1 – 3	Variable (10-25)	ft			
Layers 4 - 8	20	ft			
Layer 9	150	ft			
Layer 10	200	ft			
Layer 11	300	ft			
COORDINATE TRANSFORMATION					
X Offset (to Y-12 Coordinate System)	52723.33	ft			
Y Offset (to Y-12 Coordinate System)	27510.47	ft			
Rotation	90.23	degree			
MODEL BOUNDARY CONDITIONS					
Constant Heads	3,981	# of cells			
Rivers	0	# of cells			
Drains*	126,126	# of cells			
General Heads	0	# of cells			
Wells	8	# of cells			
No Flow	968,751	# of cells			
RECHARGE					
Areas/Geologic Units	**Recharge Rate**	**Unit**			
Closed Landfill/Paved Park Area	2.28E-04	ft/day			
Rome	2.00E-03	ft/day			
Maryville-Rogersville-Rutledge	1.60E-03	ft/day			
Nolichucky	2.00E-03	ft/day			
Knox	2.00E-03	ft/day			
EMDF* and EMWMF	9.00E-05	ft/day			
HYDRAULIC CONDUCTIVITY					
Material or Geologic Formation	**Model Layer**	**Kx**	**Ky**	**Kz**	**Unit**
Knox	1--3	1.56E+00	7.80E+00	1.56E+00	ft/day
Knox	4--8	9.18E-03	9.18E-02	9.18E-03	ft/day
Knox	9	2.54E-03	2.54E-02	2.54E-03	ft/day
Knox	10	1.16E-03	1.16E-02	1.16E-03	ft/day
Knox	11	3.60E-04	3.60E-03	3.60E-04	ft/day
Maynardville	1--3	2.13E+00	1.07E+01	2.13E+00	ft/day
Maynardville	4--8	1.21E-02	1.21E-01	1.21E-02	ft/day
Maynardville	9	3.34E-03	3.34E-02	3.34E-03	ft/day
Maynardville	10	1.52E-03	1.52E-02	1.52E-03	ft/day
Nolichucky	1--3	1.50E-01	7.50E-01	1.50E-01	ft/day
Nolichucky	4--8	6.81E-03	6.81E-02	6.81E-03	ft/day
Nolichucky	9	2.52E-03	2.52E-02	2.52E-03	ft/day
Nolichucky	10	6.10E-04	6.10E-03	6.10E-04	ft/day
Nolichucky	11	5.00E-05	5.00E-04	5.00E-05	ft/day

Table F-4. UBCV Groundwater Model Parameter Summary (Future Condition) (Continued)

HYDRAULIC CONDUCTIVITY (CONTINUED)					
Material or Geologic Formation	**Model Layer**	**Kx**	**Ky**	**Kz**	**Unit**
Maryville-Rogersville-Rutledge	1--3	4.95E-02	2.48E-01	4.95E-02	ft/day
Maryville-Rogersville-Rutledge	4--8	3.60E-03	3.60E-02	3.60E-03	ft/day
Maryville-Rogersville-Rutledge	9	1.35E-03	1.35E-02	1.35E-03	ft/day
Maryville-Rogersville-Rutledge	10	3.20E-04	3.20E-03	3.20E-04	ft/day
Maryville-Rogersville-Rutledge	11	4.50E-05	4.50E-04	4.50E-05	ft/day
Pumpkin Valley	1--3	3.00E-02	1.50E-01	3.00E-02	ft/day
Pumpkin Valley	4--8	4.72E-03	4.72E-02	4.72E-03	ft/day
Pumpkin Valley	9	1.75E-03	1.75E-02	1.75E-03	ft/day
Pumpkin Valley	10	4.20E-04	4.20E-03	4.20E-04	ft/day
Pumpkin Valley	11	5.60E-05	5.60E-04	5.60E-05	ft/day
Rome	1--3	8.00E-02	4.00E-01	8.00E-02	ft/day
Rome	4--8	5.00E-03	5.00E-02	5.00E-03	ft/day
Rome	9	2.00E-03	2.00E-02	2.00E-03	ft/day
Rome	10	5.00E-04	5.00E-03	5.00E-04	ft/day
Rome	11	8.00E-05	8.00E-04	8.00E-05	ft/day
compacted clay	1	1.00E-02	1.00E-02	1.00E-02	ft/day
compacted clay berm	1	2.00E-02	2.00E-02	2.00E-02	ft/day

* Indicates the parameter shown for the future condition model is different from the current condition (2012) model parameter

4.2.5 Model Calibration

Calibration of a groundwater 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 groundwater 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 UBCV model was constructed using the TMR approach based on the calibrated UBCV model and used extensive knowledge derived from EMWMF models. 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 groundwater flow model, additional extensive calibration of the refined model is usually not necessary. Since there are no new groundwater monitoring wells installed within the EMDF area and all previous monitoring wells have been used in UBCV model calibration, well-specific head comparison with the monitoring wells within the EMDF area was not performed. Instead, model predicted water level distribution pattern, flow path, and mass (water) balance were used for the model calibration process using the current condition UBCV model.

The water balance conducted for the calibrated current condition UBCV model compared observed and predicted groundwater discharge rates. Groundwater 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 groundwater discharge above the Bear Creek/NT-3 junction is 0.31 cfs. For comparison, the average flow rate measured at the location is 0.55 cfs (Appendix C, Sect. 3.0), which includes both base flow (groundwater 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 5%. The water balance shows that essentially all water has been mathematically accounted for and that MODFLOW simulation has correctly solved the governing flow equations. The comparison suggests that the UBCV model provides very good discharge result, indicating that the parameters (K) and recharge rates are properly represented in the model.

4.2.6 Sensitivity Analysis

The Maynardville Formation in BCV, composed of interbedded limestone and shale, underlies the valley floor. The main channel of Bear Creek tends to follow the lower Maynardville units. The Maynardville contains numerous well-developed cavities which form an interconnected strike-parallel conduit system. A dense network of fractures also occurs in the Maynardville Limestone, and these are connected to fractures in the other stratigraphic units of the BCV. See Sect. 3.3.1.3 in Appendix C for a more detailed discussion of cavities/conduits in BCV.

To evaluate the possible impact of these features on flow velocities and contaminant transport, a sensitivity analysis was conducted using the current condition (2012) model. The sensitivity analysis was conducted by assigning very high permeabilities to simulate the presence of a highly conductive fracture or conduit in the bedrock unit along geologic strike in the valley axis.

Two scenarios were analyzed in the sensitivity analysis. The first scenario assumed the high density fractures/conduits occur within the bedrock zone (model layers 4-8) and second assumed that they occur in both weathered and bedrock zones (model layer 1-8) in the Maynardville. In both scenarios, the hydraulic conductivity in the strike (valley axis) direction of the zone was increased by a factor of 10 from the base (current condition) model. Figures F-12 and F-13 show the model predicted water levels compared to the base case for Scenarios 1 and 2 in shallow and intermediate groundwater zones, respectively. As shown in the figures, the impact of extremely high permeability along the valley axis causes changes in the groundwater levels and flow field. For the first scenario where a higher density of fractures/conduits occur only within the bedrock zone (model layers 4-8), the impact is minimal because most of the active groundwater flow is within weathered bedrock zone. In the second scenario, where high density fractures/conduits occur in both weathered and bedrock zone (model layer 1-8), the water levels in the intermediate groundwater zone are primarily impacted in the Maynardville Limestone, and not the surrounding units. The change to groundwater levels and the flow field in the EMDF footprint area is negligible. The model predicted water levels and flow field for the second scenario are inconsistent with current groundwater levels observed in the field. This indicates that there may not be full down-valley connectivity of conduits in the Maynardville Limestone, or that there are some limiting restrictions within the conduit system. Thus, it is an unlikely scenario.

The sensitivity analysis suggests that although the presence of larger and denser fractures or dissolution/karst features may impact the groundwater flow velocity within the Maynardville Limestone, it has minimal impact on the protectiveness of the PWAC, as demonstrated by the results of the fate-transport model. In addition, because the peak risk calculated for any time during the 0 to 100,000 year period modeled for each individual constituent is used to develop the analytic PWAC, the rapid first arrival of contaminants (e.g., as reported for tracer tests) is less important than the overall water balance data used to establish dilution ratios for calculating the PWAC. Because the risk receptor is assumed to be near the junction of Bear Creek and NT-3, higher conductivities in this area would result in higher DFs and lower contaminant concentrations. The base-case current condition model accurately represents hydraulic heads and surface water discharge as determined by the water budget, and is therefore appropriate to develop the future condition model that is used to calculate risks from dilution factors between source and exposure area that are based on ratios of Darcy fluxes.

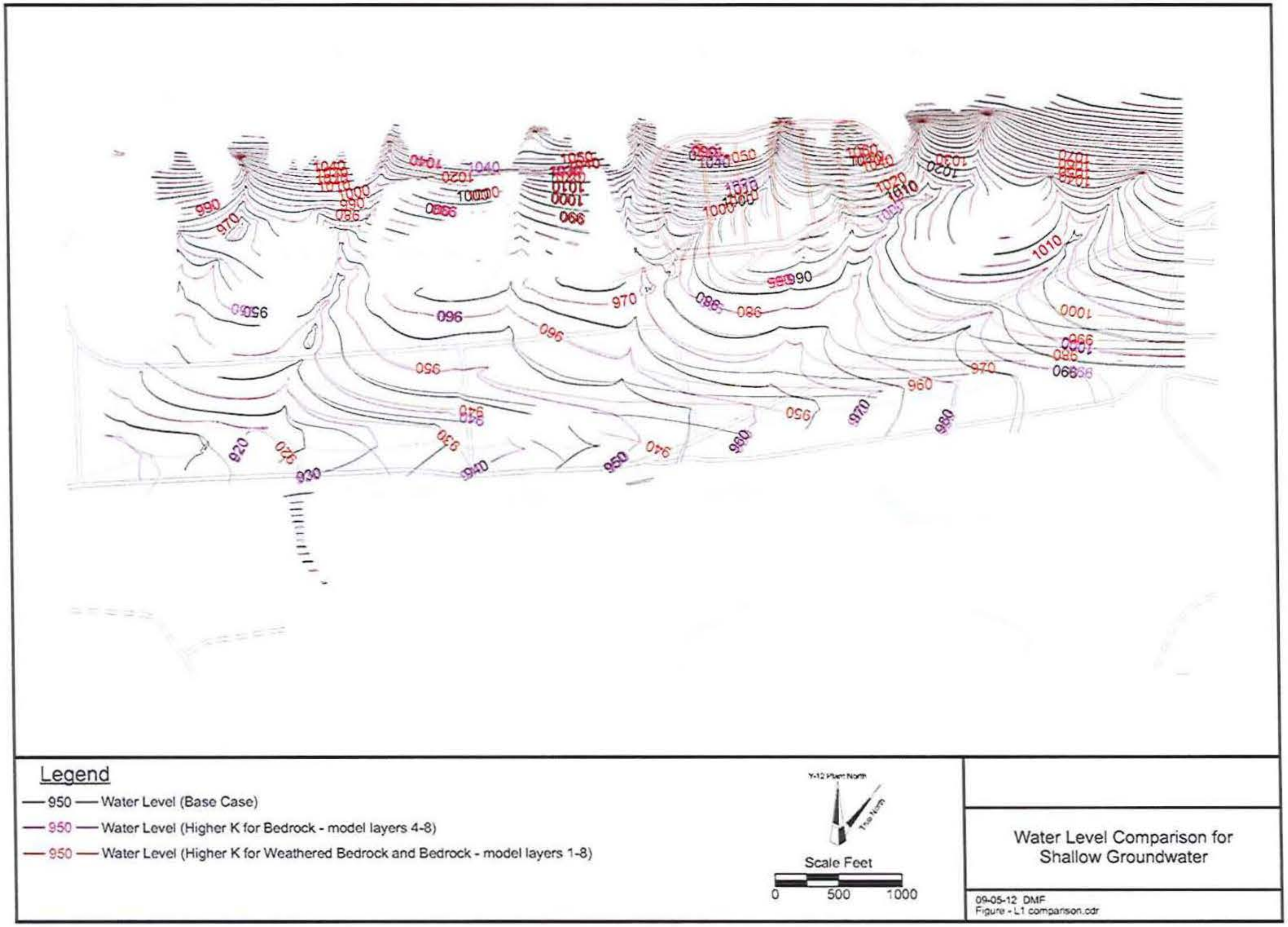


Figure F-12. Water Level Comparison for Shallow Groundwater

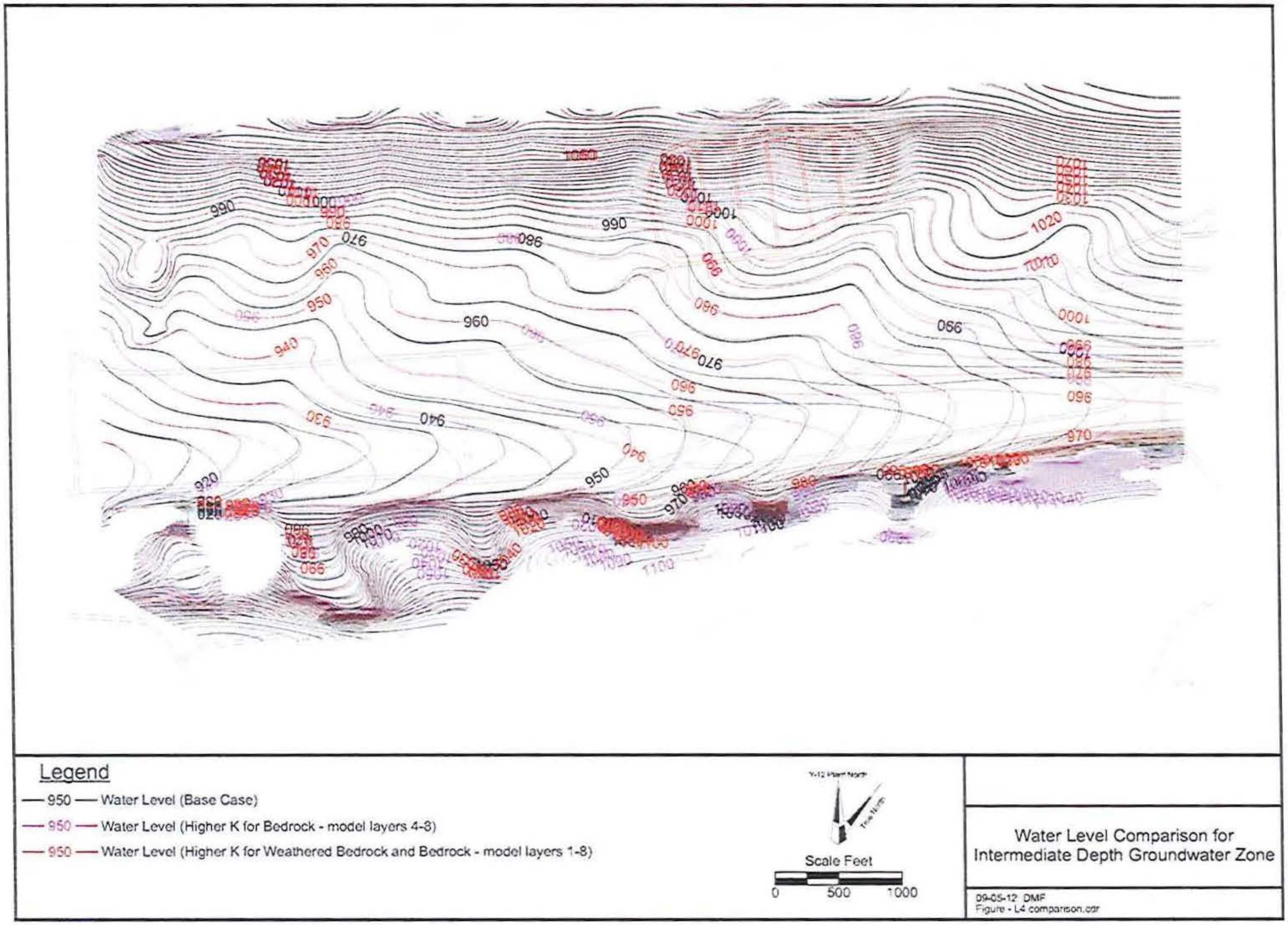


Figure F-13. Water Level Comparison for Intermediate Depth Groundwater Zone

4.2.7 Groundwater Model Results – Future Condition

Figures F-14 and F-15 show the future condition model predicted shallow and intermediate zone groundwater levels and flow direction and gradient. Generally, the figures indicate that shallow groundwater discharges into Bear Creek and its tributaries. However the tributaries exhibit a less pronounced influence on groundwater flow in the intermediate bedrock groundwater zone. Even though there is an upward gradient toward the NTs in the intermediate zone, the flow vectors indicate deeper groundwater may underflow the NTs. The simulated groundwater 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 C.

Groundwater flow paths and particle travel times from cells to surface discharge locations are determined using the MODPATH model (Pollock 1989). Figure F-16 shows the groundwater flow paths and discharge locations from various cell locations. The data are used to calculate the flow velocity in the groundwater zone that are used for PATHRAE modeling.

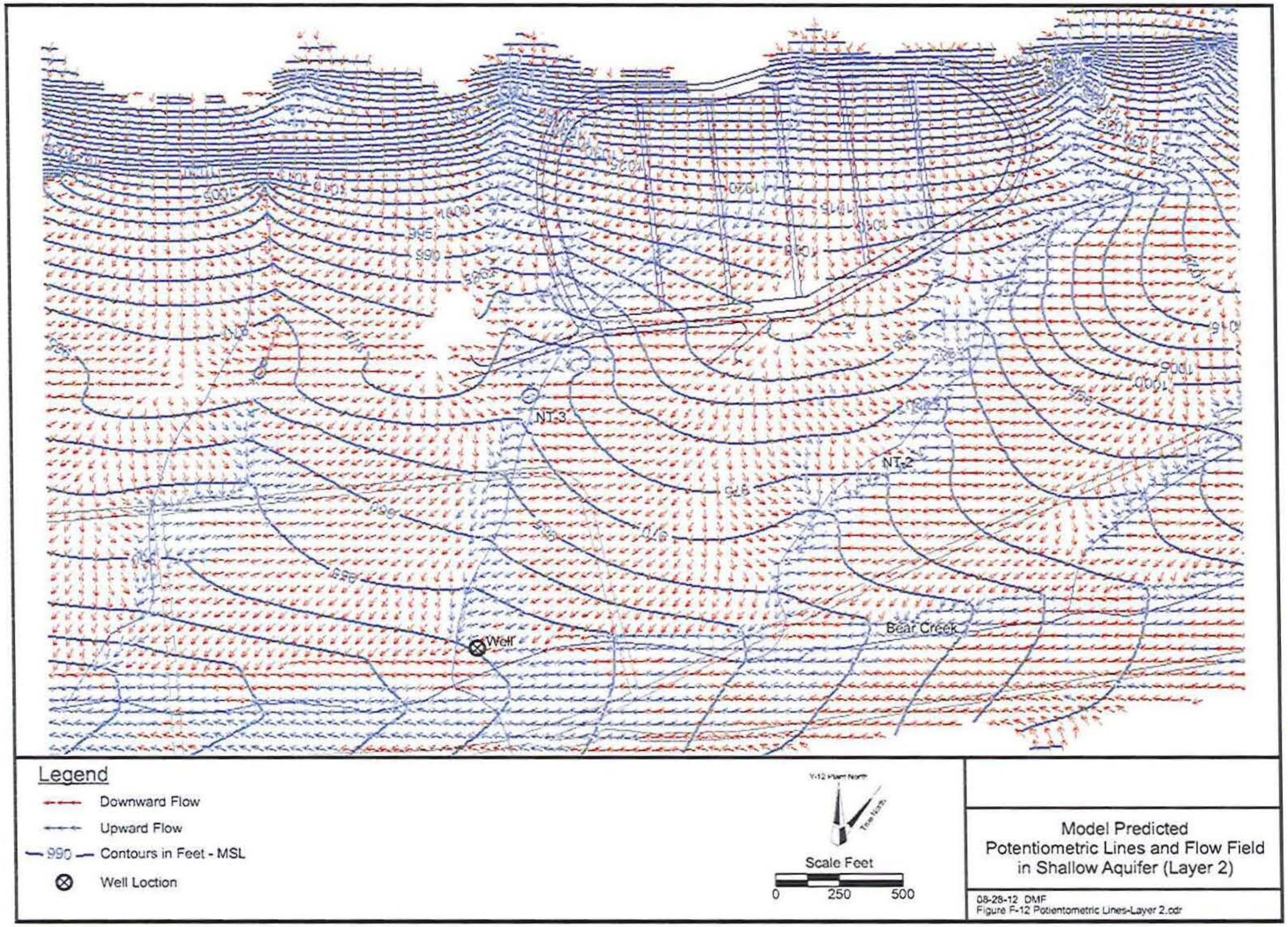


Figure F-14. Model Predicted Potentiometric Lines and Flow Field in Shallow Aquifer

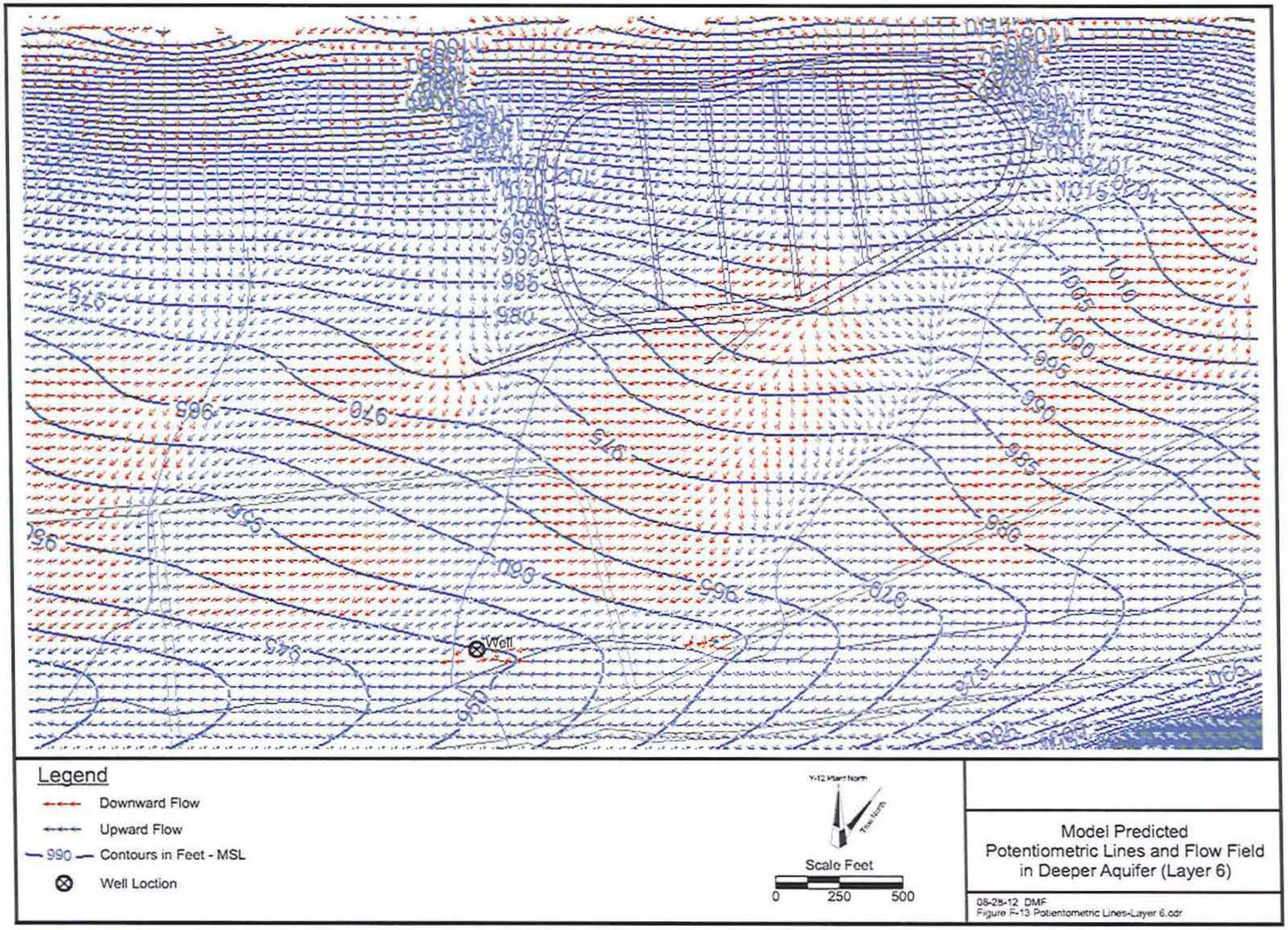


Figure F-15. Model Predicted Potentiometric Lines and Flow Field in Intermediate Aquifer

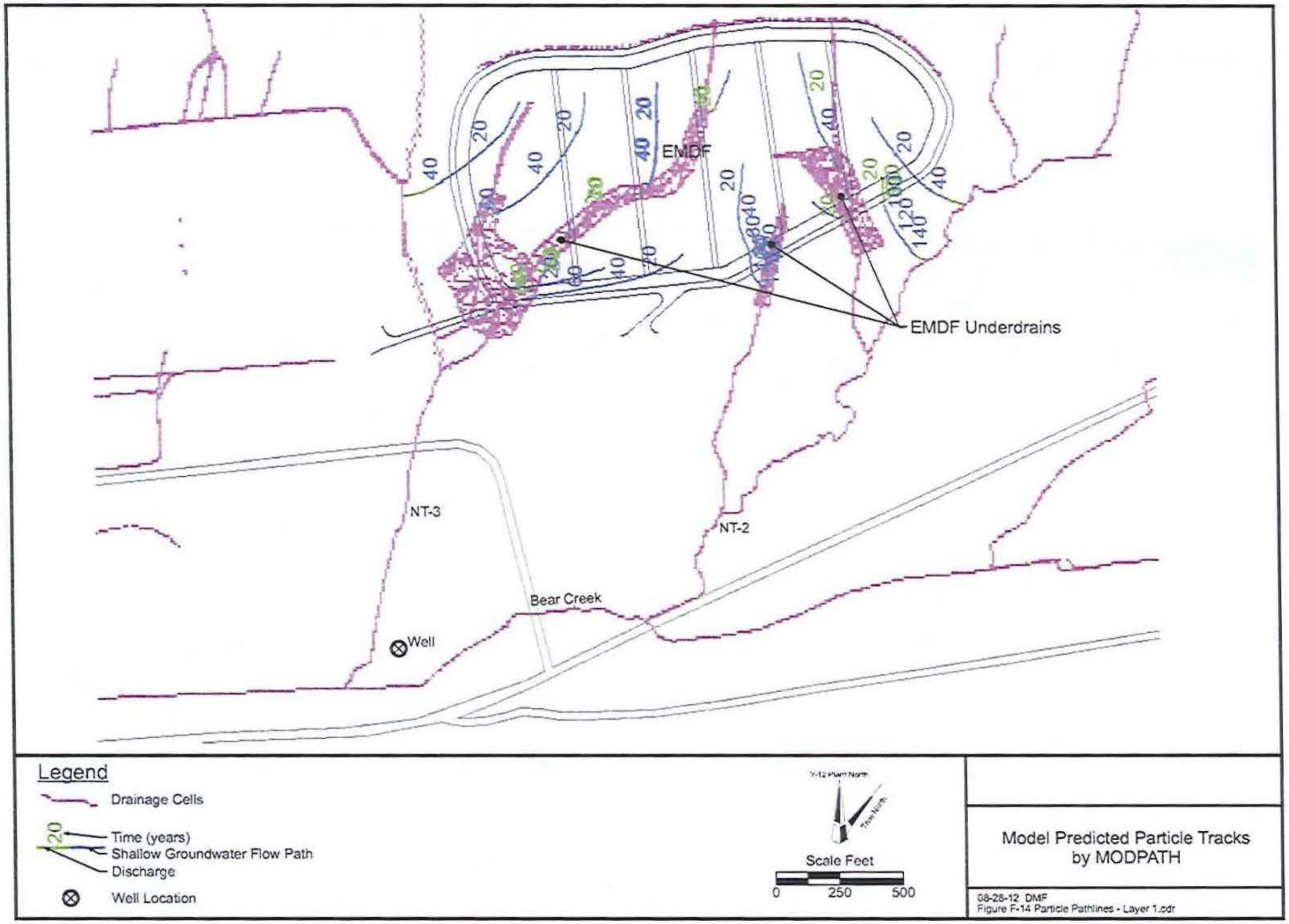


Figure F-16. Model Predicted Particle Tracks by MODPATH

4.3 FATE-TRANSPORT MODEL APPLICATION

The movement of contaminants from the waste cell to various receptors outside of the waste disposal site in groundwater were simulated by using MT3D (Zheng, 1990), a fate-transport model code that is coupled to the groundwater flow field results for the future site condition generated by MODFLOW. Based on the results of MODFLOW flow simulation for the future closed EMDF scenario, MT3D is used to predict the contaminant concentration distribution in the site.

A constant leaching source from the waste disposal cell to groundwater underneath the cell was assumed in the model (see Figure F-17). This is a very conservative assumption as the contaminant mass (thus leaching rate) will likely decrease due to reduced mass in the cells. Only the advection process was considered. No hydrodynamic dispersion or retardation processes were considered in the MT3D simulations. The MOC solution method was used for all the simulations to minimize the potential error from numerical dispersion. Retardation and dispersion processes are considered in the PATHRAE analysis.

To perform risk analysis on the proposed EMDF, a risk scenario was analyzed in which a hypothetical domestic groundwater supply well is placed hydraulically downgradient from the disposal cell. The hypothetical well is assumed to be located on the BCV floor between the EMDF and Bear Creek before the intersection of downgradient tributary NT-3 as shown in Figure F-17. The location is similar to the well setting for the EMWMF WAC analysis, and is completed in model layers 5 through 8. The well location was selected in the Nolichucky Shale near the more permeable Maynardville/Nolichucky formation boundary at a depth where sufficient water yield is met. Other factors, such as distance to the resident farmer's house and the topography of EBCV were considered. The well is assumed to be a typical domestic water supply well that pumps water from the bedrock aquifer. The well is pumped at a rate (240 gallons per day) to supply water adequate for a family of four.

The model analyses were carried out in the following steps:

1. For the pumping well location and well scenario, a groundwater flow simulation run was performed to determine the specific groundwater flow field.
2. Contaminant movement in the flow field with time was simulated with MT3D. After a steady state was achieved for the contaminant plume, the maximum concentration field was established. The steady state was established by assuming a constant leaching source of 1 (C_L= 1) for the duration of the model simulation. This establishes a constant DF that is later applied to all contaminants.
3. For the risk scenario, a concentration versus time graph was plotted to show the concentration change with pumping at the well location.

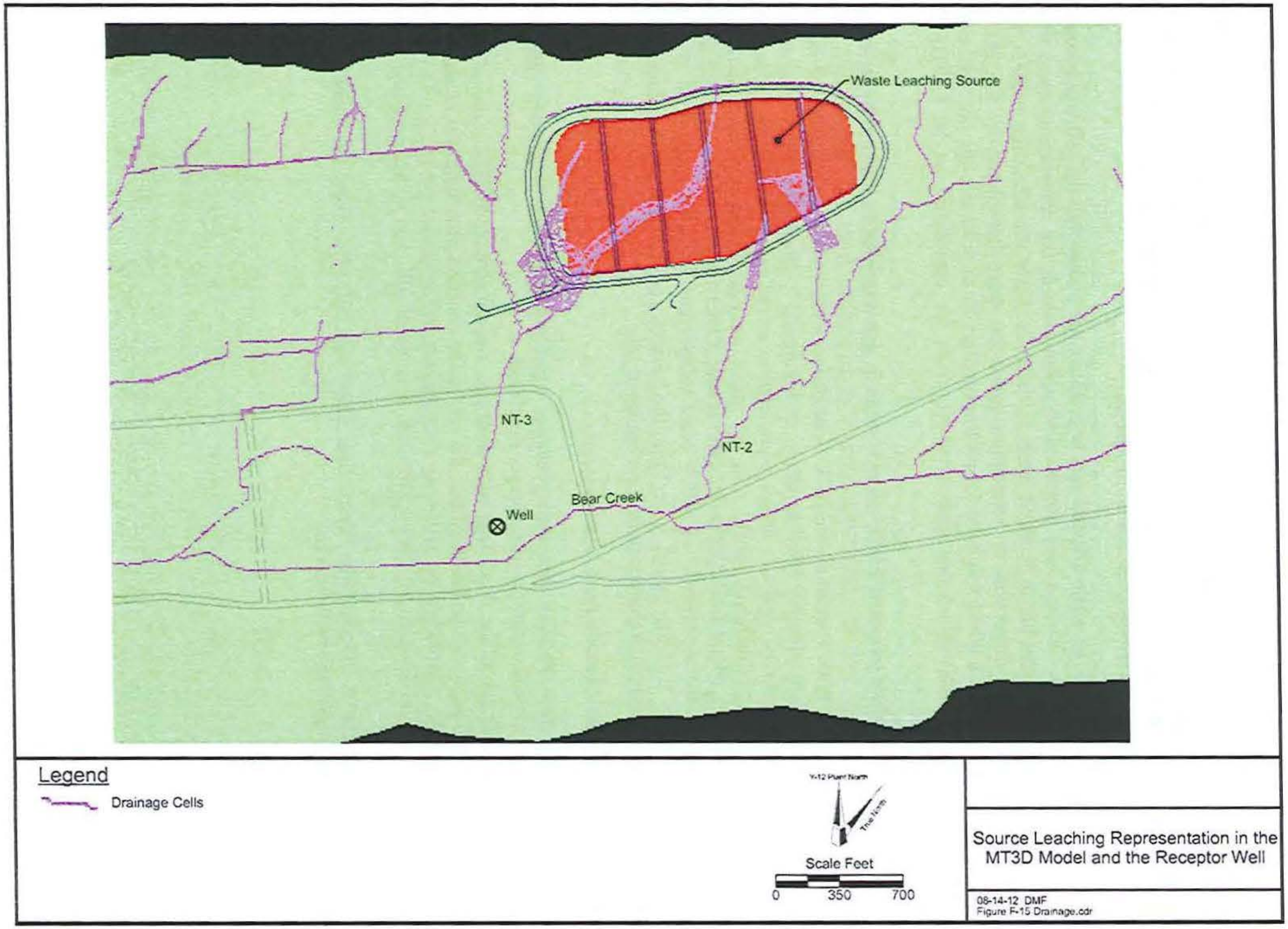


Figure F-17. Source Leaching Representation in the MT3D Model and the Receptor Well

Based on the results of UBCV flow simulations for the closed-cell scenario (i.e., permanent cover system in place) with a water supply well, the MT3D code was used to predict the contaminant concentration distribution in the site. Figure F-18 shows the steady-state plume in the shallow groundwater intervals. The steady-state plume represents the maximum plume resulting from the constant EMDF source that is predicted to be achieved 1,500 years after facility closure. The plume in Figure F-18 shows the relative groundwater concentration as compared to the leachate concentration at the source. As predicted by the site conceptual model, most of the shallow plume discharges into surface water features (gravelly backfilled former tributaries, NT-3, and Bear Creek).

Figure F-19 shows the steady state plume in Model Layer 6 and is representative of the plume at the screened interval of the hypothetical receptor well. The plume shows some local irregularities because the model layers cross stratigraphic boundaries and vary in elevation across the modeled area. Figure F-20 shows the steady plume distribution in a south-north cross section. The plume maps in Figures F-18 through F-20 show the plume from the proposed disposal facility discharges into Bear Creek eventually. Model layer 9 shows a thickened plume that is an artifact of the model layer thicknesses. As noted above, model layers 1 through 8 are relatively thin, reflecting the fact that most groundwater flow occurs in the shallow interval. Model layers 9 through 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.

DFs for the residential well were calculated in the same manner as for the EMWMF. The DF_{well} values are defined as the ratios of C_{well} [the peak steady-state contaminant concentrations in the continuously pumped well (240 gallons per day)] to C_L [the unit contaminant concentrations (leachate) entering the groundwater beneath the disposal facility]. Figure F-21 shows the predicted concentrations in model layers at the hypothetical domestic groundwater supply well location. The hypothetical receptor well is screened at depths corresponding to model layers 5 through 8. The average C_{well}/C_L or DF_{well} extracted from the well screen is also shown in Figure F-21. This calculated average ratio of the concentration at the well relative to leachate concentration at the cells is 0.000015 which equals the DF_{well}.

The calculated DFs for the residential well, along with DF calculated for surface water at Bear Creek, are used to calculate the projected peak risks and doses from radioactive or hazardous constituents for risk analysis as discussed in Sect. 5.2.

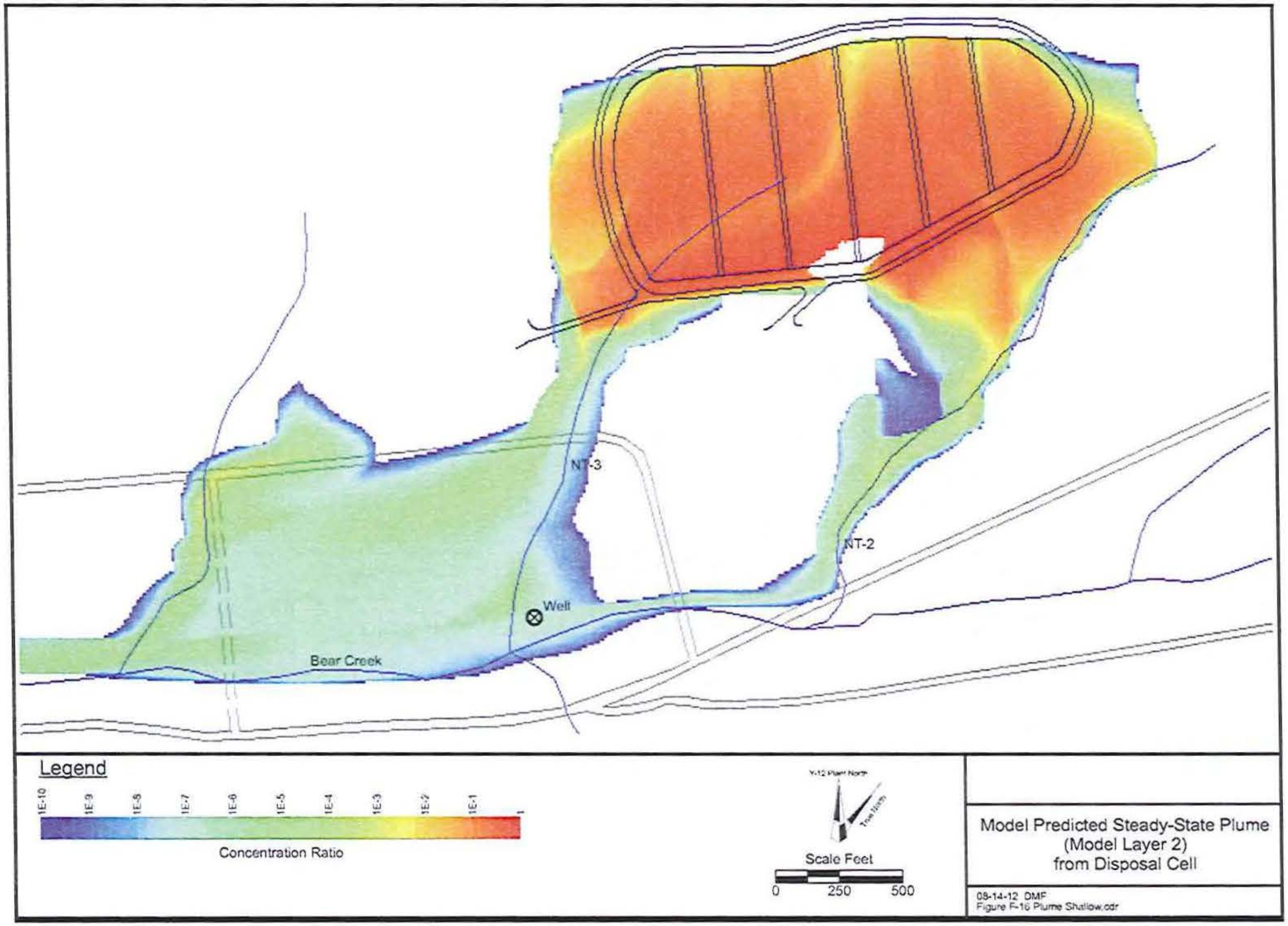


Figure F-18. Model Predicted Steady-state Plume (Model Layer 2) Result from Disposal Cell

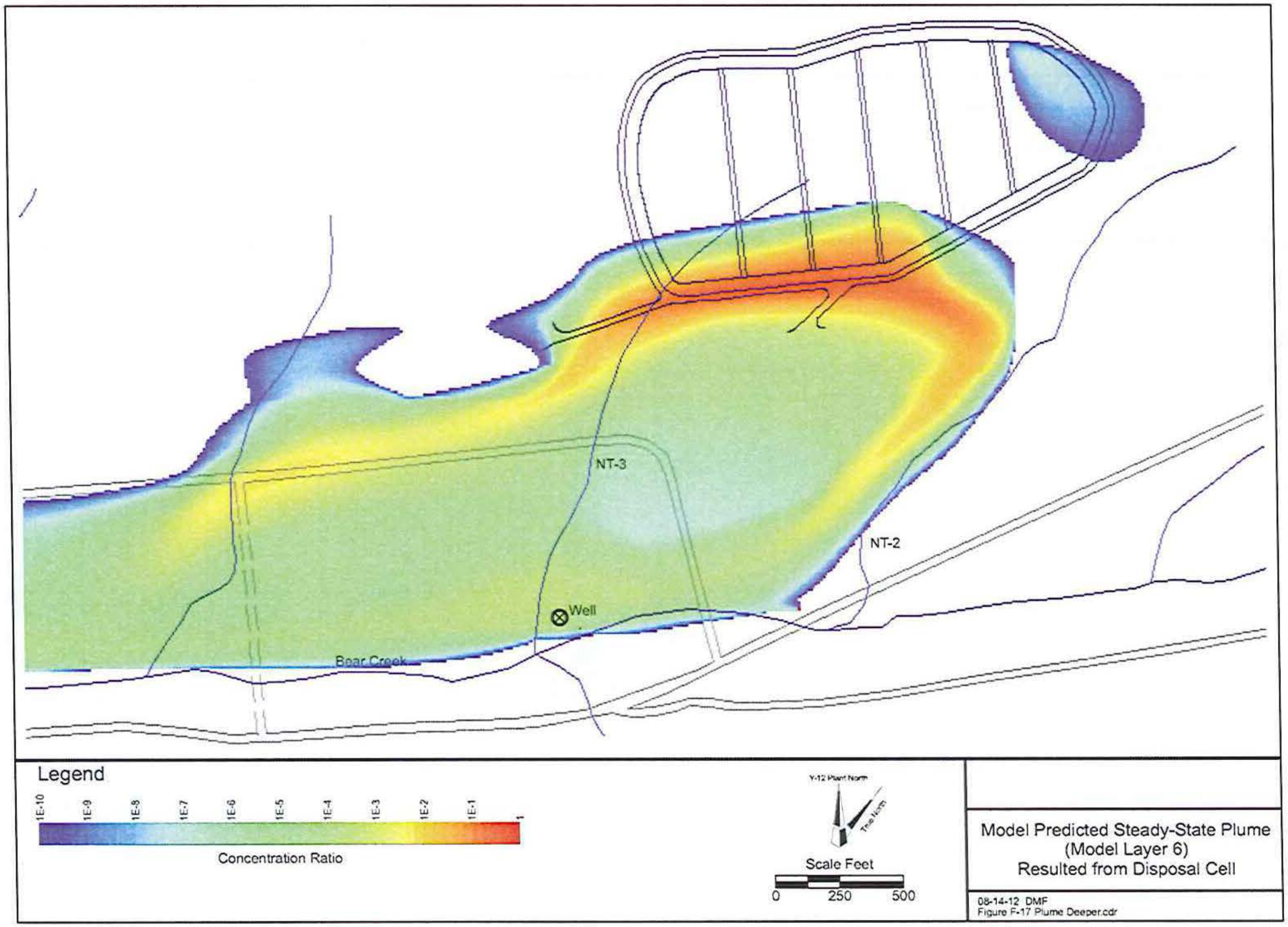


Figure F-19. Model Predicted Steady-state Plume (Model Layer 6) Result from Disposal Cell

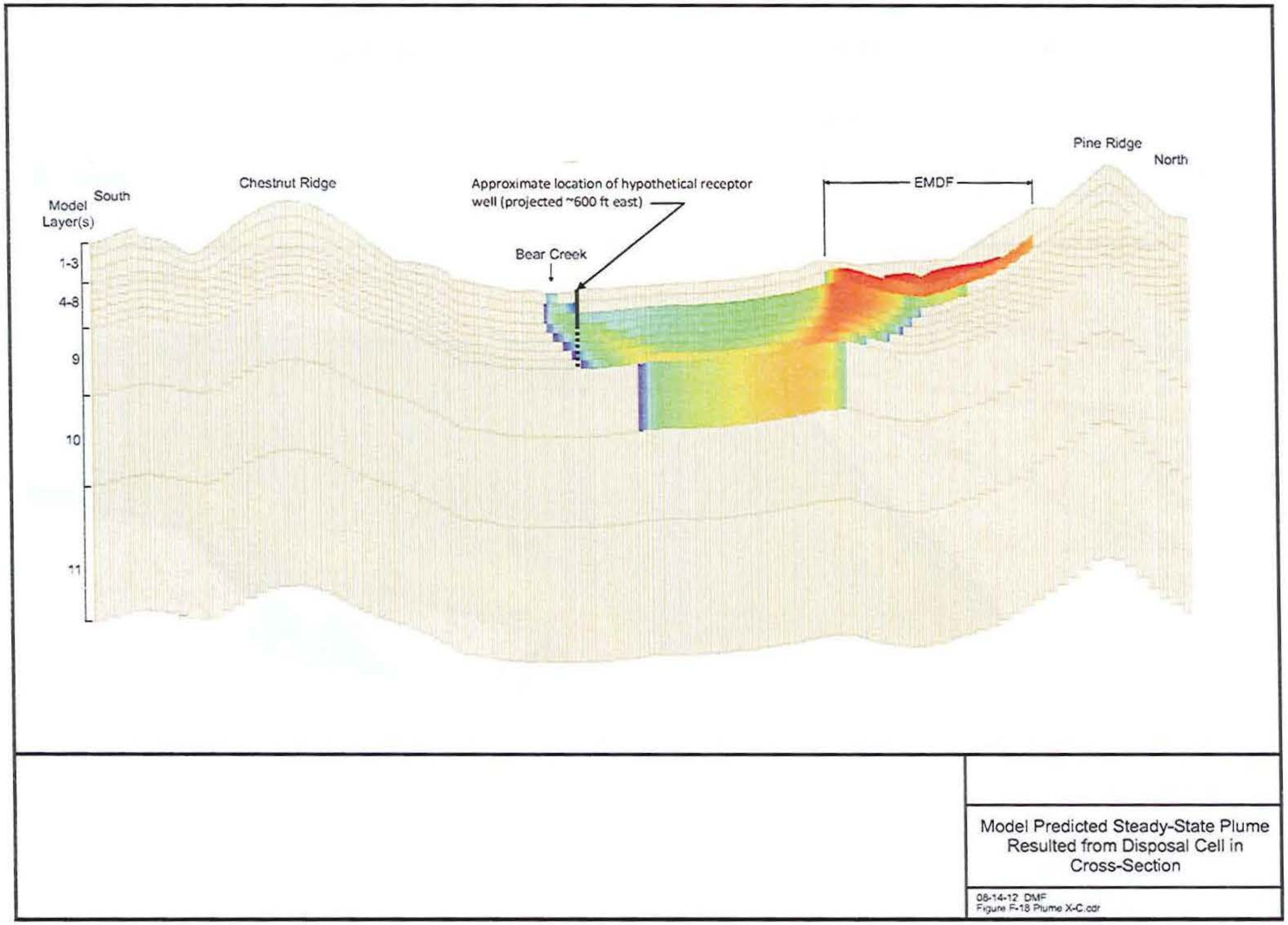


Figure F-20. Model Predicted Steady-state Plume Result from Disposal Cell in Cross-section

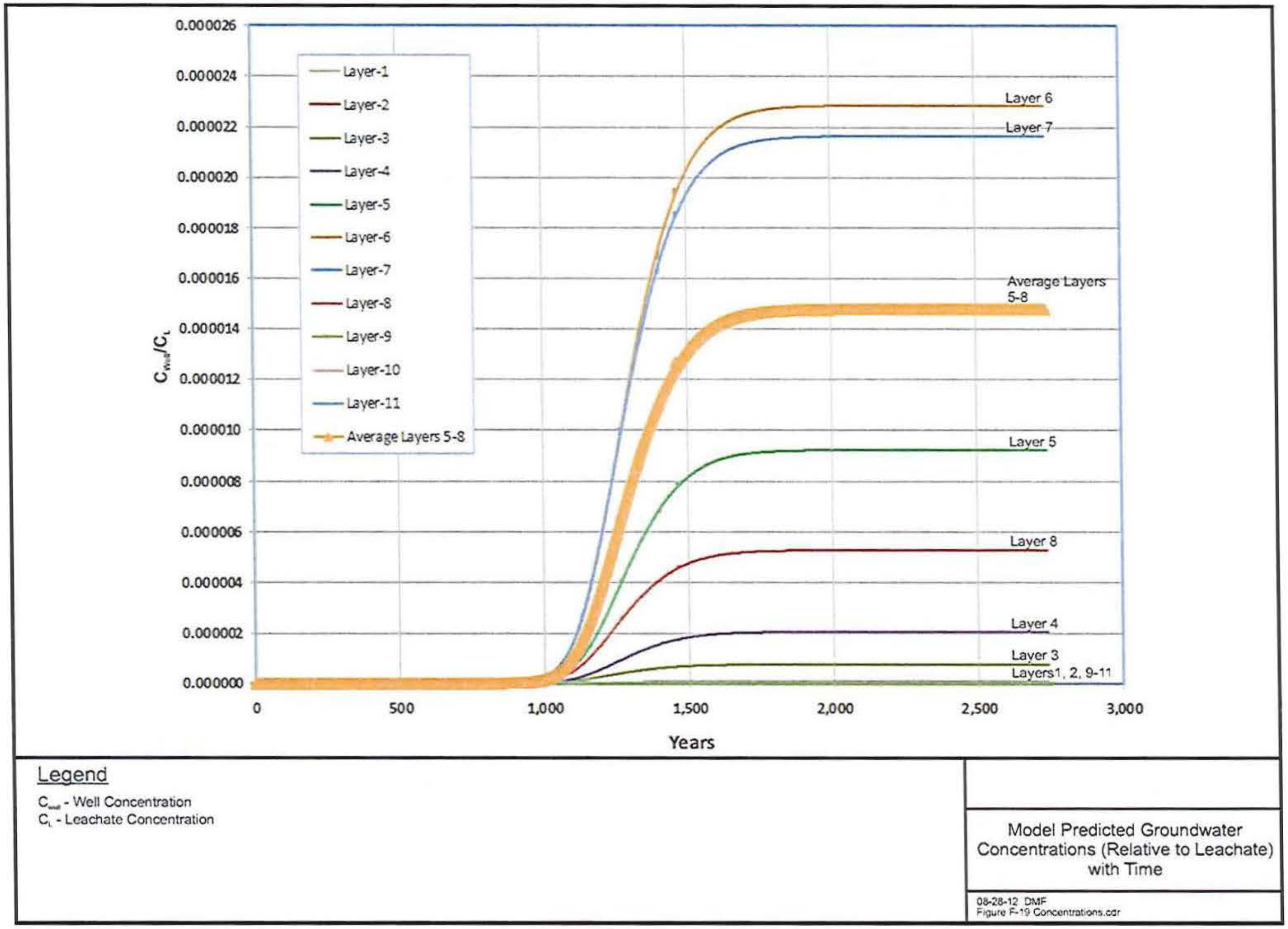


Figure F-21. Model Predicted Groundwater Well Concentrations (Relative to Leachate) with Time

5. PATHRAE MODELING AND RISK/DOSE ANALYSIS

The PWAC development methodology used for the proposed EMDF is similar to the methodology used to develop the EMWMF WAC (DOE 1998a, b). The PATHRAE model is used to estimate the risk and dose for the surface water pathway and additional calculations are used to determine overall risk and dose for the hypothetical receptor. It is assumed under the hypothetical receptor scenario that a resident farmer family of four consumes drinking water from a well and uses Bear Creek surface water for agricultural purposes.

PATHRAE model input and assumptions are described in Sect. 5.1. PATHRAE model output and risk/dose calculations are described in Sect. 5.2.

5.1 PATHRAE MODEL INPUT AND ASSUMPTIONS

Developing a PWAC for a constituent requires determining the risk/dose to a potentially exposed resident farmer from a unit concentration in the waste that occupied the entire disposal facility volume (1 Ci/m^3 for radiological and 1 mg/kg for toxicological constituents, respectively). The risk and hazard index calculated for unit source terms is then used to rescale the allowable waste concentration (PWAC) to correspond to the risk and dose criteria for the 0 to 1,000 - and >1,000 to 100,000-year time frames (see Sect. 2.3 of this Appendix).

Using the input parameters generated from supporting models and site-specific data, PATHRAE-RAD and PATHRAE-HAZ modeling are used to perform risk analysis. The PATHRAE analyses are conducted for the points of assessment of the EMDF.

The assumed waste contaminant leaching characteristics used a simple K_d release mechanism. The K_d values used to develop the EMWMF WAC are used to develop the PWAC for the proposed EMDF and all waste being modeled is assumed to be soil-like. The majority of projected waste to be generated is debris; however, as shown in Fig. 2-2 in Chapter 2 of this RI/FS, the volume of clean fill and waste fill that would actually occupy the proposed 2.5M yd^3 facility is roughly twice the volume of debris. Debris would be surrounded in the landfill by clean and waste soil fill to meet void fill 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 is the most representative for the overall waste since the waste cell is modeled as a single unit source. Section 6.2 of this Appendix provides additional information about the soil-like material assumption.

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 2012) are used to calculate risk/dose in groundwater and surface water pathways. Where no values are provided in the EPA risk guidance, values previously used to calculate the EMWMF WAC are used. Also, site-specific parameters for the proposed EMDF design and conditions are used. Table F-5 summarizes the input parameters used to conduct PATHRAE analysis.

Table F-5. EMDF Parameters for PATHRAE and PWAC Calculation

Zone	Parameter	Value	Unit
Top/Surface	Cover thickness	13	ft
	Porosity of surface soil	0.25	vol/vol
Waste Zone	Waste volume	2500000	cubic yard
	X (along groundwater flow path)	1596	ft
	Y (cross groundwater flow path)	798	ft
	Disposal cell surface area	1273134	ft^2
	Waste thickness (average)	53	ft
	Waste density	1600	kg/m^3
	Recharge rate to groundwater from waste zone	0.4	in/yr
	Amount of water percolating through the waste cell	0.00135	cfs
Vadose Zone	Depth to groundwater	23	ft
	Bulk soil density	1600	kg/m^3
	Porosity of vadose zone	0.25	vol/vol
	Saturated hydraulic conductivity of vadose zone	1.00E-06	cm/s
Groundwater	Bedrock density	1800	kg/m^3
	Soil/Weathered bedrock porosity	0.2	vol/vol
	Bedrock porosity	0.05	vol/vol
	Longitudinal dispersivity in bedrock aquifer	6	meter
	Transverse dispersion coefficient in bedrock aquifer	0	m^2/yr
	Horizontal groundwater velocity (calculate using particle tracking trajectories)	14	ft/yr
Surface Water	Stream flow rate at compliance point (Junction NT-3 and Bear Creek)	0.55	cfs
	Surface water Dilution Factor	0.00245	unitless
	Distance from nearest edge of waste to surface water compliance location	1570	ft
Groundwater Well	Groundwater well Dilution Factor	0.000015	unitless

5.2 PATHRAE MODEL OUTPUT AND RISK/DOSE CALCULATIONS

PATHRAE-RAD and PATHRAE-HAZ models were used to calculate the arrival and peak time for the radioactive constituents and toxicological constituents at the surface water receptor location, respectively. For each contaminant that has peaked within the 100,000-year timeframe, the peak concentration of the contaminant in the creek is used.

PATHRAE calculations were performed to determine the equivalent annual water consumption per year for the creek (defined as the Equivalent Uptake [EU]). This equivalent uptake water consumption is derived by scaling the use of creek water for drinking and agricultural purposes to an equivalent annual drinking water ingestion that would give the same annual constituent uptake as calculated to come from all pathways. Because drinking water in the resident farmer exposure scenario will be supplied by a well rather than the creek, the annual drinking water volume of 730 L per year to be supplied by the well is subtracted from the creek EU to estimate the effective drinking water ingestion that can be associated with agricultural uses for the creek surface water. The PATHRAE calculations also provide peak concentrations of contaminants in the creek water corresponding to a unit source term, the corresponding peak doses or risks associated with those concentrations, and the times of occurrence of the peak concentrations.

The input and output text files for the PATHRAE model runs (PATHRAE-RAD and PATHRAE-HAZ) are included in the Sect. 3 of the modeling attachment to this Appendix. The input files contain all the input parameters in tabulated form.

The calculated DFs for the creek and residential well were used for scaling the constituent concentrations in the creek to corresponding well concentrations. The DF calculations are carried out in the following steps:

- The steady state well concentration (maximum concentration) obtained while pumping (C_{well}) was compared (i.e., ratioed) to a unit seepage from the disposal cell (C_L) to obtain a well dilution factor DF_{well} = steady-state pumped (0.167 gpm) concentration in the well divided by unit concentration seeping from disposal cell or C_{well}/C_L as shown in Figure F-21. As discussed in Sect. 4.3, the DF_{well} is obtained from the MT3D model. The steady state was established by assuming a constant leaching source of 1 ($C_L = 1$) for the duration of the model simulation. This establishes a constant DF ratio ($DF_{well} = 0.000015$) that is later applied to all contaminants.
- The surface water dilution factor DF_{creek} = water flux from disposal cell divided by creek water flow rate at the location in Bear Creek near the hypothetical receptor ($DF_{creek} = 0.00245$).
- Therefore, the modeled contaminant concentration in the well due to a unit waste concentration is then calculated $C_{well} = (DF_{well}/DF_{creek}) \times C_{creek}$ (PATHRAE modeled contaminant concentration in the surface water).

The peak effective risk or dose was calculated as the risk or dose due to ingestion of 730 L per year of water drawn from the well, plus the consumption of agricultural products and livestock irrigated or consumed with the creek surface water. Thus:

$PR_{eff} = PR_{creek} \times [EU - 730 + (DF_{well}/DF_{creek}) \times 730]/EU$, where

PR_{eff} = Peak Effective Risk,

PR_{creek} = Peak Creek Risk,

EU = Equivalent Uptake,

and DF_{well} and DF_{creek} are the dilution factors calculated for the well and the creek, respectively. Similarly,

$PD_{eff} = PD_{creek} \times [EU - 730 + (DF_{well}/DF_{creek}) \times 730]/EU$, where

PD_{eff} = Peak Effective Dose, and

PD_{creek} = Peak Creek Dose.

The Peak Creek Risk (PR_{creek}) or Peak Creek Dose (PD_{creek}) corresponds to ingestion of the creek water at the annual EU rate.

5.2.1 Radioactive Constituents - Risk

The Peak Creek Risk for radioactive constituents is:

$PR_{creek} = PC_{creek} \times EU \times SF \times$ 30-yr exposure duration, where

PC_{creek} = Peak Creek concentration, and

SF = Slope Factor = Excess Lifetime Cancer Risk (ELCR)/Concentration (pCi)

The Peak Creek concentration is calculated directly by the PATHRAE-RAD computer code and slope factors are obtained from the latest EPA risk guidance (EPA 2012).

5.2.2 Hazardous Constituents - Risk and Dose

For hazardous constituents, both carcinogenic risk and non-carcinogenic dose are calculated. For carcinogens:

$PR_{creek} = PLI_{creek} \times SF$, where

PLI_{creek} = Peak Creek Lifetime Intake for Carcinogens = $PC_{creek} \times EU \times$ 30-yr exposure duration/ [70 kg body weight × 365 d/yr × 70-yr life].

For non-carcinogens the Peak Creek Daily Intake (Dose) for non-carcinogens (PD_{creek}) is calculated using PATHRAE-HAZ generated data and the formula below:

$PD_{creek} = PC_{creek} \times EU/(70$ kg body weight × 365 d/yr)

The peak effective risks and doses calculated using the PATHRAE-RAD and PATHRAE-HAZ results and equations listed above for EMDF, based on unit source terms, are given in Tables F-6 and F-7 for the radioactive and hazardous contaminants of concern (COCs), respectively. The COC list is based on the list of constituents in Table A.1 of the approved EMWMF WAC (DOE 2001a, Table A.1 revised 10/28/2008) for which a WAC limit is provided.

Table F-6. Peak Effective Risks for the Proposed EMDF for Radioactive Constituents

Nuclide COC	Peak Conc. in Bear Creek (pCi/L) or PC_{creek}	Ingestion Slope Factor (1/pCi)	Equivalent Uptake (L/yr)	Peak Effective Risk* or PR_{eff} (GW+SW) (ELCR)	Peak Time (yr)
H-3	7.23E-05	5.07E-14	1.166E+03	4.84E-14	401
C-14	1.14E+06	1.55E-12	9.564E+02	1.22E-02	570
Tc-99	1.05E+06	2.75E-12	7.403E+02	1.27E-03	607
I-129	5.37E+05	1.48E-10	8.327E+02	2.55E-01	1,096
U-233	3.14E+04	7.18E-11	7.380E+02	8.39E-04	42,452
U-234	3.35E+04	7.07E-11	7.380E+02	8.82E-04	42,472
U-235	3.78E+04	6.96E-11	7.380E+02	9.79E-04	51,628
U-236	3.78E+04	6.70E-11	7.380E+02	9.43E-04	42,593
U-238	3.78E+04	6.40E-11	7.380E+02	9.01E-04	51,628
Np-237	2.65E+04	6.18E-11	7.338E+02	4.03E-04	90,317
Pu-239	2.03E+03	1.35E-10	7.329E+02	6.01E-05	88,714
Pu-240	2.22E+00	1.35E-10	7.329E+02	6.57E-08	87,960
Am-241	**	1.04E-10	7.338E+02	**	**

*Based on a 1 Ci/m^3 concentration in the waste.

** Contamination migration was modeled and radioactively decays to an insignificant level.

Table F-7. Peak Effective Risks and Doses for the Proposed EMDF for Hazardous Constituents

COC	Peak Dose in Bear Creek (mg/kg-day) or PD_{creek}	Peak Conc. in Bear Creek PC_{creek} (mg/L)	Peak Time (year)	Reference Dose (mg/kg-day)	Equivalent Uptake (L/yr)	Slope Factor (1/(mg/kg-d))	Peak Eff. Risk* or PR_{eff}(GW + SW) (ELCR)	Peak Effective Dose* or PD_{eff} (GW + SW) (mg/kg-day)
Antimony	1.99E-03	6.94E-02	50,363	4.00E-04	7.332E+02			2.07E-05
Barium	6.95E-04	2.41E-02	144,849**	2.00E-01	7.372E+02			1.09E-05
Boron	1.23E-02	4.21E-01	8,369	2.00E-01	7.474E+02			3.59E-04
Chromium (Total)	3.99E-03	1.31E-01	26,741	1.00E+00	7.787E+02			2.72E-04
Lead	3.83E-04	1.33E-02	262,956**	1.40E-03	7.369E+02			5.88E-06
Manganese	1.91E-04	6.64E-03	525,416**	1.40E-01	7.355E+02			2.57E-06
Molybdenum	1.93E-03	6.59E-02	52,987	5.00E-03	7.498E+02			6.23E-05
Selenium	4.50E-03	8.77E-02	39,864	5.00E-03	1.312E+03			2.01E-03
Strontium	3.02E-03	9.73E-02	34,515	6.00E-01	7.941E+02			2.61E-04
Tin	1.55E-02	5.00E-01	7,057	6.00E-01	7.907E+02			1.28E-03
Vanadium	3.87E-04	1.33E-02	262,956**	5.00E-03	7.457E+02			1.04E-05
U-233	7.93E-04	2.75E-02	42,452	3.00E-03	7.371E+02			1.24E-05
U-234	8.46E-04	2.93E-02	42,472	3.00E-03	7.371E+02			1.32E-05
U-235	9.54E-04	3.31E-02	51,628	3.00E-03	7.371E+02			1.49E-05
U-236	9.53E-04	3.30E-02	42,593	3.00E-03	7.371E+02			1.49E-05

Table F-7. Peak Effective Risks and Doses for the Proposed EMDF for Hazardous Constituents (Continued)

COC	Peak Dose in Bear Creek (mg/kg-day) or PD_{creek}	Peak Conc. in Bear Creek PC_{creek} (mg/L)	Peak Time (year)	Reference Dose (mg/kg-day)	Equivalent Uptake (L/yr)	Slope Factor (1/(mg/kg-d))	Peak Eff. Risk* or PR_{eff} (GW + SW) (ELCR)	Peak Effective Dose* or PD_{eff} (GW + SW) (mg/kg-day)
U-238	9.55E-04	3.31E-02	51,628	3.00E-03	7.371E+02			1.49E-05
2,4-D	4.71E-02	1.64E+00	1,039	1.00E-02	7.328E+02			4.63E-04
2,4,5-T[Silvex]	1.38E-02	4.81E-01	1,101	8.00E-03	7.342E+02			1.62E-04
Acenaphthene	2.37E-04	8.23E-03	241,959**	6.00E-02	7.365E+02			3.51E-06
Acenaphthylene	1.11E-03	3.87E-02	32,515	6.00E-02	7.337E+02			1.23E-05
Acetone	1.90E-01	6.63E+00	849	9.00E-01	7.328E+02			1.87E-03
Acetonitrile	2.42E-01	8.42E+00	699	6.00E-03	7.329E+02			2.41E-03
Acetophenone	1.53E-01	5.34E+00	885	1.00E-01	7.328E+02			1.51E-03
Acrolein	2.40E-01	8.35E+00	704	5.00E-04	7.329E+02			2.39E-03
Acrylonitrile	2.37E-01	8.27E+00	710	4.00E-02	7.328E+02	5.40E-01	5.40E-04	2.33E-03
Aldrin	1.17E-06	4.09E-05	256,132**	3.00E-05	7.330E+02	1.70E+01	8.64E-08	1.18E-08
Aroclor-1221	3.18E-04	1.11E-02	556,946**	0.00E+00	7.351E+02	2.00E+00	3.54E-06	4.11E-06
Aroclor-1232	3.33E-04	1.16E-02	75,580	0.00E+00	7.331E+02	2.00E+00	2.92E-06	3.41E-06
Benzene	2.05E-02	7.16E-01	4,779	4.00E-03	7.328E+02	5.50E-02	4.76E-06	2.02E-04
Benzoic Acid	2.35E-01	8.18E+00	698	4.00E+00	7.328E+02			2.31E-03

Table F-7. Peak Effective Risks and Doses for the Proposed EMDF for Hazardous Constituents (Continued)

COC	Peak Dose in Bear Creek (mg/kg-day) or PD_{creek}	Peak Conc. in Bear Creek PC_{creek} (mg/L)	Peak Time (year)	Reference Dose (mg/kg-day)	Equivalent Uptake (L/yr)	Slope Factor (1/(mg/kg-d))	Peak Eff. Risk* or PR_{eff} (GW + SW) (ELCR)	Peak Effective Dose* or PD_{eff} (GW + SW) (mg/kg-day)
Benzyl Alcohol	2.03E-01	7.08E+00	808	1.00E-01	7.328E+02			2.00E-03
Benzidine	6.76E-03	2.36E-01	14,878	3.00E-03	7.328E+02	2.30E+02	6.56E-03	6.65E-05
alpha-BHC	5.53E-04	1.92E-02	9,734	8.00E-03	7.342E+02	6.30E+00	1.75E-05	6.48E-06
beta-BHC	5.53E-04	1.92E-02	11,729	0.00E+00	7.346E+02	1.80E+00	5.22E-06	6.78E-06
delta-BHC	5.52E-04	1.92E-02	11,729	0.00E+00	7.329E+02	1.80E+00	4.24E-06	5.51E-06
Bromodichloromethane	2.09E-01	7.29E+00	733	2.00E-02	7.328E+02	6.20E-02	5.47E-05	2.06E-03
Bromoform	6.90E-03	2.41E-01	1,388	2.00E-02	7.328E+02	7.90E-03	2.30E-07	6.79E-05
Bromomethane	2.06E-01	7.20E+00	797	1.40E-03	7.328E+02			2.03E-03
Butylbenzene	4.23E-03	1.47E-01	5,728	5.00E-02	7.334E+02			4.50E-05
Carbazole	1.24E-04	4.33E-03	18,290	0.00E+00	7.340E+02	2.00E-02	1.22E-08	1.42E-06
Carbon Disulfide	8.14E-02	2.84E+00	919	1.00E-01	7.328E+02			8.01E-04
Carbon tetrachloride	1.62E-02	5.64E-01	6,039	4.00E-03	7.329E+02	7.00E-02	4.84E-06	1.62E-04
Chlordane	4.17E-06	1.35E-04	454,552**	5.00E-04	7.905E+02	3.50E-01	5.14E-08	3.42E-07
Chlorobenzene	3.44E-02	1.20E+00	1,974	2.00E-02	7.329E+02			3.43E-04
Chloroform	4.91E-02	1.71E+00	2,058	1.00E-02	7.328E+02	3.10E-02	6.41E-06	4.83E-04

Table F-7. Peak Effective Risks and Doses for the Proposed EMDF for Hazardous Constituents (Continued)

COC	Peak Dose in Bear Creek (mg/kg-day) or PD_{creek}	Peak Conc. in Bear Creek PC_{creek} (mg/L)	Peak Time (year)	Reference Dose (mg/kg-day)	Equivalent Uptake (L/yr)	Slope Factor (1/(mg/kg-d))	Peak Eff. Risk* or PR_{eff}(GW + SW) (ELCR)	Peak Effective Dose* or PD_{eff} (GW + SW) (mg/kg-day)
Chloromethane [Methyl Chloride]	2.06E-01	7.19E+00	799	0.00E+00	7.328E+02	1.30E-02	1.13E-05	2.03E-03
o-Chlorotoluene	2.58E-02	9.00E-01	3,385	2.00E-02	7.332E+02			2.68E-04
m-Cresol	1.51E-01	5.28E+00	895	5.00E-02	7.328E+02			1.49E-03
o-Cresol	1.13E-01	3.93E+00	1,168	5.00E-02	7.328E+02			1.11E-03
p-Cresol	1.53E-01	5.35E+00	885	1.00E-01	7.328E+02			1.51E-03
Cumene [Isopropylbenzene]	4.23E-03	1.47E-01	5,791	1.00E-01	7.334E+02			4.50E-05
Cyanide	3.79E-03	1.32E-01	26,479	6.00E-04	7.328E+02			3.73E-05
DDD	7.20E-06	2.16E-04	240,909**	0.00E+00	8.493E+02	2.40E-01	1.08E-07	1.05E-06
DDE	3.11E-06	9.62E-05	6,043	0.00E+00	8.270E+02	3.40E-01	5.56E-08	3.81E-07
Di-n-butylphthalate	2.68E-01	8.50E+00	693	1.00E-01	8.061E+02			2.68E-02
Dibromochloromethane	1.28E-01	4.47E+00	1,038	2.00E-02	7.328E+02	8.40E-02	4.54E-05	1.26E-03
1,2-Dichlorobenzene	5.52E-03	1.92E-01	2,982	9.00E-02	7.333E+02			5.80E-05
1,3-Dichlorobenzene	2.35E-03	8.19E-02	42,646	8.90E-02	7.335E+02			2.53E-05

Table F-7. Peak Effective Risks and Doses for the Proposed EMDF for Hazardous Constituents (Continued)

COC	Peak Dose in Bear Creek (mg/kg-day) or PD_{creek}	Peak Conc. in Bear Creek PC_{creek} (mg/L)	Peak Time (year)	Reference Dose (mg/kg-day)	Equivalent Uptake (L/yr)	Slope Factor (1/(mg/kg-d))	Peak Eff. Risk* or PR_{eff}(GW + SW) (ELCR)	Peak Effective Dose* or PD_{eff} (GW + SW) (mg/kg-day)
1,4-Dichlorobenzene	5.61E-03	1.96E-01	4,475	7.00E-02	7.332E+02	5.40E-03	1.35E-07	5.82E-05
1,2,-cis-Dichloroethylene	3.31E-02	1.15E+00	3,731	2.00E-03	7.328E+02			3.26E-04
1,2-trans-Dichloroethylene	1.64E-01	5.72E+00	973	2.00E-02	7.328E+02			1.61E-03
Dichlorodifluoromethane	1.93E-02	6.73E-01	850	2.00E-01	7.328E+02			1.90E-04
1,2-Dichloropropane	1.52E-01	5.31E+00	890	9.00E-02	7.328E+02	3.60E-02	2.31E-05	1.50E-03
Dieldrin	1.26E-03	3.89E-02	86,175	5.00E-05	8.286E+02	1.60E+01	1.08E-03	1.57E-04
Diethylphthalate	7.45E-02	2.60E+00	1,388	8.00E-01	7.328E+02			7.33E-04
1,2-Dimethylbenzene	1.52E-02	5.29E-01	2,106	2.00E-01	7.330E+02			1.54E-04
2,4-Dimethylphenol	1.42E-02	4.96E-01	8,531	2.00E-02	7.328E+02			1.40E-04
Dimethylphthalate	1.65E-01	5.77E+00	966	1.00E+01	7.328E+02			1.62E-03
2,4 Dinitrotoluene	1.86E-02	6.49E-01	916	2.00E-03	7.328E+02	3.10E-01	2.43E-05	1.83E-04
2,6 Dinitrotoluene	2.43E-02	8.47E-01	859	1.00E-03	7.328E+02	6.8E-01	6.97E-05	2.39E-04
Endosulfan plus metabolites	3.11E-05	1.08E-03	13,899	6.00E-03	7.334E+02			3.31E-07
Endrin	1.74E-05	6.01E-04	57,187	3.00E-04	7.400E+02			3.39E-07
Endrin Aldehyde	1.74E-05	6.01E-04	62,772	3.00E-04	7.400E+02			3.39E-07

Table F-7. Peak Effective Risks and Doses for the Proposed EMDF for Hazardous Constituents (Continued)

COC	Peak Dose in Bear Creek (mg/kg-day) or PD_{creek}	Peak Conc. in Bear Creek PC_{creek} (mg/L)	Peak Time (year)	Reference Dose (mg/kg-day)	Equivalent Uptake (L/yr)	Slope Factor (1/(mg/kg-d))	Peak Eff. Risk* or PR_{eff} (GW + SW) (ELCR)	Peak Effective Dose* or PD_{eff} (GW + SW) (mg/kg-day)
Endrin Ketone	1.74E-05	6.01E-04	62,772	3.00E-04	7.400E+02			3.39E-07
Ethylbenzene	1.17E-02	4.06E-01	1,879	1.00E-01	7.330E+02	1.10E-02	5.55E-07	1.18E-04
Ethylchloride	1.87E-01	6.52E+00	868	4.00E-01	7.328E+02	2.90E-03	2.29E-06	1.84E-03
Heptachlor	1.25E-05	4.33E-04	126,476**	5.00E-04	7.365E+02	4.50E+00	3.57E-07	1.85E-07
Heptachlor Epoxide	1.47E-05	4.81E-04	45,901	1.30E-05	7.789E+02	9.10E+00	3.91E-06	1.01E-06
Hexachlorobenzene	4.49E-07	1.49E-05	289,202**	8.00E-04	7.695E+02	1.60E+00	1.76E-08	2.56E-08
Hexachloroethane	3.46E-03	1.20E-01	9,839	7.00E-04	7.342E+02	4.00E-02	6.93E-07	4.06E-05
n-Hexane	6.57E-04	2.28E-02	1,533	6.00E-02	7.342E+02			7.70E-06
1-Hexanol	2.09E-01	7.29E+00	789	4.00E-02	7.328E+02			2.06E-03
2-Hexanone	2.09E-01	7.29E+00	789	5.00E-03	7.328E+02			2.06E-03
Isophorone	2.05E-02	7.16E-01	4,779	2.00E-01	7.329E+02	9.50E-04	8.34E-08	2.04E-04
Lindane	5.53E-04	1.92E-02	18,238	3.00E-04	7.337E+02	1.10E+00	2.87E-06	6.11E-06
Methanol	2.41E-01	8.40E+00	701	5.00E-01	7.330E+02			2.44E-03
Methylene Chloride	1.91E-01	6.65E+00	853	6.00E-03	7.328E+02	2.00E-03	1.61E-06	1.88E-03
Methylcyclohexane	9.66E-04	3.37E-02	793	6.00E-02	7.329E+02			9.63E-06

Table F-7. Peak Effective Risks and Doses for the Proposed EMDF for Hazardous Constituents (Continued)

COC	Peak Dose in Bear Creek (mg/kg-day) or PD_{creek}	Peak Conc. in Bear Creek PC_{creek} (mg/L)	Peak Time (year)	Reference Dose (mg/kg-day)	Equivalent Uptake (L/yr)	Slope Factor (1/(mg/kg-d))	Peak Eff. Risk* or PR_{eff} (GW + SW) (ELCR)	Peak Effective Dose* or PD_{eff} (GW + SW) (mg/kg-day)
Methyl Isobutyl Ketone	2.37E-01	8.25E+00	711	8.00E-02	7.328E+02			2.33E-03
Methyl Methacrylate	2.16E-01	7.54E+00	767	1.40E+00	7.328E+02			2.13E-03
1-Methyl-4-(1-methylethyl)-benzene	4.21E-03	1.47E-01	4,826	3.70E-02	7.334E+02			4.48E-05
2-Methylnapthalene	1.70E-03	5.92E-02	16,085	4.00E-03	7.342E+02			1.99E-05
(1-Methylpropyl)benzene	4.21E-03	1.47E-01	4,826	3.70E-02	7.334E+02			4.48E-05
Naphthalene	1.99E-03	6.94E-02	50,363	2.00E-02	7.332E+02			2.07E-05
4-Nitrobenzenamine [4-Nitroaniline]	7.38E-10	2.57E-08	1,678	4.00E-03	7.328E+02	2.00E-02	6.22E-14	7.26E-12
Nitrobenzene	1.34E-01	4.66E+00	1,001	2.00E-03	7.328E+02			1.32E-03
2-Nitrophenol	4.40E-02	1.53E+00	2,831	6.20E-02	7.328E+02			4.33E-04
4-Nitrophenol	3.70E-02	1.29E+00	2,789	6.20E-02	7.328E+02			3.64E-04
N-nitroso-di-n-propylamine	8.35E-02	2.91E+00	1,539	0.00E+00	7.328E+02	7.00E+00	2.46E-03	8.22E-04
N-Nitrosodiphenylamine	2.42E-03	8.42E-02	2,654	2.00E-02	7.330E+02	4.90E-03	5.13E-08	2.45E-05
Phenol	8.74E-02	3.05E+00	1,476	3.00E-01	7.328E+02			8.60E-04
Propylbenzene	4.21E-03	1.47E-01	4,826	3.70E-02	7.334E+02			4.48E-05
Propylene glycol	2.41E-01	8.40E+00	701	2.00E+01	7.334E+02			2.57E-03

Table F-7. Peak Effective Risks and Doses for the Proposed EMDF for Hazardous Constituents (Continued)

COC	Peak Dose in Bear Creek (mg/kg-day) or PD_{creek}	Peak Conc. in Bear Creek PC_{creek} (mg/L)	Peak Time (year)	Reference Dose (mg/kg-day)	Equivalent Uptake (L/yr)	Slope Factor (1/(mg/kg-d))	Peak Eff. Risk* or PR_{eff} (GW + SW) (ELCR)	Peak Effective Dose* or PD_{eff} (GW + SW) (mg/kg-day)
Pyridine	2.24E-01	7.81E+00	744	1.00E-03	7.328E+02			2.20E-03
Styrene	1.93E-02	6.72E-01	5,272	2.00E-01	7.329E+02			1.92E-04
1,1,1,2-Tetrachloroethane	7.38E-02	2.57E+00	1,596	3.00E-02	7.330E+02	2.60E-02	8.31E-06	7.46E-04
1,1,2,2-Tetrachloroethane	1.21E-01	4.23E+00	1,086	2.00E-02	7.328E+02	2.00E-01	1.02E-04	1.19E-03
Tetrachloroethene	5.18E-03	1.81E-01	18,639	6.00E-03	7.329E+02	2.10E-03	4.66E-08	5.17E-05
2,3,4,6-Tetrachlorophenol	1.53E-04	5.33E-03	654,022**	3.00E-02	7.351E+02			1.98E-06
Toluene	6.19E-03	2.16E-01	15,615	8.00E-02	7.330E+02			6.26E-05
1,2,4-Trichlorobenzene	3.94E-03	1.37E-01	5,130	1.00E-02	7.339E+02	2.90E-02	5.54E-07	4.46E-05
Trichloroethene	1.38E-02	4.82E-01	7,047	5.00E-04	7.329E+02	4.60E-02	2.72E-06	1.38E-04
Trichlorofluoromethane	7.59E-02	2.65E+00	1,438	3.00E-01	7.328E+02			7.47E-04
2,4,6-Trichlorophenol	4.82E-02	1.68E+00	2,165	1.00E-03	7.337E+02	1.10E-02	2.51E-06	5.33E-04
1,2,3-Trichloropropane	1.21E-01	4.19E+00	1,101	4.00E-03	7.400E+02	3.00E+01	3.04E-02	2.36E-03
Trimethylbenzene [mixture of isomers]	3.94E-03	1.37E-01	5,130	5.00E-02	7.339E+02			4.46E-05
1,2,4-Trimethylbenzene	3.94E-03	1.37E-01	5,130	5.00E-02	7.339E+02			4.46E-05

Table F-7. Peak Effective Risks and Doses for the Proposed EMDF for Hazardous Constituents (Continued)

COC	Peak Dose in Bear Creek (mg/kg-day) or PD_{creek}	Peak Conc. in Bear Creek PC_{creek} (mg/L)	Peak Time (year)	Reference Dose (mg/kg-day)	Equivalent Uptake (L/yr)	Slope Factor (1/(mg/kg-d))	Peak Eff. Risk* or PR_{eff}(GW + SW) (ELCR)	Peak Effective Dose* or PD_{eff} (GW + SW) (mg/kg-day)
1,3,5-Trimethylbenzene	3.33E-03	1.16E-01	9,262	1.00E-02	7.333E+02			3.50E-05
Vinyl Chloride	7.21E-02	2.52E+00	1,766	3.00E-03	7.328E+02	7.20E-01	2.19E-04	7.09E-04
Xylene [mixture of isomers]	7.32E-03	2.55E-01	3,385	2.00E-01	7.332E+02			7.60E-05

*Based on a 1 kg/m^3 concentration in the waste.

** COC was modeled and did not arrive at the hypothetical receptor location within 100,000 years (model results indicate there would be no PWAC limit for the COC). The PATHRAE model predicts peak concentrations for a time period 10 times the defined time limit. For purposes of comparing EMDF PWAC values to the EMWMF WAC, a PWAC value was derived from the peak concentration in the 100,000 to 1,000,000 year timeframe.

6. ANALYTIC PWAC

Based on the peak effective risk and dose from PATHRAE modeling and calculations, the analytic PWAC for COC were calculated for radioactive and hazardous COCs as described below.

6.1 PWAC CALCULATION

The following risk/toxicity criteria for the radionuclides and hazardous constituents for the EMDF are used to calculate the analytic PWAC (see Sect. 2.3 of this Appendix).

- An ELCR (carcinogenic risk) $\leq 1 \times 10^{-5}$ and a hazard index (HI) ≤ 1 for the first 1,000 years after closure.
- Carcinogenic risk $\leq 10^{-4}$ and HI ≤ 3 for >1,000 years to 100,000 years after closure.

Respective ELCR and HI were used for each constituent based on their peak time at the receptor location.

For each radioactive constituent:

$$\text{Risk PWAC} = 6.25 \times 10^{5} \times \text{ELCR} / [PR_{eff} \text{ from a 1 Ci/m}^3 \text{ source}]$$

The PWAC resulting from risk are expressed in picocuries per gram (pCi/g) and the factor 6.25×10^{5} results from unit conversions. ELCR are 10^{-5} (for ≤1,000 years) and 10^{-4} (for >1,000 years), respectively.

For each hazardous constituent:

$$\text{Risk PWAC} = 625 \times \text{ELCR} / [PR_{eff} \text{ from a 1 kg/m}^3 \text{ source}]$$

$$\text{HI PWAC} = 625 \times \text{HI} / [PD_{eff} \text{ from a 1 kg/m}^3 \text{ source/RD}], \text{ where}$$

RD = Reference Dose

The PWAC are expressed in milligrams per kilogram (mg/kg) and the factor of 625 comes from unit conversions. ELCR is 10^{-5} (for ≤1,000 years) or 10^{-4} (for >1000 years), respectively, for carcinogens. HI is 1 (for ≤1,000 years) and 3 (for >1,000 years), respectively, for non-carcinogens.

Tables F-8 and F-9 summarize the analytic PWAC calculated for the 0 to 1,000-year and 1,000- to 100,000-year periods after EMDF closure for radioactive and hazardous constituents. The PWAC for each constituent is based on a calculation that assumes a single waste stream of that constituent occupies the entire cell.

Table F-8. EMDF Analytic PWAC for Radionuclides

Nuclide COC	Carcinogenic PWAC (pCi/g) 0 to 1000 Years	Carcinogenic PWAC (pCi/g) - >1000 to 100,000 Years
H-3	1.29E+14	
C-14	5.11E+02	
Tc-99	4.90E+03	
I-129		2.45E+02
U-233		7.45E+04
U-234		7.09E+04
U-235		6.38E+04
U-236		6.63E+04
U-238		6.94E+04
Np-237		1.55E+05
Pu-239		1.04E+06
Pu-240		9.51E+08
Am-241	NL	NL

NL = no limit. "NL" indicates contaminant migration was modeled and radioactively decays to an insignificant level.

Table F-9. EMDF Analytic PWAC for Hazardous Constituents

COC	Carcinogenic PWAC (mg/kg) 0 to 1000 Years	HI PWAC (mg/kg) 0 to 1000 Years	Carcinogenic PWAC* (mg/kg) ->1000 to 100,000 Years	HI PWAC* (mg/kg) - >1000 to 100,000 Years
Antimony				3.63E+04
Barium				3.43E+07**
Boron				1.04E+06
Chromium (Total)				6.89E+06
Lead				4.47E+05**
Manganese				1.02E+08**
Molybdenum				1.50E+05
Selenium				4.66E+03
Strontium				4.32E+06
Tin				8.81E+05
Vanadium				8.98E+05**
U-233				4.54E+05
U-234				4.26E+05
U-235				3.78E+05
U-236				3.78E+05
U-238				3.77E+05
2,4-D				4.05E+04
2,4,5-T[Silvex]				9.27E+04
Acenaphthene				3.20E+07**
Acenaphthylene				9.17E+06
Acetone		3.01E+05		
Acetonitrile		1.55E+03		
Acetophenone		4.15E+04		
Acrolein		1.31E+02		
Acrylonitrile	1.16E+01	1.07E+04		
Aldrin			7.23E+05*	4.76E+06**
Aroclor-1221			1.76E+04**	
Aroclor-1232			2.14E+04	
Benzene			1.31E+04	3.72E+04
Benzoic Acid		1.08E+06		
Benzyl Alcohol		3.13E+04		
Benzidine			9.52E+00	8.46E+04
alpha-BHC			3.58E+03	2.31E+06
beta-BHC			1.20E+04	
delta-BHC			1.47E+04	
Bromodichloromethane	1.14E+02	6.08E+03		
Bromoform			2.71E+05	5.52E+05
Bromomethane		4.32E+02		
Butylbenzene				2.08E+06
Carbazole			5.12E+06	

Table F-9. EMDF Analytic PWAC for Hazardous Constituents (Continued)

COC	Carcinogenic PWAC (mg/kg) 0 to 1000 Years	HI PWAC (mg/kg) 0 to 1000 Years	Carcinogenic PWAC* (mg/kg) ->1000 to 100,000 Years	HI PWAC* (mg/kg) - >1000 to 100,000 Years
Carbon Disulfide		7.80E+04		
Carbon tetrachloride			1.29E+04	4.64E+04
Chlordane			1.21E+06**	2.74E+06**
Chlorobenzene				1.09E+05
Chloroform			9.75E+03	3.88E+04
Chloromethane [Methyl Chloride]	5.53E+02			
o-Chlorotoluene				1.40E+05
m-Cresol		2.10E+04		
o-Cresol				8.43E+04
p-Cresol		4.15E+04		
Cumene [Isopropylbenzene]				4.16E+06
Cyanide				3.02E+04
DDD			5.81E+05**	
DDE			1.12E+06	
Di-n-butylphthalate		2.33E+03		
Dibromochloromethane			1.38E+03	2.98E+04
1,2-Dichlorobenzene				2.91E+06
1,3-Dichlorobenzene				6.58E+06
1,4-Dichlorobenzene			4.63E+05	2.25E+06
1,2,-cis-Dichloroethylene				1.15E+04
1,2-trans-Dichloroethylene		7.75E+03		
Dichlorodifluoromethane		6.58E+05		
1,2-Dichloropropane	2.70E+02	3.76E+04		
Dieldrin			5.81E+01	5.99E+02
Diethylphthalate				2.05E+06
1,2-Dimethylbenzene				2.44E+06
2,4-Dimethylphenol				2.68E+05
Dimethylphthalate		3.85E+06		
2,4 Dinitrotoluene	2.57E+02	6.83E+03		
2,6 Dinitrotoluene	8.97E+01	2.61E+03		
Endosulfan plus metabolites				3.40E+07
Endrin				1.66E+06
Endrin Aldehyde				1.66E+06
Endrin Ketone				1.66E+06
Ethylbenzene			1.13E+05	1.59E+06
Ethylchloride	2.73E+03	1.36E+05		
Heptachlor			1.75E+05**	5.06E+06**
Heptachlor Epoxide			1.60E+04	2.42E+04
Hexachlorobenzene			3.56E+06**	5.85E+07**
Hexachloroethane			9.02E+04	3.23E+04

Table F-9. EMDF Analytic PWAC for Hazardous Constituents (Continued)

COC	Carcinogenic PWAC (mg/kg) 0 to 1000 Year	HI PWAC (mg/kg) 0 to 1000 Years	Carcinogenic PWAC* (mg/kg) ->1000 to 100,000 Years	HI PWAC* (mgskg) - >1000 to 100,000 Years
n-Hexane				1.46E+07
1-Hexanol		1.22E+04		
2-Hexanone		1.52E+03		
Isophorone			7.49E+05	1.83E+06
Lindane			2.18E+04	9.20E+04
Methanol		1.28E+05		
Methylene Chloride	3.89E+03	2.00E+03		
Methylcyclohexane		3.89E+06		
Methyl Isobutyl Ketone		2.14E+04		
Methyl Methacrylate		4.12E+05		
1-Methyl-4-(1-methylethyl)-benzene				1.55E+06
2-Methylnapthalene				3.76E+05
(1-Methylpropyl)benzene				1.55E+06
Naphthalene				1.82E+06
4-Nitrobenzenamine [4-Nitroaniline]			1.01E+12	1.03E+12
Nitrobenzene				2.84E+03
2-Nitrophenol				2.69E+05
4-Nitrophenol				3.19E+05
N-nitroso-di-n-propylamine			2.54E+01	
N-Nitrosodiphenylamine			1.22E+06	4.56E+04
Phenol				6.54E+05
Propylbenzene				1.55E+06
Propylene glycol		4.87E+06		
Pyridine		2.84E+02		
Styrene				1.95E+06
1,1,1,2-Tetrachloroethane			7.53E+03	7.54E+04
1,1,2,2-Tetrachloroethane			6.11E+02	3.15E+04
Tetrachloroethene			1.34E+06	2.18E+05
2,3,4,6-Tetrachlorophenol				2.84E+07**
Toluene				2.40E+06
1,2,4-Trichlorobenzene			1.13E+05	4.20E+05
Trichloroethene			2.30E+04	6.81E+03
Trichlorofluoromethane				7.53E+05
2,4,6-Trichlorophenol			2.49E+04	3.52E+03
1,2,3-Trichloropropane			2.06E+00	3.18E+03

Table F-9. EMDF Analytic PWAC for Hazardous Constituents (Continued)

COC	Carcinogenic PWAC (mg/kg) 0 to 1000 Year	HI PWAC (mg/kg) 0 to 1000 Years	Carcinogenic PWAC* (mg/kg) ->1000 to 100,000 Years	HI PWAC* (mgskg) - >1000 to 100,000 Years
Trimethylbenzene [mixture of isomers]				2.10E+06
1,2,4-Trimethylbenzene				2.10E+06
1,3,5-Trimethylbenzene				5.36E+05
Vinyl Chloride			2.85E+02	7.93E+03
Xylene [mixture of isomers]				4.94E+06

* Waste with a constituent concentration greater than 1.00E+06 mg/kg is not physically possible. A PWAC value greater than 1.00E+06 mg/kg would be used only in the content of a SOF calculation (see Sect. 6.2).

** COC was modeled and did not arrive at the hypothetical receptor location within 100,000 years (model results indicate there would be no PWAC limit for the COC). The PATHRAE model predicts peak concentrations for a time period 10 times the defined time limit. For purposes of comparing EMDF PWAC values to the EMWMF WAC, a PWAC value was derived from the peak concentration in the 1,000,000 year timeframe.

6.2 DISCUSSION OF PWAC RESULTS

The analytic PWAC calculated for radioactive constituents consist mostly of long-lived radionuclides, such as Tc-99, uranium, and plutonium. Short-lived radionuclides rapidly decay before migrating to the environment. PWAC for hazardous constituents are developed for risk (carcinogenic PWAC) and dose (HI PWAC).

Note that the PWAC for many of the individual COCs are higher than the COC's physical limit (pure form), suggesting there is no analytic PWAC limit on the constituent if it is placed in the disposal cell as a single constituent occupying the entire disposal cell volume. However, as described in Sect. 1.1, the SOF calculation method was developed for the existing EMWMF to determine whether a waste containing multiple contaminants is acceptable for disposal. For those constituents with a calculated PWAC limit higher than the physical limit, even the presence of the constituent in a nearly pure form in a multi-contaminant waste stream would have a very small contributing impact on risk in a SOF calculation.

Several conservative assumptions were made for WAC development. It was assumed that organic constituents would not degrade and the initial contaminant mass would remain constant in the disposal cell. This assumption is conservative because organic COCs in the disposal cell would undergo biodegradation or volatilization during cell operation and during the early years after facility closure when the cell design features would be fully functional or during migration after release. Thus, there would be negligible adverse impact to the environment from organic COCs. Sensitivity runs were performed using biodegradation rates for organic COCs during the PATHRAE simulations for EMDF and resulted in unlimited PWAC for many of the COCs.

The development of the analytic PWAC assumed that all waste is a soil or soil-like matrix with one K_d value for each radiological and chemical constituent within the waste (see Sect. 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.

Another conservatism in the analytic PWAC development is that no credit is taken in the performance period for the man-made geosynthetic components, such as HDPE liners, in the final cover and liner systems. Landfill design and disposal experts have recently developed evidence through empirical testing and research that HDPE liners could perform their intended function for upwards of 500 to 1,000 years or more (Rowe, et al. 2009) in the likely soil temperature range for this region. An additional conservative aspect of the methodology used to develop the EMWMF analytic WAC was the use of an additive approach to calculate risk from each radioisotope and/or chemical constituent that individually occurs within the post-closure modeled period. The peak risk from each single constituent to the hypothetical resident farmer was combined and collectively compared against the performance measures. This is more conservative than typical time-dependent based analytic WAC that are widely used at other DOE and/or NRC-regulated LLW disposal facilities.

There are uncertainties in the PWAC analysis due to data gaps in site-specific information and the conceptual stage of the disposal facility design at the proposed EMDF site. As the site selection and design process proceeds, additional site-specific data obtained through site investigation and hydrogeological/geotechnical analysis (e.g., groundwater depth), 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 PWAC analysis would be re-evaluated to confirm that the EMDF WAC is still protective for radionuclide and chemical constituents.

6.3 COMPARISON TO EMWMF ANALYTIC WAC

Table F-10 compares the analytic PWAC developed for EMDF with the EMWMF analytic WAC. As shown in the table, the analytic PWAC for EMDF are generally 10 to 100 times higher than the analytic WAC for EMWMF.

Table F-10. EMDF Analytic PWAC Comparison with EMWMF Analytic WAC

RADIONUCLIDES				
COC	EMWMF		Proposed EMDF	
	Carcinogenic PWAC (pCi/g)	HI PWAC (pCi/g)	Carcinogenic PWAC (pCi/g)	HI PWAC (pCi/g)
Am-241	2.00E+21		NL	
C-14	1.65E+02		5.11E+02	
I-129	1.30E+01		2.45E+02	
Np-237	3.20E+02		1.55E+05	
Pu-239	7.20E+02		1.04E+06	
Pu-240	5.80E+03		9.51E+08	
Tc-99	1.72E+02		4.90E+03	
H-3 (Tritium)	1.50E+05		1.29E+14	
U-233	1.70E+03	4.50E+07	7.45E+04	4.54E+05
U-234	1.70E+03	2.80E+07	7.09E+04	4.26E+05
U-235	1.50E+03	9.50E+03	6.38E+04	3.78E+05
U-236	1.70E+03	2.80E+05	6.63E+04	3.78E+05
U-238	1.20E+03	1.50E+03	6.94E+04	3.77E+05

Table F-10. EMDF Analytic PWAC Comparison with EMWMF Analytic WAC (Continued)

INORGANICS

COC	EMWMF		Proposed EMDF	
	Carcinogenic PWAC (mg/kg)	HI PWAC (mg/kg)	Carcinogenic PWAC* (mg/kg)	HI PWAC* (mg/kg)
Antimony		1.60E+02		3.63E+04
Barium		1.50E+05		3.43E+07**
Boron		2.40E+04		1.04E+06
Chromium (Total)		1.40E+05		6.89E+06
Lead		1.50E+03		4.47E+05**
Manganese		3.60E+05		1.02E+08**
Molybdenum		3.90E+03		1.50E+05
Selenium		1.60E+03		4.66E+03
Strontium		3.00E+05		4.32E+06
Tin		2.20E+03		8.81E+05
Vanadium		2.50E+04		8.98E+05**

ORGANICS

COC	EMWMF		Proposed EMDF	
	Carcinogenic PWAC (mg/kg)	HI PWAC (mg/kg)	Carcinogenic PWAC* (mg/kg)	HI PWAC* (mg/kg)
2,4-D		1.19E+02		4.05E+04
2,4,5-T[Silvex]		3.30E+02		9.27E+04
Acenaphthene		3.90E+05		3.20E+07**
Acenaphthylene		9.32E+04		9.17E+06
Acetone		2.70E+02		3.01E+05
Acetonitrile		1.30E+01		1.55E+03
Acetophenone		3.30E+02		4.15E+04
Acrolein		1.10E+00		1.31E+02
Acrylonitrile	9.30E-02	2.10E+00	1.16E+01	1.07E+04
Aldrin	6.60E+03	4.40E+04	7.23E+05**	4.76E+06**
Aroclor-1221	2.30E+03		1.76E+04**	
Aroclor-1232	1.00E+03		2.14E+04	
Benzene	2.00E+02		1.31E+04	3.72E+04
Benzoic Acid		9.81E+03		1.08E+06
Benzyl Alcohol		1.20E+03		3.13E+04
Benzidine	1.61E-01	1.20E+00	9.52E+00	8.46E+04
alpha-BHC	3.90E+01		3.58E+03	2.31E+06
beta-BHC	1.40E+02		1.20E+04	
delta-BHC	1.40E+02		1.47E+04	

Table F-10. EMDF Analytic PWAC Comparison with EMWMF Analytic WAC (Continued)

COC	EMWMF		Proposed EMDF	
	Carcinogenic PWAC (mg/kg)	HI PWAC (mg/kg)	Carcinogenic PWAC* (mg/kg)	HI PWAC* (mg/kg)
Bromodichloromethane	1.00E+00	5.50E+01	1.14E+02	6.08E+03
Bromoform	1.60E+01	1.10E+02	2.71E+05	5.52E+05
Bromomethane		3.50E+00		4.32E+02
Butylbenzene		1.51E+04		2.08E+06
Carbazole	1.10E+05		5.12E+06	
Carbon Disulfide		7.10E+02		7.80E+04
Carbon tetrachloride	5.60E+01	6.60E+01	1.29E+04	4.64E+04
Chlordane	9.20E+04	2.10E+05	1.21E+06**	2.74E+06**
Chlorobenzene		3.30E+02		1.09E+05
Chloroform	4.00E+01	1.00E+02	9.75E+03	3.88E+04
Chloromethane [Methyl Chloride]	4.40E+00		5.53E+02	
o-Chlorotoluene		4.40E+02		1.40E+05
m-Cresol		1.70E+02		2.10E+04
o-Cresol		2.32E+02		8.43E+04
p-Cresol		1.70E+02		4.15E+04
Cumene [Isopropylbenzene]		4.08E+04		4.16E+06
Cyanide		8.10E+03		3.02E+04
DDD	7.70E+04		5.81E+05**	
DDE	1.30E+05		1.12E+06	
Di-n-butylphthalate		1.90E+02		2.33E+03
Dibromochloromethane	1.10E+00	7.90E+01	1.38E+03	2.98E+04
1,2-Dichlorobenzene		9.40E+03		2.91E+06
1,3-Dichlorobenzene		5.80E+04		6.58E+06
1,4-Dichlorobenzene	1.00E+02	2.40E+04	4.63E+05	2.25E+06
1,2,-cis-Dichloroethylene		1.50E+02		1.15E+04
1,2-trans-Dichloroethylene		6.20E+01		7.75E+03
Dichlorodifluoromethane		6.00E+03		6.58E+05
1,2-Dichloropropane	1.10E+00		2.70E+02	3.76E+04
Dieldrin	7.10E+00	6.00E+01	5.81E+01	5.99E+02
Diethylphthalate		6.18E+03		2.05E+06
1,2-Dimethylbenzene		7.56E+04		2.44E+06
2,4-Dimethylphenol		2.15E+03		2.68E+05
Dimethylphthalate		3.07E+04		3.85E+06
2,4 Dinitrotoluene	1.00E+00	6.20E+01	2.57E+02	6.83E+03
2,6 Dinitrotoluene	8.10E-01	2.40E+01	8.97E+01	2.61E+03
Endosulfan plus metabolites		3.30E+05		3.40E+07
Endrin		3.00E+04		1.66E+06
Endrin Aldehyde		3.00E+04		1.66E+06

Table F-10. EMDF Analytic PWAC Comparison with EMWMF Analytic WAC (Continued)

COC	EMWMF		Proposed EMDF	
	Carcinogenic PWAC (mg/kg)	HI PWAC (mg/kg)	Carcinogenic PWAC* (mg/kg)	HI PWAC* (mg/kg)
Endrin Ketone		3.00E+04		1.66E+06
Ethylbenzene		4.90E+03	1.13E+05	1.59E+06
Ethylchloride	2.20E+01	1.10E+03	2.73E+03	1.36E+05
Heptachlor	2.40E+03	6.90E+04	1.75E+05**	5.06E+06**
Heptachlor Epoxide	1.00E+03	1.50E+03	1.60E+04	2.42E+04
Hexachlorobenzene	3.97E+06	7.73E+05	3.56E+06**	5.85E+07**
Hexachloroethane	2.80E+03	5.00E+02	9.02E+04	3.23E+04
n-Hexane		5.30E+04		1.46E+07
1-Hexanol		9.70E+01		1.22E+04
2-Hexanone		9.70E+01		1.52E+03
Isophorone	6.10E+03	1.50E+04	7.49E+05	1.83E+06
Lindane	1.80E+02	9.40E+02	2.18E+04	9.20E+04
Methanol		1.10E+03		1.28E+05
Methylene Chloride	7.30E+00	1.40E+02	3.89E+03	2.00E+03
Methylcyclohexane		3.60E+04		3.89E+06
Methyl Isobutyl Ketone		1.70E+02		2.14E+04
Methyl Methacrylate		3.30E+03		4.12E+05
1-Methyl-4-(1-methylethyl)-benzene		1.51E+04		1.55E+06
2-Methylnapthalene		4.00E+03		3.76E+05
(1-Methylpropyl)benzene		1.51E+04		1.55E+06
Naphthalene		9.90E+03		1.82E+06
4-Nitrobenzenamine [4-Nitroaniline]	8.70E+08	2.30E+09	1.01E+12	1.03E+12
Nitrobenzene		1.98E+00		2.84E+03
2-Nitrophenol		1.80E+00		2.69E+05
4-Nitrophenol		8.50E+02		3.19E+05
N-nitroso-di-n-propylamine	1.90E-02		2.54E+01	
N-Nitrosodiphenylamine	1.10E+03	4.80E+03	1.22E+06	4.56E+04
Phenol		3.20E+03		6.54E+05
Propylbenzene		1.51E+04		1.55E+06
Propylene glycol		1.10E+03		4.87E+06
Pyridine		2.20E+00		2.84E+02
Styrene		1.60E+04		1.95E+06
1,1,1,2-Tetrachloroethane	7.00E+00	2.30E+02	7.53E+03	7.54E+04
1,1,2,2-Tetrachloroethane	4.89E-01	2.50E+02	6.11E+02	3.15E+04
Tetrachloroethene	4.40E+02	2.90E+03	1.34E+06	2.18E+05
2,3,4,6-Tetrachlorophenol		1.08E+04		2.84E+07**
Toluene		4.90E+04		2.40E+06

Table F-10. EMDF Analytic PWAC Comparison with EMWMF Analytic WAC (Continued)

COC	EMWMF		Proposed EMDF	
	Carcinogenic PWAC (mg/kg)	HI PWAC (mg/kg)	Carcinogenic PWAC* (mg/kg)	HI PWAC* (mg/kg)
1,2,4-Trichlorobenzene		5.10E+03	1.13E+05	4.20E+05
Trichloroethene	7.80E+02		2.30E+04	6.81E+03
Trichlorofluoromethane		2.30E+03		7.53E+05
2,4,6-Trichlorophenol	2.20E+01		2.49E+04	3.52E+03
1,2,3-Trichloropropane	1.60E-02	2.80E+01	2.06E+00	3.18E+03
Trimethylbenzene [mixture of isomers]		2.20E+04		2.10E+06
1,2,4-Trimethylbenzene		2.18E+04		2.10E+06
1,3,5-Trimethylbenzene		2.60E+04		5.36E+05
Vinyl Chloride	2.90E-01	7.77E+00	2.85E+02	7.93E+03
Total Xylenes [mixture of isomers]		1.50E+04		4.94E+06

NL = no limit. "NL"indicates contaminant migration was modeled and contamination radioactively decays to an insignificant level.

* Waste with a constituent concentration greater than 1.00E+06 mg/kg is not physically possible. A PWAC value greater than 1.00E+06 mg/kg would be used only in the context of a SOF calculation (see Sect. 6.2).

** COC was modeled and did not arrive at the hypothetical receptor location within 100,000 years (model results indicate there would be no PWAC limit for the COC). The PATHRAE model predicts peak concentrations for a time period 10 times the defined time limit. For purposes of comparing EMDF PWAC values to the EMWMF WAC, a PWAC value was derived from the peak concentration in the 1,000,000 year timeframe.

The higher analytic PWAC for the EMDF relative to EMWMF are the result of several factors. The most significant factor is the distance from the disposal cell to the receptor location and DF_{well}. The EMWMF analytic WAC were developed based on an initial conceptual design of a cell located closer to Bear Creek than the constructed footprint. The actual EMWMF facility was constructed farther upslope on Pine Ridge at a greater distance from Bear Creek and the hypothetical receptor near NT-5 (see Figure F-22). The distance between the original EMWMF cell conceptual design and the hypothetical receptor location used to develop the EMWMF WAC is shorter than the distance between the as-built EMWMF and the hypothetical receptor location. Similarly, the distance between the original EMWMF cell conceptual design and the hypothetical receptor location used to develop the EMWMF WAC is shorter than the distance between the proposed EMDF and the assumed hypothetical receptor for EMDF near NT-3.

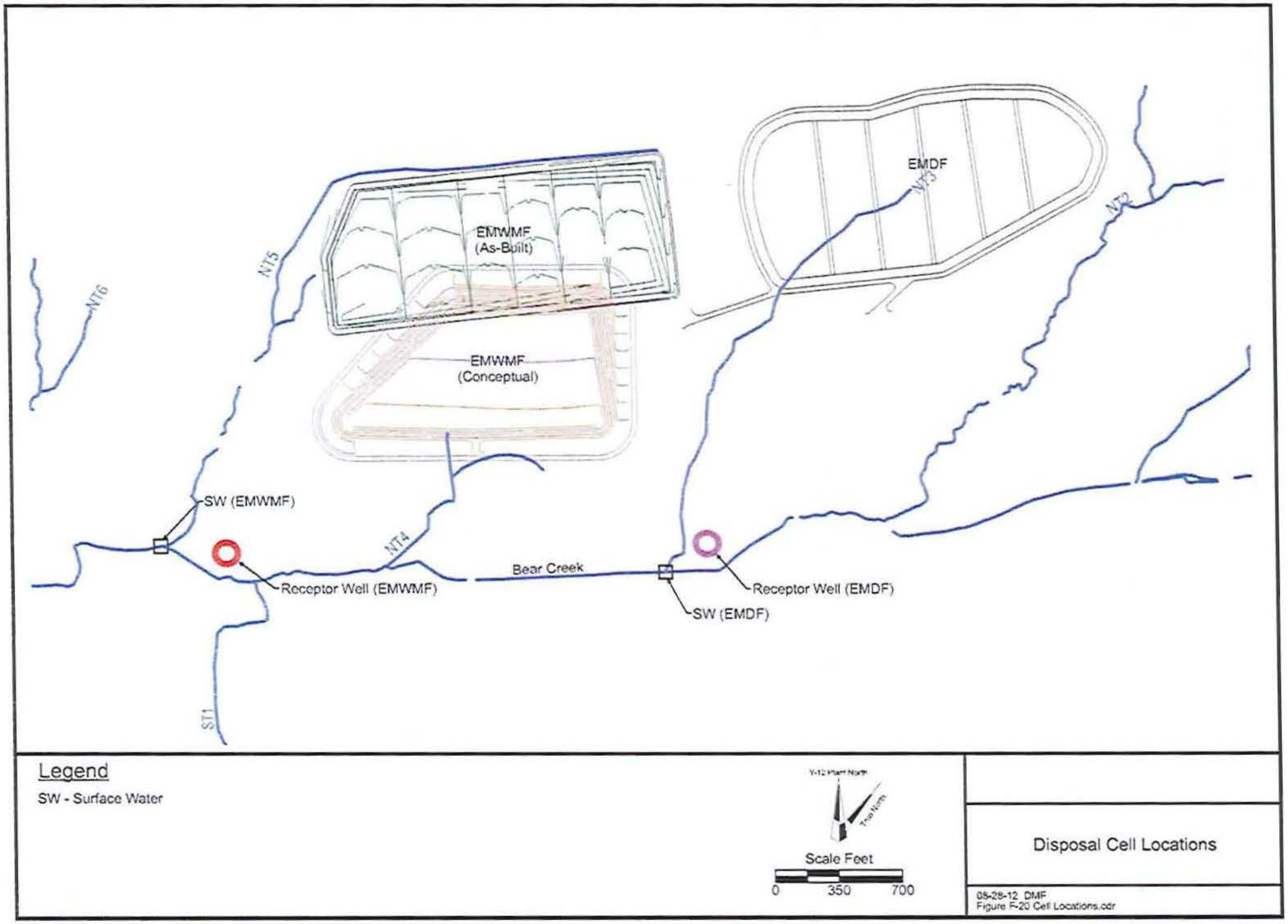


Figure F-22. EMWMF Conceptual Design, EMWMF As-built, EMDF Conceptual Design, and Hypothetical Receptor Well Locations

The shorter distance from the EMWMF conceptual design cell to the hypothetical receptor location results in higher concentrations in the creek. It also greatly impacts the groundwater dilution factor. For example, the EMWMF analytic WAC was developed using a DF_{well} of 0.0027. Subsequent analyses using the revised EMWMF design and as-built construction yielded a DF_{well} in the 10^{-4} range (0.00057 for the six-cell design). This lower DF_{well} resulted in lower risks and doses that would support a lower analytic WAC than the approved EMWMF analytic WAC; however no request to lower the approved EWMMF WAC was made to reflect the design change.

For comparison, the DF_{well} for the proposed EMDF is 0.000015 or 180 times lower than the DF_{well} used to develop the EMWMF WAC. As shown in Sect. 5.2, the well concentration (C_{well}) is directly proportional to the DF and indirectly proportional to the analytic PWAC value. As a result, a lower DF_{well} results in a lower C_{well} and a higher analytic PWAC value.

Another contributing factor to a higher PWAC is the underdrain system and the impact of backfilled existing channels within the proposed EMDF footprint. Disposal cell siting requires the groundwater separation between the bottom of the disposal cell liner system and top of the water table. Lessons learned from the EMWMF construction and operation (BJC 2003) guided the conceptual design of the EMDF.

To prevent the groundwater from rising within the proposed EMDF, the major existing drainage features within the landfill footprint would be backfilled with gravelly conductive material so the future groundwater flow system after cell construction would be similar to the current condition. These backfilled existing channels would behave hydraulically as underdrains to allow shallow groundwater discharge preferably to surface water.

The underdrain system would act as a preferred migration pathway for contaminant movement under some conditions. While contaminant leachate could percolate into the groundwater system and migrate downgradient in the groundwater zone, some leachate would be captured in the underdrain system and discharge into the surface water, resulting in lower contaminant concentrations in groundwater and a higher PWAC.

The analysis demonstrates that an analytic PWAC for the EMDF that is higher than the EMWMF WAC 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 WAC identified in this RI/FS are a preliminary data set provided to show viability of land disposal at the proposed site. If on-site disposal is the selected remedy as determined by the CERCLA process, final WAC (administrative, analytic, ASA-derived, and physical) would be approved for a new facility at the selected site prior to waste receipt. The final analytic WAC approved by the FFA parties may be similar to the analytic WAC approved for EMWMF.

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ATTACHMENT A TO APPENDIX F

SUPPLEMENTAL MODELING INFORMATION

CONTENTS

TABLES

ACRONYMS

COC	contaminant of concern
EMDF	Environmental Management Disposal Facility
EMWMF	Environmental Management Waste Management Facility
EPA	U.S. Environmental Protection Agency
HELP	Hydrologic Evaluation of Landfill Performance
HI	hazard index
K_d	solid-to-liquid partition coefficient
PWAC	preliminary waste acceptance criteria
RD	Reference Dose
SF	Slope Factor
U.S.	United States

1. INTRODUCTION

This attachment provides supplemental modeling information to Appendix F, *On-site Disposal Facility Preliminary Waste Acceptance Criteria* (PWAC). Section 2 provides information about the Hydrologic Evaluation of Landfill Performance (HELP) model, including model input and output files. Section 3 provides information about the PATHRAE model and PWAC calculations, including PATHRAE input and output files.

2. HELP MODEL

Detailed information about the HELP modeling analysis that was conducted to support PWAC development is presented in this section. HELP model input parameters are summarized in Sect. 2.1, including the complete design and long-term (worst case) scenarios. The long-term (worst case) scenario was used for PWAC development. HELP model output parameters are summarized in Sect. 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 (U.S.) 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 both complete design profile and long-term scenarios.

```
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 Complete Design Profile and Parameters

```
                              LAYER  1
                              --------
                TYPE 1 - VERTICAL PERCOLATION LAYER
                    MATERIAL TEXTURE NUMBER   4
  THICKNESS                         =     60.00    INCHES
  POROSITY                          =      0.4370 VOL/VOL
  FIELD CAPACITY                    =      0.1050 VOL/VOL
  WILTING POINT                     =      0.0470 VOL/VOL
  INITIAL SOIL WATER CONTENT        =      0.1832 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        =      0.1947 VOL/VOL
  EFFECTIVE SAT. HYD. COND.         =  0.310000009000E-02 CM/SEC

                              LAYER  3
                              --------
                TYPE 1 - VERTICAL PERCOLATION LAYER
                    MATERIAL TEXTURE NUMBER   1
  THICKNESS                         =     36.00    INCHES
  POROSITY                          =      0.4170 VOL/VOL
  FIELD CAPACITY                    =      0.0450 VOL/VOL
  WILTING POINT                     =      0.0180 VOL/VOL
  INITIAL SOIL WATER CONTENT        =      0.1395 VOL/VOL
  EFFECTIVE SAT. HYD. COND.         =  0.999999978000E-02 CM/SEC

                              LAYER  4
                              --------
                  TYPE 2 - LATERAL DRAINAGE 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        =      0.0369 VOL/VOL
  EFFECTIVE SAT. HYD. COND.         =  0.300000012000     CM/SEC
  SLOPE                             =      5.00    PERCENT
  DRAINAGE LENGTH                   =    100.0     FEET

                              LAYER  5
                              --------
                  TYPE 4 - FLEXIBLE MEMBRANE LINER
                    MATERIAL TEXTURE NUMBER  35
  THICKNESS                         =      0.06    INCHES
  POROSITY                          =      0.0000 VOL/VOL
  FIELD CAPACITY                    =      0.0000 VOL/VOL
  WILTING POINT                     =      0.0000 VOL/VOL
  INITIAL SOIL WATER CONTENT        =      0.0000 VOL/VOL
  EFFECTIVE SAT. HYD. COND.         =  0.199999996000E-12 CM/SEC
  FML PINHOLE DENSITY               =      1.00    HOLES/ACRE
```

```
FML INSTALLATION DEFECTS      =       4.00   HOLES/ACRE
FML PLACEMENT QUALITY         =  3 - GOOD

                          LAYER  6
                          --------

              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.     =  0.349999993000E-07 CM/SEC

                          LAYER  7
                          --------

          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    =       0.4094 VOL/VOL
EFFECTIVE SAT. HYD. COND.     =  0.100000001000E-06 CM/SEC


                          LAYER  8
                          --------


          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    =       0.0349 VOL/VOL
EFFECTIVE SAT. HYD. COND.     =  0.300000012000     CM/SEC
                          LAYER  9
                          --------

          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 10
                          --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  26
THICKNESS                     =      12.00    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 11
                          --------

            TYPE 2 - LATERAL DRAINAGE 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   =       0.0320 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.300000012000      CM/SEC
SLOPE                        =       2.50    PERCENT
DRAINAGE LENGTH              =     100.0     FEET

                         LAYER 12
                         --------

             TYPE 4 - FLEXIBLE MEMBRANE LINER
               MATERIAL TEXTURE NUMBER  35
THICKNESS                    =       0.06    INCHES
POROSITY                     =       0.0000 VOL/VOL
FIELD CAPACITY               =       0.0000 VOL/VOL
WILTING POINT                =       0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT   =       0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY          =       1.00    HOLES/ACRE
FML INSTALLATION DEFECTS     =       4.00    HOLES/ACRE
FML PLACEMENT QUALITY        =  3 - GOOD

                         LAYER 13
                         --------

             TYPE 2 - LATERAL DRAINAGE 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
SLOPE                        =       2.50    PERCENT
DRAINAGE LENGTH              =     100.0     FEET

                         LAYER 14
                         --------

             TYPE 4 - FLEXIBLE MEMBRANE LINER
               MATERIAL TEXTURE NUMBER  35
THICKNESS                    =       0.06    INCHES
POROSITY                     =       0.0000 VOL/VOL
FIELD CAPACITY               =       0.0000 VOL/VOL
WILTING POINT                =       0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT   =       0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY          =       1.00    HOLES/ACRE
FML INSTALLATION DEFECTS     =       4.00    HOLES/ACRE
FML PLACEMENT QUALITY        =  3 - GOOD

                         LAYER 15
                         --------

               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 16
                         --------
```

```
          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
```

2.1.3 Long-term (Worst Case) Profile and Parameters

```
                          LAYER  1
                          --------
          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   4
THICKNESS                 =      60.00   INCHES
POROSITY                  =      0.4370 VOL/VOL
FIELD CAPACITY            =      0.1050 VOL/VOL
WILTING POINT             =      0.0470 VOL/VOL
INITIAL SOIL WATER CONTENT =     0.1832 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 =     0.1947 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.310000009000E-02 CM/SEC

                          LAYER  3
                          --------
          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   1
THICKNESS                 =      36.00   INCHES
POROSITY                  =      0.4170 VOL/VOL
FIELD CAPACITY            =      0.0450 VOL/VOL
WILTING POINT             =      0.0180 VOL/VOL
INITIAL SOIL WATER CONTENT =     0.1395 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.999999978000E-02 CM/SEC

                          LAYER  4
                          --------
            TYPE 2 - LATERAL DRAINAGE 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 =     0.0368 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.300000012000      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.      =  0.349999993000E-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     =        0.4191 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     =        0.0470 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  26
THICKNESS                      =       12.00    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 10
                          --------
              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 11
                    --------
        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
```

2.1.4 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    =   285.107   INCHES
TOTAL INITIAL WATER                 =   285.107   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 Sect. 2.2.1 and 2.2.2, respectively.

2.2.1 Complete Design Scenario

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	INCHES	CU. FEET	PERCENT
PRECIPITATION	54.39 (7.835)	6910300.5	100.00
RUNOFF	0.685 (1.3124)	87066.65	1.260
EVAPOTRANSPIRATION	30.899 (2.7986)	3925722.50	56.810
LATERAL DRAINAGE COLLECTED FROM LAYER 4	22.79604 (5.99463)	2896236.500	41.91188
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00004 (0.00001)	5.618	0.00008
AVERAGE HEAD ON TOP OF LAYER 5	0.074 (0.019)		
LATERAL DRAINAGE COLLECTED FROM LAYER 11	0.00001 (0.00007)	1.853	0.00003
PERCOLATION/LEAKAGE THROUGH LAYER 12	0.00078 (0.00351)	99.580	0.00144
AVERAGE HEAD ON TOP OF LAYER 12	0.000 (0.000)		
LATERAL DRAINAGE COLLECTED FROM LAYER 13	0.00078 (0.00351)	99.508	0.00144
PERCOLATION/LEAKAGE THROUGH LAYER 15	0.00000 (0.00000)	0.073	0.00000
AVERAGE HEAD ON TOP OF LAYER 14	0.000 (0.000)		
PERCOLATION/LEAKAGE THROUGH LAYER 16	0.00000 (0.00000)	0.000	0.00000
CHANGE IN WATER STORAGE	0.009 (2.6932)	1171.90	0.017

****

2.2.2 Long-term (Worst Case) Scenario

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	INCHES		CU. FEET	PERCENT
PRECIPITATION	54.39	(7.835)	6910300.5	100.00
RUNOFF	0.685	(1.3124)	87066.65	1.260
EVAPOTRANSPIRATION	30.899	(2.7986)	3925722.50	56.810
LATERAL DRAINAGE COLLECTED FROM LAYER 4	22.37147	(5.99331)	2842295.250	41.13128
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.42462	(0.00521)	53947.691	0.78069
AVERAGE HEAD ON TOP OF LAYER 5	0.072	(0.019)		
PERCOLATION/LEAKAGE THROUGH LAYER 10	0.42443	(0.00662)	53924.336	0.78035
AVERAGE HEAD ON TOP OF LAYER 10	0.002	(0.000)		
PERCOLATION/LEAKAGE THROUGH LAYER 11	**0.42443**	(0.00645)	53923.512	0.78034
CHANGE IN WATER STORAGE	0.010	(2.6927)	1291.82	0.019

****

3. PATHRAE MODEL

PATHRAE-RAD and PATHRAE-HAZ (Rogers and Associates Engineering, 1995a, b) models are used to calculate the arrival peak time and concentrations for the radioactive constituents and toxicological constituents at the hypothetical receptor surface water location, respectively. PATHRAE calculations are also performed to determine the equivalent annual water consumption per year for the creek (defined as the Equivalent Uptake).

Section 3.1 provides information about some of the PATHRAE input parameters. Sect. 3.2 provides a listing of PATHRAE modeling input and output files.

3.1 PATHRAE INPUT PARAMETERS

The solid-to-liquid partition coefficient (K_d) values used to develop the Environmental Management Waste Management Facility (EMWMF) WAC were based on site-specific and generic K_d factors for soils and were also used to develop the PWAC for the proposed EMDF. These K_d values used in PATHRAE are provided below in Table 3-1 and Table 3-2.

Table 3-1. K_d Values for Radionuclide Constituents used in PATHRAE

RAD	K_d		
	Waste	Vadose zone	Aquifer
H-3	1.99E-01	0.00E+00	0.00E+00
C-14	1.09E+00	0.00E+00	0.00E+00
Tc-99	1.29E+00	0.00E+00	0.00E+00
U-233	4.00E+01	2.00E+01	7.00E-01
U-234	4.00E+01	2.00E+01	7.00E-01
U-235	4.00E+01	2.00E+01	7.00E-01
U-236	4.00E+01	2.00E+01	7.00E-01
U-238	4.00E+01	2.00E+01	7.00E-01
Np-237	5.56E+01	4.00E+01	4.00E+00
Pu-239	5.76E+01	4.00E+01	4.00E+00
Pu-240	5.76E+01	4.00E+01	4.00E+00
Am-241	5.76E+01	4.00E+01	4.00E+00
I-129	1.99E-01	1.99E-01	0.00E+00

Table 3-2. K_d Values for Hazardous Constituents used in PATHRAE

COC	CAS	K_d		
		Waste	Vadose zone	Aquifer
Antimony	(7440-36-0)	1.90E+01	1.90E+01	1.90E+00
Barium	(7440-39-3)	5.50E+01	5.50E+01	5.50E+00
Boron	(7440-42-8)	3.00E+00	3.00E+00	3.00E-01
Chromium (Total)	(7440-47-3)	1.00E+01	1.00E+01	1.00E+00
Lead	(7439-92-1)	1.00E+02	1.00E+02	1.00E+01
Manganese	(7439-96-5)	2.00E+02	2.00E+02	2.00E+01
Molybdenum	(7439-98-7)	2.00E+01	2.00E+01	2.00E+00
Selenium	(7782-49-2)	1.50E+01	1.50E+01	1.50E+00
Strontium	(7440-24-6)	1.35E+01	1.35E+01	0.00E+00
Tin	(7440-31-5)	2.50E+00	2.50E+00	2.50E-01
Vanadium	(7440-62-2)	1.00E+02	1.00E+02	1.00E+01
U-233	(1-1)	4.00E+01	2.00E+01	7.00E-01
U-234	(1-2)	4.00E+01	2.00E+01	7.00E-01
U-235	(1-3)	4.00E+01	2.00E+01	7.00E-01
U-236	(1-4)	4.00E+01	2.00E+01	7.00E-01
U-238	(1-5)	4.00E+01	2.00E+01	7.00E-01
2,4-D	(94-75-7)	5.88E-02	5.88E-02	5.88E-03
2,4,5-T[Silvex]	(93-72-1)	1.61E-01	1.61E-01	1.61E-02
Acenaphthene	(83-32-9)	9.20E+01	9.20E+01	9.20E+00
Acenaphthylene	(208-96-8)	1.22E+01	1.22E+01	1.22E+00
Acetone	(67-64-1)	4.40E-02	4.40E-02	0.00E+00
Acetonitrile	(75-05-8)	1.54E-03	1.54E-03	1.54E-04
Acetophenone	(98-86-2)	9.24E-02	9.24E-02	9.24E-03
Acrolein	(107-02-8)	2.78E-03	2.78E-03	2.78E-04
Acrylonitrile	(107-13-1)	4.44E-03	4.44E-03	4.44E-04
Aldrin	(309-00-2)	9.74E+01	9.74E+01	9.74E+00
Aroclor-1221	(11104-28-2)	1.20E+02	1.20E+02	1.20E+02
Aroclor-1232	(11141-16-5)	1.50E+01	1.50E+01	1.50E+01
Benzene	(71-43-2)	1.70E+00	1.70E+00	0.00E+00
Benzoic Acid	(65-85-0)	1.20E-03	1.20E-03	1.20E-04

Table 3-2. K_d Values for Hazardous Constituents used in PATHRAE (Continued)

COC	CAS	K_d		
		Waste	Vadose zone	Aquifer
Benzyl Alcohol	(100-51-6)	3.13E-02	3.13E-02	3.13E-03
Benzidine	(92-87-5)	5.48E+00	5.48E+00	5.48E-01
alpha-BHC	(319-84-6)	3.52E+00	3.52E+00	3.52E-01
beta-BHC	(319-85-7)	4.28E+00	4.28E+00	4.28E-01
delta-BHC	(319-86-8)	4.28E+00	4.28E+00	4.28E-01
Bromodichloromethane	(75-27-4)	1.08E-02	1.08E-02	1.08E-03
Bromoform	(75-25-2)	2.52E-01	2.52E-01	2.52E-02
Bromomethane	(74-83-9)	2.83E-02	2.83E-02	2.83E-03
Butylbenzene	(104-51-8)	1.63E+00	1.63E+00	1.63E-01
Carbazole	(86-74-8)	6.78E+00	6.78E+00	6.78E-01
Carbon Tetrachloride	(56-23-5)	1.03E-01	1.03E-01	1.03E-02
Carbon Disulfide	(75-15-0)	2.20E+00	2.20E+00	0.00E+00
Chlordane	(57-74-9)	1.73E+02	1.73E+02	1.73E+01
Chlorobenzene	(108-90-7)	4.38E-01	4.38E-01	4.38E-02
Chloroform	(67-66-3)	6.20E-01	6.20E-01	0.00E+00
Chloromethane [Methyl Chloride]	(74-87-3)	2.86E-02	2.86E-02	2.86E-03
o-Chlorotoluene	(95-49-8)	8.86E-01	8.86E-01	8.86E-02
m-Cresol	(108-39-4)	9.56E-02	9.56E-02	9.56E-03
o-Cresol	(95-48-7)	1.82E-01	1.82E-01	1.82E-02
p-Cresol	(106-44-5)	9.22E-02	9.22E-02	9.22E-03
Cumene [Isopropylbenzene]	(98-82-8)	1.65E+00	1.65E+00	1.65E-01
Cyanide	(57-12-5)	9.90E+00	9.90E+00	9.90E-01
DDD	(72-54-8)	9.16E+01	9.16E+01	9.16E+00
DDE	(72-55-9)	1.73E+00	1.73E+00	1.73E-01
Di-n-butylphthalate	(84-74-2)	1.00E-06	1.00E-06	0.00E+00
Dibromochloromethane	(124-48-1)	1.41E-01	1.41E-01	1.41E-02
1,2-Dichlorobenzene	(95-50-1)	7.58E-01	7.58E-01	7.58E-02
1,3-Dichlorobenzene	(541-73-1)	1.61E+01	1.61E+01	1.61E+00
1,4-Dichlorobenzene	(106-46-7)	1.23E+00	1.23E+00	1.23E-01
1,2,-cis-Dichloroethylene	(156-59-2)	9.96E-01	9.96E-01	9.96E-02
1,2-trans-Dichloroethylene	(156-60-5)	7.60E-02	7.60E-02	7.60E-03

Table 3-2. K_d Values for Hazardous Constituents used in PATHRAE (Continued)

COC	CAS	K_d		
		Waste	Vadose zone	Aquifer
Dichlorodifluoromethane	(75-71-8)	1.37E-02	1.37E-02	1.37E-03
1,2-Dichloropropane	(78-87-5)	9.40E-02	9.40E-02	9.40E-03
Dieldrin	(60-57-1)	3.40E+01	3.40E+01	0.00E+00
Diethylphthalate	(84-66-2)	2.52E-01	2.52E-01	2.52E-02
1,2-Dimethylbenzene	(95-47-6)	4.80E-01	4.80E-01	4.80E-02
2,4-Dimethylphenol	(105-67-9)	2.52E+00	2.52E+00	2.52E-01
Dimethylphthalate	(131-11-3)	7.42E-02	7.42E-02	7.42E-03
2,4 Dinitrotoluene	(121-14-2)	1.02E-01	1.02E-01	1.02E-02
2,6 Dinitrotoluene	(606-20-2)	8.39E-02	8.39E-02	8.39E-03
Endosulfan plus metabolites****	(959-98-8)	4.08E+00	4.08E-01	4.08E+00
Endrin	(72-20-8)	2.16E+01	2.16E+01	2.16E+00
Endrin Aldehyde	(7421-93-4)	2.16E+01	2.16E+00	2.16E+01
Endrin Ketone	(53494-70-5)	2.16E+01	2.16E+00	2.16E+01
Ethylbenzene	(100-41-4)	4.08E-01	4.08E-01	4.08E-02
Ethylchloride	(75-00-3)	4.75E-02	4.75E-02	4.75E-03
Heptachlor	(76-44-8)	4.80E+01	4.80E+01	4.80E+00
Heptachlor Epoxide	(1024-57-3)	1.73E+01	1.73E+01	1.73E+00
Hexachlorobenzene	(118-74-1)	1.10E+02	1.10E+02	1.10E+01
Hexachloroethane	(67-72-1)	3.56E+00	3.56E+00	3.56E-01
n-Hexane	(110-54-3)	2.98E-01	2.98E-01	2.98E-02
1-Hexanol	(111-27-3)	2.60E-02	2.60E-02	2.60E-03
2-Hexanone	(591-78-6)	2.60E-02	2.60E-02	2.60E-03
Isophorone	(78-59-1)	1.70E+00	1.70E+00	0.00E+00
Lindane	(58-89-9)	6.76E+00	6.76E+00	6.76E-01
Methanol	(67-56-1)	2.00E-03	2.00E-03	2.00E-04
Methylene Chloride	(75-09-2)	4.34E-02	4.34E-02	4.34E-03
Methylcyclohexane	(108-87-2)	1.99E-01	0.00E+00	0.00E+00
Methyl Isobutyl Ketone	(108-10-1)	4.70E-03	4.70E-03	4.70E-04
Methyl Methacrylate	(80-62-6)	2.00E-02	2.00E-02	2.00E-03
1-Methyl-4-(1-methylethyl)-benzene	(99-87-6)	1.65E+00	1.65E+00	1.65E-01
2-Methylnapthalene	(91-57-6)	5.94E+00	5.94E+00	5.94E-01

Table 3-2. K_d Values for Hazardous Constituents used in PATHRAE (Continued)

COC	CAS	K_d		
		Waste	Vadose zone	Aquifer
(1-Methylpropyl)benzene	(135-98-8)	1.65E+00	1.65E+00	1.65E-01
Naphthalene	(91-20-3)	1.90E+01	1.90E+01	1.90E+00
4-Nitrobenzenamine [4-Nitroaniline]	(100-01-6)	3.44E-01	3.44E-01	3.44E-02
Nitrobenzene	(98-95-3)	1.29E-01	1.29E-01	1.29E-02
2-Nitrophenol	(88-75-5)	7.10E-01	7.10E-01	7.10E-02
4-Nitrophenol	(100-02-7)	8.74E-01	8.74E-01	8.74E-02
N-nitroso-di-n-propylamine	(621-64-7)	3.00E-01	3.00E-01	3.00E-02
N-Nitrosodiphenylamine	(86-30-6)	6.54E-01	6.54E-01	6.54E-02
Phenol	(108-95-2)	2.80E-01	2.80E-01	2.80E-02
Propylbenzene	(103-65-1)	1.65E+00	1.65E+00	1.65E-01
Propylene glycol	(57-55-6)	2.00E-03	2.00E-03	2.00E-04
Pyridine	(110-86-1)	1.38E-02	1.38E-02	1.38E-03
Styrene	(100-42-5)	1.82E+00	1.82E+00	1.82E-01
1,1,1,2-Tetrachloroethane	(630-20-6)	3.18E-01	3.18E-01	3.18E-02
1,1,2,2-Tetrachloroethane	(79-34-5)	1.58E-01	1.56E-01	1.56E-02
Tetrachloroethene	(127-18-4)	7.20E+00	7.20E+00	0.00E+00
2,3,4,6-Tetrachlorophenol	(58-90-2)	2.49E+02	2.49E+02	2.49E+01
Toluene	(108-88-3)	6.00E+00	6.00E+00	0.00E+00
1,2,4-Trichlorobenzene	(120-82-1)	1.44E+00	1.44E+00	1.44E-01
Trichloroethene	(79-01-6)	2.60E+00	2.60E+00	0.00E+00
Trichlorofluoromethane	(75-69-4)	2.68E-01	2.68E-01	2.68E-02
2,4,6-Trichlorophenol	(88-06-02)	6.36E-01	6.36E-01	6.36E-02
1,2,3-Trichloropropane	(96-18-4)	1.61E-01	1.61E-01	1.61E-02
Trimethylbenzene [mixture of isomers]	(25551-13-7)	1.44E+00	1.44E+00	1.44E-01
1,2,4-Trimethylbenzene	(95-63-6)	1.44E+00	1.44E+00	1.44E-01
1,3,5-Trimethylbenzene	(108-67-8)	3.34E+00	3.34E+00	3.34E-01
Vinyl Chloride	(75-01-4)	3.72E-01	3.72E-01	3.72E-02
Xylene [mixture of isomers]	(1330-20-7)	8.86E-01	8.86E-01	8.86E-02

Reference Dose (RD) and Slope Factor (SF) parameters based on updated values in U.S. Environmental Protection Agency (EPA) risk guidance (EPA 2012) are used to calculate the EMDF PWAC. Where no values are provided in the EPA risk guidance, values previously used to calculate the EMWMF WAC are used. Table 3-3 lists SF values for radioactive constituents. Table 3-4 lists SF and RD values for hazardous constituents.

Table 3-3. Slope Factor Values for Radioactive Constituents

Nuclide	Water Ingestion Slope Factor (1/pCi)
H-3	5.07E-14
C-14	1.55E-12
Tc-99	2.75E-12
I-129	1.48E-10
U-233	7.18E-11
U-234	7.07E-11
U-235	6.96E-11
U-236	6.70E-11
U-238	6.40E-11
Np-237	6.18E-11
Pu-239	1.35E-10
Pu-240	1.35E-10
Am-241	1.04E-10

Table 3-4. Slope Factor and Reference Dose Values for Hazardous Constituents

COC	Slope Factor (1/(mg/kg-d))	Reference Dose (mg/kg-day)
Antimony		4.00E-04
Barium		2.00E-01
Boron		2.00E-01
Chromium (Total)		1.00E+00
Lead		1.40E-03
Manganese		1.40E-01
Molybdenum		5.00E-03
Selenium		5.00E-03
Strontium		6.00E-01
Tin		6.00E-01
Vanadium		5.00E-03
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
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
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

Table 3-4. Slope Factor and Reference Dose Values for Hazardous Constituents (Continued)

COC	Slope Factor (1/(mg/kg-d))	Reference Dose (mg/kg-day)
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
Chloromethane [Methyl Chloride]	1.30E.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
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
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	6.80E-01	1.00E-03
Endosulfan plus metabolites		6.00E-03
Endrin		3.00E-04
Endrin Aldehyde		3.00E-04

Table 3-4. Slope Factor and Reference Dose Values for Hazardous Constituents (Continued)

COC	Slope Factor (1/(mg/kg-d))	Reference Dose (mg/kg-day)
Endrin Ketone		3.00E-04
Ethylbenzene	1.10E-02	1.00E-01
Ethylchloride	2.90E-03	4.00E-01
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		5.00E-01
Methylene Chloride	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-nitroso-di-n-propylamine	7.00E+00	
N-Nitrosodiphenylamine	4.90E-03	2.00E-02
Phenol		3.00E-01
Propylbenzene		3.70E-02
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
Tetrachloroethene	2.10E-03	6.00E-03
2,3,4,6-Tetrachlorophenol		3.00E-02
Toluene		8.00E-02

Table 3-4. Slope Factor and Reference Dose Values for Hazardous Constituents (Continued)

COC	Slope Factor (1/(mg/kg-d))	Reference Dose (mg/kg-day)
1,2,4-Trichlorobenzene	2.90E-02	1.00E-02
Trichloroethene	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]		5.00E-02
1,2,4-Trimethylbenzene		5.00E-02
1,3,5-Trimethylbenzene		1.00E-02
Vinyl Chloride	7.20E-01	3.00E-03
Xylene [mixture of isomers]		2.00E-01

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. The PATHRAE-RAD and PATHRAE-HAZ output (text) files are listed in Sect. 3.2.1 and 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

```
PATHRAE-RAD(PC)  Version 2.2d  February 1995
   Date:  9-11-2012
   Time: 20:22:17

 pWAC - July, 2012 New Proposed Cell in UBCV

 *****  Mirror Image of Input Files  *****

 -- Input File:  ABCDEF.DAT
 pWAC - July, 2012 New Proposed Cell in UBCV
 3,1000.,1200.,100000.
 13,0,5
 1,2,
 0.,486.0,243.0,4.91E+05,1.,476.,0.
 1800.,6.,0.,0.,0.,0.,0.315,0.
 20,2,0,1,1
 4.0,16.,1.91E+06,150.,450.,1600.,.40,.705,0.90,1.
 1.0E-7,8000.,.705,0.,1.0E+00,0.01
 240.,5.56E-04,.22,.02,3.0E-4,20.,0.01
 4,6.3,.23,0.,1.1E-06,0.01,0.,0.,0.,0.,0.
 0,0,0,0,0,0,0
 1,0,0,1
 0.010,4.2,0.25,7.0,0.025,24.,0.00001,1.,0.,0.25

 -- Input File:  BRCDCF.DAT
 101,H-3       1.55E-07,  6.40E-08,  0.00E+00,
 102,C-14      2.15E-06,  2.10E-06,  1.88E-09,
 108,Tc-99     2.37E-06,  7.50E-06,  6.30E-11,
 054,U-233     1.89E-04,  1.40E-01,  8.36E-08,
 038,U-234     1.81E-04,  1.30E-01,  8.74E-08,
 039,U-235     1.74E-04,  1.20E-01,  1.73E-05,
 040,U-236     1.74E-04,  1.30E-01,  7.59E-08,
 041,U-238     1.67E-04,  1.20E-01,  2.82E-06,
 042,Np-237    4.07E-04,  4.90E-01,  3.20E-06,
 044,Pu-239    9.25E-04,  4.30E-01,  4.29E-08,
 045,Pu-240    9.25E-04,  5.10E-01,  8.20E-08,
 048,Am-241    7.40E-04,  4.40E-01,  3.21E-06,
 020,I-129     4.07E-04,  1.80E-04,  2.20E-06,


 -- Input File:  INVNTRY.DAT
 101, 1.23E+01, 1.91E+06,     .0,  .000,         0., 0.,     1.,  H-3
 102, 5.73E+03, 1.91E+06,     .0,  .000,         0., 0.,     1.,  C-14
 108, 2.13E+05, 1.91E+06,   29.2,  .089,         0., 0.,     1.,  Tc-99
 054, 1.59E+05, 1.91E+06,   25.7,  .115,         0., 0.,     1.,  U-233
 038, 2.44E+05, 1.91E+06,   35.5,  .070,         0., 0.,     1.,  U-234
 039, 7.04E+08, 1.91E+06,   21.6,  .169,         0., 0.,     1.,  U-235
 040, 2.34E+07, 1.91E+06,   36.6,  .068,         0., 0.,     1.,  U-236
 041, 4.47E+09, 1.91E+06,   12.0,  .718,         0., 0.,     1.,  U-238
 042, 2.14E+06, 1.91E+06,   34.9,  .072,         0., 0.,     1.,  Np-237
 044, 2.41E+04, 1.91E+06,   25.8,  .113,         0., 0.,     1.,  Pu-239
 045, 6.54E+03, 1.91E+06,   46.3,  .054,         0., 0.,     1.,  Pu-240
 048, 4.32E+02, 1.91E+06,   43.5,  .057,         0., 0.,     1.,  Am-241
 020, 1.60E+07, 1.91E+06,   62.0,  .040, 1.0e-02, 0.,     1.,  I-129

 -- Input File:  RQSITE.DAT
 101,-1.99e-1, 0.00E+0, 0.00E+0,  H-3
 102,-1.09e+0, 0.00E+0, 0.00E+0,  C-14
 108,-1.29e+0, 0.00E+0, 0.00E+0,  Tc-99
 054,-4.00e+1, 7.00E-1, 2.00E+1,  U-233
 038,-4.00e+1, 7.00E-1, 2.00E+1,  U-234
 039,-4.00e+1, 7.00E-1, 2.00E+1,  U-235
 040,-4.00e+1, 7.00E-1, 2.00E+1,  U-236
 041,-4.00e+1, 7.00E-1, 2.00E+1,  U-238
 042,-5.56e+1, 4.00E+0, 4.00E+1,  Np-237
 044,-5.76e+1, 4.00E+0, 4.00E+1,  Pu-239
 045,-5.76e+1, 4.00E+0, 4.00E+1,  Pu-240
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048,-5.76e+1, 4.00E+0, 4.00E+1,  Am-241
020,-1.99E-1, 0.00E+0, 1.99E-1,  I-129


-- 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., 6.9
H-3                 .25, 4.8E+0, 4.8E-1, 1.0E-2,   0., 1.2E-2, 9.0E-1
C-14                .25, 5.5E+0, 5.5E-1, 1.2E-2,   0., 3.1E-2, 4.6E+3
Tc-99               .25, 2.5E-1, 2.5E-2, 1.0E-3,   0., 1.0E-4, 1.5E+1
U-233               .25, 2.5E-3, 2.5E-4, 5.0E-4,   0., 3.4E-4, 2.0E+0
U-234               .25, 2.5E-3, 2.5E-4, 5.0E-4,   0., 3.4E-4, 2.0E+0
U-235               .25, 2.5E-3, 2.5E-4, 5.0E-4,   0., 3.4E-4, 2.0E+0
U-236               .25, 2.5E-3, 2.5E-4, 5.0E-4,   0., 3.4E-4, 2.0E+0
U-238               .25, 2.5E-3, 2.5E-4, 5.0E-4,   0., 3.4E-4, 2.0E+0
Np-237              .25, 2.5E-3, 2.5E-4, 5.0E-6,   0., 2.0E-4, 1.0E+1
Pu-239              .25, 2.5E-4, 2.5E-5, 2.0E-6,   0., 1.4E-5, 3.5E+0
Pu-240              .25, 2.5E-4, 2.5E-5, 2.0E-6,   0., 1.4E-5, 3.5E+0
Am-241              .25, 2.5E-4, 2.5E-5, 5.0E-6,   0., 2.0E-4, 2.5E+1
I-129               .25, 2.0E-2, 2.0E-3, 7.0E-3,   0., 1.0E-2, 4.0E+1
1
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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
H-3	1.166E+03	1.166E+03	1.172E+03	1.172E+03	1.172E+03	0.000E+00
C-14	9.564E+02	9.564E+02	3.270E+04	3.270E+04	3.270E+04	0.000E+00
Tc-99	7.403E+02	7.403E+02	8.438E+02	8.438E+02	8.438E+02	1.469E+00
I-129	8.327E+02	8.327E+02	1.109E+03	1.109E+03	1.109E+03	5.624E-01
U-234	7.380E+02	7.380E+02	7.518E+02	7.518E+02	7.518E+02	1.357E-02
U-235	7.380E+02	7.380E+02	7.518E+02	7.518E+02	7.518E+02	1.357E-02
U-236	7.380E+02	7.380E+02	7.518E+02	7.518E+02	7.518E+02	1.357E-02
U-238	7.380E+02	7.380E+02	7.518E+02	7.518E+02	7.518E+02	1.357E-02
Np-237	7.338E+02	7.338E+02	8.028E+02	8.028E+02	8.028E+02	1.122E-02
Pu-239	7.329E+02	7.329E+02	7.570E+02	7.570E+02	7.570E+02	1.059E-03
Pu-240	7.329E+02	7.329E+02	7.570E+02	7.570E+02	7.570E+02	1.059E-03
Am-241	7.338E+02	7.338E+02	9.063E+02	9.063E+02	9.063E+02	1.121E-03
U-233	7.380E+02	7.380E+02	7.518E+02	7.518E+02	7.518E+02	1.357E-02

```
**********  PATHRAE INPUT SUMMARY  **********

THERE ARE 60 ISOTOPES IN THE DOSE FACTOR LIBRARY
NUMBER OF TIMES FOR CALCULATION IS  3
YEARS TO BE CALCULATED ARE ...

  1000.00  1200.00100000.00

THERE ARE  13 ISOTOPES IN THE INVENTORY FILE
THE VALUE OF IFLAG IS 0
NUMBER OF PATHWAYS IS  5

          PATHWAY              TYPE OF USAGE
                             FOR UPTAKE FACTORS
  1  GROUNDWATER TO RIVER            2
  0  3X,I2,2X,A22,6X,I2))            0
  0  3X,I2,2X,A22,6X,I2))            0
  0  3X,I2,2X,A22,6X,I2))            0
  0  3X,I2,2X,A22,6X,I2))            0

TIME OF OPERATION OF WASTE FACILITY IN YEARS                 0.
LENGTH OF REPOSITORY (M)                                     486.
WIDTH OF REPOSITORY (M)                                      243.
RIVER FLOW RATE (M**3/YR)                                      4.91E+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)                                  6.00E+00
LATERAL DISPERSION COEFFICIENT -- Y AXIS (M**2/YR)             0.00E+00
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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)	4.00
THICKNESS OF WASTE IN PITS (M)	16.00
TOTAL WASTE VOLUME (M**3)	1.910E+06
DISTANCE TO WELL -- X COORDINATE (M)	150.
DISTANCE TO WELL -- Y COORDINATE (M)	450.
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)	0.
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)	1.00E-02
DEGREE OF SOIL SATURATION	1.000
RESIDUAL SOIL SATURATION	.000
PERMEABILITY OF VERTICAL ZONE (M/YR)	.32
SOIL NUMBER	.000
POROSITY OF AQUIFER	.25
POROSITY OF UNSATURATED ZONE	.25
DISTANCE FROM AQUIFER TO WASTE (M)	7.0
AVERAGE VERTICAL GROUNDWATER VELOCITY (M/YR)	2.50E-02
HORIZONTAL VELOCITY OF AQUIFER (M/YR)	4.2
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)
H-3	1.550E-07	6.400E-08	0.000E+00	1.230E+01
C-14	2.150E-06	2.100E-06	1.880E-09	5.730E+03
Tc-99	2.370E-06	7.500E-06	6.300E-11	2.130E+05
I-129	4.070E-04	1.800E-04	2.200E-06	1.600E+07
U-234	1.810E-04	1.300E-01	8.740E-08	2.440E+05
U-235	1.740E-04	1.200E-01	1.730E-05	7.040E+08
U-236	1.740E-04	1.300E-01	7.590E-08	2.340E+07
U-238	1.670E-04	1.200E-01	2.820E-06	4.470E+09
Np-237	4.070E-04	4.900E-01	3.200E-06	2.140E+06
Pu-239	9.250E-04	4.300E-01	4.290E-08	2.410E+04
Pu-240	9.250E-04	5.100E-01	8.200E-08	6.540E+03
Am-241	7.400E-04	4.400E-01	3.210E-06	4.320E+02

U-233	1.890E-04	1.400E-01	8.360E-08	1.590E+05

NUCLIDE	VOLATILITY FRACTION	GAMMA ENERGY (MEV)	GAMMA ATTENUATION (1/M)
H-3	0.000E+00	0.000E+00	0.000E+00
C-14	0.000E+00	0.000E+00	0.000E+00
Tc-99	0.000E+00	8.900E-02	2.920E+01
I-129	0.000E+00	4.000E-02	6.200E+01
U-234	0.000E+00	7.000E-02	3.550E+01
U-235	0.000E+00	1.690E-01	2.160E+01
U-236	0.000E+00	6.800E-02	3.660E+01
U-238	0.000E+00	7.180E-01	1.200E+01
Np-237	0.000E+00	7.200E-02	3.490E+01
Pu-239	0.000E+00	1.130E-01	2.580E+01
Pu-240	0.000E+00	5.400E-02	4.630E+01
Am-241	0.000E+00	5.700E-02	4.350E+01
U-233	0.000E+00	1.150E-01	2.570E+01

NUCLIDE	INPUT LEACH RATE (1/YR)	FINAL LEACH RATE (1/YR)	SOLUBILITY (MOLE/L)	INPUT INVENTORY (CI)
H-3	-1.990E-01	1.100E-03	0.000E+00	1.910E+06
C-14	-1.090E+00	3.134E-04	0.000E+00	1.910E+06
Tc-99	-1.290E+00	2.701E-04	0.000E+00	1.910E+06
I-129	-1.990E-01	1.381E-04	1.000E-02	1.910E+06
U-234	-4.000E+01	9.728E-06	0.000E+00	1.910E+06
U-235	-4.000E+01	9.728E-06	0.000E+00	1.910E+06
U-236	-4.000E+01	9.728E-06	0.000E+00	1.910E+06
U-238	-4.000E+01	9.728E-06	0.000E+00	1.910E+06
Np-237	-5.560E+01	7.006E-06	0.000E+00	1.910E+06
Pu-239	-5.760E+01	6.763E-06	0.000E+00	1.910E+06
Pu-240	-5.760E+01	6.763E-06	0.000E+00	1.910E+06
Am-241	-5.760E+01	6.763E-06	0.000E+00	1.910E+06
U-233	-4.000E+01	9.728E-06	0.000E+00	1.910E+06

NUCLIDE	AQUIFER SORPTION	AQUIFER RETARDATION	VERTICAL SORPTION	VERTICAL RETARDATION
H-3	0.000E+00	1.000E+00	0.000E+00	1.000E+00
C-14	0.000E+00	1.000E+00	0.000E+00	1.000E+00
Tc-99	0.000E+00	1.000E+00	0.000E+00	1.000E+00
I-129	0.000E+00	1.000E+00	1.990E-01	2.433E+00
U-234	7.000E-01	6.040E+00	2.000E+01	1.450E+02
U-235	7.000E-01	6.040E+00	2.000E+01	1.450E+02
U-236	7.000E-01	6.040E+00	2.000E+01	1.450E+02
U-238	7.000E-01	6.040E+00	2.000E+01	1.450E+02
Np-237	4.000E+00	2.980E+01	4.000E+01	2.890E+02
Pu-239	4.000E+00	2.980E+01	4.000E+01	2.890E+02
Pu-240	4.000E+00	2.980E+01	4.000E+01	2.890E+02
Am-241	4.000E+00	2.980E+01	4.000E+01	2.890E+02
U-233	7.000E-01	6.040E+00	2.000E+01	1.450E+02

		BIOACCUMULATION FACTORS		
NUCLIDE	SOIL-PLANT Bv	SOIL-PLANT Br	FORAGE-MILK Fm (D/L)	FORAGE-MEAT Ff (D/KG)
H-3	4.800E+00	4.800E-01	1.000E-02	1.200E-02
C-14	5.500E+00	5.500E-01	1.200E-02	3.100E-02
Tc-99	2.500E-01	2.500E-02	1.000E-03	1.000E-04
I-129	2.000E-02	2.000E-03	7.000E-03	1.000E-02
U-234	2.500E-03	2.500E-04	5.000E-04	3.400E-04
U-235	2.500E-03	2.500E-04	5.000E-04	3.400E-04
U-236	2.500E-03	2.500E-04	5.000E-04	3.400E-04
U-238	2.500E-03	2.500E-04	5.000E-04	3.400E-04
Np-237	2.500E-03	2.500E-04	5.000E-06	2.000E-04
Pu-239	2.500E-04	2.500E-05	2.000E-06	1.400E-05
Pu-240	2.500E-04	2.500E-05	2.000E-06	1.400E-05
Am-241	2.500E-04	2.500E-05	5.000E-06	2.000E-04
U-233	2.500E-03	2.500E-04	5.000E-04	3.400E-04

***** 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)
H-3	7.23E-14	401.0	1.31E-08	3.66E-15
C-14	1.14E-03	569.6	2.34E+03	6.54E-04
Tc-99	1.05E-03	606.7	1.84E+03	5.15E-04
I-129	5.37E-04	1096.4	1.82E+05	5.10E-02
U-234	3.35E-05	42471.7	4.48E+03	1.25E-03
U-235	3.78E-05	51627.5	4.86E+03	1.36E-03
U-236	3.78E-05	42592.7	4.85E+03	1.36E-03
U-238	3.78E-05	51627.5	4.66E+03	1.31E-03
Np-237	2.65E-05	90316.8	7.90E+03	2.21E-03
Pu-239	2.03E-06	88714.0	1.37E+03	3.85E-04
Pu-240	2.22E-09	87960.1	1.50E+00	4.21E-07
U-233	3.14E-05	42451.5	4.39E+03	1.23E-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 99 COCs and the remaining COCs are provided in Sect. 3.2.2.1 and Sect. 3.2.2.2, respectively.

3.2.2.1 First 99 Contaminants of Concern

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PATHRAE-HAZ(PC)  Version 2.3d  January 1997
  Date:  8-22-2012
  Time: 14:54: 7

pWAC - July, 2012 New Proposed Cell in UBCV - HAZ
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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
Antimony	7.332E+02	7.332E+02	1.423E+03	1.423E+03	1.423E+03	2.153E-01
Barium	7.372E+02	7.372E+02	7.648E+02	7.649E+02	7.649E+02	5.213E-01
Boron	7.474E+02	7.474E+02	7.474E+02	7.477E+02	7.477E+02	3.026E+01
Chromium-III	7.787E+02	7.787E+02	2.159E+03	2.159E+03	2.159E+03	6.445E-01
Lead	7.369E+02	7.369E+02	2.807E+03	2.807E+03	2.807E+03	4.682E-01
Manganese	7.355E+02	7.355E+02	3.496E+03	3.498E+03	3.498E+03	3.346E+00
Molybdenum	7.498E+02	7.498E+02	7.498E+02	7.500E+02	7.500E+02	3.254E+00
Selenium	1.312E+03	1.312E+03	1.312E+03	1.316E+03	1.316E+03	7.577E+01
Strontium	7.941E+02	7.941E+02	7.931E+02	7.941E+02	7.941E+02	2.096E+01
Tin	7.907E+02	7.907E+02	2.149E+04	2.149E+04	2.149E+04	1.895E+01
Vanadium	7.457E+02	7.457E+02	8.147E+02	8.147E+02	8.147E+02	4.151E-02
U-233	7.371E+02	7.371E+02	8.061E+02	8.061E+02	8.061E+02	1.201E-01
U-234	7.371E+02	7.371E+02	8.061E+02	8.061E+02	8.061E+02	1.201E-01
U-235	7.371E+02	7.371E+02	8.061E+02	8.061E+02	8.061E+02	1.201E-01
U-236	7.371E+02	7.371E+02	8.061E+02	8.061E+02	8.061E+02	1.201E-01
U-238	7.371E+02	7.371E+02	8.061E+02	8.061E+02	8.061E+02	1.201E-01
24-D	7.328E+02	7.328E+02	7.328E+02	7.328E+02	7.328E+02	5.498E+00
245-TP(Silvex)	7.342E+02	7.342E+02	7.342E+02	7.342E+02	7.342E+02	9.609E-01
Acenaphthene	7.365E+02	7.365E+02	8.326E+03	8.327E+03	8.327E+03	6.144E-01
Acenaphthylene	7.337E+02	7.337E+02	7.337E+02	7.338E+02	7.338E+02	1.201E+00
Acetone	7.328E+02	7.328E+02	7.328E+02	7.328E+02	7.328E+02	5.480E+01
Acentonitrile	7.329E+02	7.329E+02	7.329E+02	7.329E+02	7.329E+02	2.529E+02
acetophenone	7.328E+02	7.328E+02	7.328E+02	7.328E+02	7.328E+02	1.645E+01
Acrolien	7.329E+02	7.329E+02	7.328E+02	7.329E+02	7.329E+02	1.813E+02
Acylonitrle	7.328E+02	7.328E+02	7.328E+02	7.328E+02	7.328E+02	1.138E+02
Aldrin	7.330E+02	7.330E+02	7.330E+02	7.340E+02	7.340E+02	2.940E+00
Aroclor1221	7.351E+02	7.351E+02	7.351E+02	7.354E+02	7.354E+02	7.641E-01
Aroclor1232	7.331E+02	7.331E+02	7.331E+02	7.332E+02	7.332E+02	2.273E+00
Benzene	7.328E+02	7.328E+02	7.328E+02	7.328E+02	7.328E+02	2.450E+00
Benzoic-Acid	7.328E+02	7.328E+02	7.328E+02	7.328E+02	7.328E+02	1.266E+01
Benzyl-Alcohol	7.328E+02	7.328E+02	7.328E+02	7.328E+02	7.328E+02	3.668E+01
benzidine	7.328E+02	7.328E+02	7.328E+02	7.333E+02	7.333E+02	2.825E+01
Alpha-BHC	7.342E+02	7.342E+02	7.342E+02	7.343E+02	7.343E+02	9.609E-01
Beta-BHC	7.346E+02	7.346E+02	7.346E+02	7.346E+02	7.346E+02	8.399E-01
Delta-BHC	7.329E+02	7.329E+02	7.329E+02	7.330E+02	7.330E+02	3.820E+00
Bromodichloro	7.328E+02	7.328E+02	7.328E+02	7.328E+02	7.328E+02	9.708E+00

Bromoform	7.328E+02	7.328E+02	7.328E+02	7.328E+02	7.328E+02	6.340E+00
Bromometh	7.328E+02	7.328E+02	7.328E+02	7.328E+02	7.328E+02	3.246E+01
butylbenzene	7.334E+02	7.334E+02	7.334E+02	7.334E+02	7.334E+02	1.525E+00
Carbazole	7.340E+02	7.340E+02	3.839E+03	3.839E+03	3.839E+03	1.081E+00
CarbonDiS	7.328E+02	7.328E+02	7.328E+02	7.328E+02	7.328E+02	8.445E+00
Carbontetchl	7.329E+02	7.329E+02	7.329E+02	7.329E+02	7.329E+02	1.231E+00
Chlordane	7.905E+02	7.905E+02	7.905E+02	7.908E+02	7.908E+02	4.617E-01
Chlorobenzene	7.329E+02	7.329E+02	7.329E+02	7.329E+02	7.329E+02	3.820E+00
Chloroform	7.328E+02	7.328E+02	7.328E+02	7.328E+02	7.328E+02	2.955E+00
Chlorometh	7.328E+02	7.328E+02	7.328E+02	7.328E+02	7.328E+02	4.637E+01
0-ChloroTu	7.332E+02	7.333E+02	7.332E+02	7.333E+02	7.333E+02	1.775E+00
m-cresol	7.328E+02	7.328E+02	7.328E+02	7.328E+02	7.328E+02	1.097E+01
o-cresol	7.328E+02	7.328E+02	7.328E+02	7.328E+02	7.328E+02	1.266E+01
p-cresol	7.328E+02	7.328E+02	7.328E+02	7.328E+02	7.328E+02	1.266E+01
Cumene	7.334E+02	7.334E+02	7.334E+02	7.334E+02	7.334E+02	1.525E+00
Cyanide	7.328E+02	7.328E+02	7.570E+02	7.582E+02	7.582E+02	3.668E+01
DDD	8.493E+02	8.493E+02	8.493E+02	8.494E+02	8.494E+02	5.277E-01
DDE	8.270E+02	8.270E+02	8.270E+02	8.270E+02	8.270E+02	5.224E-01
Dinbutylphthalat	8.061E+02	8.061E+02	8.061E+02	8.061E+02	8.061E+02	1.249E-01
Dibenz[ah]	1.898E+03	1.898E+03	1.941E+03	1.955E+03	1.949E+03	1.255E+00
Dibenzofuran	7.352E+02	7.352E+02	7.352E+02	7.357E+02	7.357E+02	7.206E-01
Dibromochloro	7.328E+02	7.328E+02	7.328E+02	7.328E+02	7.328E+02	8.445E+00
12Dichloro	7.333E+02	7.333E+02	1.334E+03	1.334E+03	1.334E+03	1.775E+00
13Dichloro	7.335E+02	7.335E+02	1.424E+03	1.424E+03	1.424E+03	1.362E+00
14Dichlorobenzen	7.332E+02	7.333E+02	7.332E+02	7.333E+02	7.333E+02	1.775E+00
12cisDichloro	7.328E+02	7.328E+02	7.328E+02	7.328E+02	7.328E+02	1.266E+01
12transDichl	7.328E+02	7.328E+02	7.328E+02	7.328E+02	7.328E+02	8.431E+01
Dichlorodiflo	7.328E+02	7.328E+02	7.328E+02	7.328E+02	7.328E+02	8.445E+00
12Dichlprop	7.328E+02	7.328E+02	7.328E+02	7.328E+02	7.328E+02	1.097E+01
Dieldrin	8.286E+02	8.286E+02	8.284E+02	8.287E+02	8.287E+02	2.459E+00
Diethylphth	7.328E+02	7.328E+02	7.328E+02	7.328E+02	7.328E+02	5.498E+00
12DiMethylB	7.330E+02	7.330E+02	7.330E+02	7.330E+02	7.330E+02	2.566E+00
24-Dimethylphe	7.328E+02	7.328E+02	7.328E+02	7.329E+02	7.329E+02	7.604E+00
Dimethylphth	7.328E+02	7.328E+02	7.328E+02	7.328E+02	7.328E+02	1.898E+01
24Dinitrotoluene	7.328E+02	7.328E+02	7.770E+02	7.770E+02	7.770E+02	1.097E+01
26Dinitrotoluene	7.328E+02	7.328E+02	7.756E+02	7.756E+02	7.756E+02	1.645E+01
EndosulfanII	7.334E+02	7.334E+02	7.334E+02	7.334E+02	7.334E+02	1.444E+00
Endrin	7.400E+02	7.400E+02	7.400E+02	7.401E+02	7.401E+02	4.928E-01
Aldehyde	7.400E+02	7.400E+02	7.400E+02	7.401E+02	7.401E+02	4.928E-01
Ketone	7.400E+02	7.400E+02	7.400E+02	7.401E+02	7.401E+02	4.928E-01
Ethylbenz	7.330E+02	7.330E+02	7.330E+02	7.330E+02	7.330E+02	2.605E+00
Ethylchlorid	7.328E+02	7.328E+02	7.328E+02	7.328E+02	7.328E+02	2.488E+01
Heptachlor	7.365E+02	7.365E+02	7.365E+02	7.366E+02	7.366E+02	6.144E-01
Heptachlor-epoxd	7.789E+02	7.789E+02	7.789E+02	7.789E+02	7.789E+02	4.365E-01
Hexachlorobenzen	7.695E+02	7.695E+02	7.695E+02	7.696E+02	7.696E+02	4.244E-01
Hexachloroethane	7.342E+02	7.342E+02	7.342E+02	7.343E+02	7.343E+02	9.609E-01
Nhexane	7.342E+02	7.342E+02	7.342E+02	7.342E+02	7.342E+02	9.609E-01
1hexanol	7.328E+02	7.328E+02	7.328E+02	7.328E+02	7.328E+02	2.488E+01
2hexanone	7.328E+02	7.328E+02	7.328E+02	7.328E+02	7.328E+02	2.488E+01
Isophorone	7.329E+02	7.329E+02	7.328E+02	7.329E+02	7.329E+02	2.030E+00
Lindane	7.337E+02	7.337E+02	7.337E+02	7.338E+02	7.338E+02	1.201E+00
Methonal	7.330E+02	7.330E+02	7.329E+02	7.330E+02	7.330E+02	4.637E+02
Methchloride	7.328E+02	7.328E+02	7.328E+02	7.328E+02	7.328E+02	2.825E+01
Methylcyclo	7.329E+02	7.329E+02	1.561E+03	1.561E+03	1.561E+03	3.526E+00
MethylIso	7.328E+02	7.328E+02	7.328E+02	7.328E+02	7.328E+02	3.246E+01
MMetacrylate	7.328E+02	7.328E+02	7.328E+02	7.328E+02	7.328E+02	2.825E+01
MethylEthylB	7.334E+02	7.334E+02	7.334E+02	7.334E+02	7.334E+02	1.525E+00
2Methylnaptha	7.342E+02	7.342E+02	7.342E+02	7.343E+02	7.343E+02	9.609E-01
MethylPropylB	7.334E+02	7.334E+02	7.334E+02	7.334E+02	7.334E+02	1.525E+00
Naphthalene	7.332E+02	7.332E+02	2.044E+03	2.044E+03	2.044E+03	1.981E+00
4Nitrobenzenamin	7.328E+02	7.328E+02	7.357E+03	7.357E+03	7.357E+03	2.867E+01
Nitrobenzene	7.328E+02	7.328E+02	7.328E+02	7.328E+02	7.328E+02	1.434E+01
2Nitrophenol	7.328E+02	7.328E+02	7.328E+02	7.328E+02	7.328E+02	1.519E+01

********** Image of Input Files **********

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-- Input File:  ABCDEF.DAT
pWAC - July, 2012 New Proposed Cell in UBCV - HAZ
3,1000.,1200.,100000.
99,0,2
1,2,
0.,486.0,243.0,4.91E+05,1.,476.,0.
1800.,6.,0.,0.,0.,0.,0.315,0.
20,2,0,1,1
4.0,16.,1.91E+06,150.,450.,1600.,.40,.705,0.90,1.
1.0E-7,8000.,.705,0.,1.0E+00,0.01
240.,5.56E-04,.22,.02,3.0E-4,20.,0.01
4,6.3,.23,0.,1.1E-06,0.01,0.,0.,0.,0.,0.
0,0,0,0,0,0,0
1,0,0,1
0.010,4.2,0.25,7.0,0.025,24.,0.00001,1.,0.,0.25
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-- 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
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
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
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,O-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
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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
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
641,246-Trichlorphnl 1.10E-02,1.00E-03,0.00E+00,0.00E+00
642,123TriChlopr     3.00E+01,4.00E-03,0.00E+00,0.00E+00
643,Trimethbenz      0.00E+00,5.00E-02,0.00E+00,0.00E+00
644,124trimethylb    0.00E+00,0.00E+00,0.00E+00,0.00E+00
645,135Trimeth       0.00E+00,1.00E-02,0.00E+00,0.00E+00
646,Vinyl-Chloride   7.20E-01,3.00E-03,0.00E+00,0.00E+00
647,Xylene           0.00E+00,2.00E-01,0.00E+00,0.00E+00
122,Mercury          0.00E+00,3.00E-04,0.00E+00,0.00E+00
702,Endosulfan       0.00E+00,5.00E-02,0.00E+00,0.00E+00
703,14Dichloro       2.40E-02,6.00E-03,0.00E+00,0.00E+00

-- Input File:  INVNTRY.DAT
102,  1.00E+10, 1.670E+06,      0,      0, 0.000E+00,      0,    Antimony
104,  1.00E+10, 1.670E+06,      0,      0, 0.000E+00,      0,    Barium
106,  1.00E+10, 1.670E+06,      0,      0, 0.000E+00,      0,    Boron
109,  1.00E+10, 1.670E+06,      0,      0, 0.000E+00,      0,    Chromium
118,  1.00E+10, 1.670E+06,      0,      0, 0.000E+00,      0,    Lead
121,  1.00E+10, 1.670E+06,      0,      0, 0.000E+00,      0,    Manganese
123,  1.00E+10, 1.670E+06,      0,      0, 7.660E+04,      0,    Molybdenum
128,  1.00E+10, 1.670E+06,      0,      0, 0.000E+00,      0,    Selenium
131,  1.00E+10, 1.670E+06,      0,      0, 0.000E+00,      0,    Strontium
134,  1.00E+10, 1.670E+06,      0,      0, 0.000E+00,      0,    Tin
136,  1.00E+10, 1.670E+06,      0,      0, 0.000E+00,      0,    Vanadium
140,  1.59E+05, 1.670E+06,      0,      0, 0.000E+00,      0,    U-233
141,  2.44E+05, 1.670E+06,      0,      0, 0.000E+00,      0,    U-234
142,  7.04E+08, 1.670E+06,      0,      0, 0.000E+00,      0,    U-235
143,  2.34E+07, 1.670E+06,      0,      0, 0.000E+00,      0,    U-236
144,  4.47E+09, 1.670E+06,      0,      0, 0.000E+00,      0,    U-238
501,  1.00E+10, 1.670E+06,      0,      0, 6.820E+02,      0,    24-D
502,  1.00E+10, 1.670E+06,      0,      0, 2.000E+02,      0,    245-TP
503,  1.00E+10, 1.670E+06,      0,      0, 3.420E+00,      0,    Acenaphthene
504,  1.00E+10, 1.670E+06,      0,      0, 1.610E+01,      0,    Acenaphthylene
505,  1.00E+10, 1.670E+06,      0,      0, 0.000E+00,      0,    Acetone
506,  1.00E+10, 1.670E+06,      0,      0, 1.000E+06,      0,    Acentonitrile
507,  1.00E+10, 1.670E+06,      0,      0, 6.130E+03,      0,    acetophenone
508,  1.00E+10, 1.670E+06,      0,      0, 1.200E+04,      0,    Acrolien
509,  1.00E+10, 1.670E+06,      0,      0, 7.450E+04,      0,    Acylonitrle
510,  1.00E+10, 1.670E+06,      0,      0, 1.700E-02,      0,    Aldrin
513,  1.00E+10, 1.670E+06,      0,      0, 4.830E+00,      0,    Aroclor1221
514,  1.00E+10, 1.670E+06,      0,      0, 4.830E+00,      0,    Aroclor1232
520,  1.00E+10, 1.670E+06,      0,      0, 0.000E+00,      0,    Benzene
526,  1.00E+10, 1.670E+06,      0,      0, 3.400E+03,      0,    Benzolic
527,  1.00E+10, 1.670E+06,      0,      0, 4.290E+04,      0,    Benzyl
528,  1.00E+10, 1.670E+06,      0,      0, 3.220E+02,      0,    benzidine
529,  1.00E+10, 1.670E+06,      0,      0, 8.000E+00,      0,    Alpha-BHC
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530,	1.00E+10,	1.670E+06,	0,	0,	8.000E+00,	0,	Beta-BHC
531,	1.00E+10,	1.670E+06,	0,	0,	8.000E+00,	0,	Delta-BHC
533,	1.00E+10,	1.670E+06,	0,	0,	3.030E+03,	0,	Bromodichloro
534,	1.00E+10,	1.670E+06,	0,	0,	1.000E+02,	0,	Bromoform
535,	1.00E+10,	1.670E+06,	0,	0,	5.200E+03,	0,	Bromometh
537,	1.00E+10,	1.670E+06,	0,	0,	6.130E+01,	0,	butylbenzene
539,	1.00E+10,	1.670E+06,	0,	0,	1.800E+00,	0,	Carbazole
540,	1.00E+10,	1.670E+06,	0,	0,	1.180E+03,	0,	CarbonDiS
541,	1.00E+10,	1.670E+06,	0,	0,	0.000E+00,	0,	Carbontetchl
542,	1.00E+10,	1.670E+06,	0,	0,	5.600E-02,	0,	Chlordane
543,	1.00E+10,	1.670E+06,	0,	0,	4.980E+02,	0,	Chlorobenzene
544,	1.00E+10,	1.670E+06,	0,	0,	0.000E+00,	0,	Chloroform
545,	1.00E+10,	1.670E+06,	0,	0,	5.320E+03,	0,	Chlorometh
548,	1.00E+10,	1.670E+06,	0,	0,	3.740E+02,	0,	0-ChloroTu
550,	1.00E+10,	1.670E+06,	0,	0,	2.270E+04,	0,	m-cresol
551,	1.00E+10,	1.670E+06,	0,	0,	2.590E+04,	0,	o-cresol
552,	1.00E+10,	1.670E+06,	0,	0,	2.150E+04,	0,	p-cresol
553,	1.00E+10,	1.670E+06,	0,	0,	6.130E+01,	0,	Cumene
554,	1.00E+10,	1.670E+06,	0,	0,	1.000E+06,	0,	Cyanide
555,	1.00E+10,	1.670E+06,	0,	0,	9.000E-02,	0,	DDD
556,	1.00E+10,	1.670E+06,	0,	0,	4.000E-02,	0,	DDE
558,	1.00E+10,	1.670E+06,	0,	0,	0.000E+00,	0,	Dinbutylphthalat
560,	1.00E+10,	1.670E+06,	0,	0,	1.030E-03,	0,	Dibenz[ah]
561,	1.00E+10,	1.670E+06,	0,	0,	3.100E+00,	0,	Dibenzofuran
562,	1.00E+10,	1.670E+06,	0,	0,	2.700E+03,	0,	Dibromochloro
563,	1.00E+10,	1.670E+06,	0,	0,	8.000E+01,	0,	12Dichloro
564,	1.00E+10,	1.670E+06,	0,	0,	1.250E+02,	0,	13Dichloro
565,	1.00E+10,	1.670E+06,	0,	0,	8.130E+01,	0,	14Dichlorobenzen
571,	1.00E+10,	1.670E+06,	0,	0,	3.500E+03,	0,	12cisDichloro
572,	1.00E+10,	1.670E+06,	0,	0,	3.500E+03,	0,	12transDichl
573,	1.00E+10,	1.670E+06,	0,	0,	2.800E+02,	0,	Dichlorodiflo
574,	1.00E+10,	1.670E+06,	0,	0,	2.800E+03,	0,	12Dichlprop
575,	1.00E+10,	1.670E+06,	0,	0,	0.000E+00,	0,	Dieldrin
576,	1.00E+10,	1.670E+06,	0,	0,	1.080E+03,	0,	Diethylphth
577,	1.00E+10,	1.670E+06,	0,	0,	2.200E+02,	0,	12DiMethylB
579,	1.00E+10,	1.670E+06,	0,	0,	7.870E+03,	0,	24-Dimethylphe
580,	1.00E+10,	1.670E+06,	0,	0,	4.000E+03,	0,	Dimethylphth
582,	1.00E+10,	1.670E+06,	0,	0,	2.700E+02,	0,	24Dinitrotoluene
583,	1.00E+10,	1.670E+06,	0,	0,	3.520E+02,	0,	26Dinitrotoluene
585,	1.00E+10,	1.670E+06,	0,	0,	4.500E-01,	0,	EndosufanII
586,	1.00E+10,	1.670E+06,	0,	0,	2.500E-01,	0,	Endrin
587,	1.00E+10,	1.670E+06,	0,	0,	2.500E-01,	0,	Aldehyde
588,	1.00E+10,	1.670E+06,	0,	0,	2.500E-01,	0,	Ketone
589,	1.00E+10,	1.670E+06,	0,	0,	1.690E+02,	0,	Ethylbenz
590,	1.00E+10,	1.670E+06,	0,	0,	6.700E+03,	0,	Ethylchlorid
593,	1.00E+10,	1.670E+06,	0,	0,	1.800E-01,	0,	Heptachlor
594,	1.00E+10,	1.670E+06,	0,	0,	2.000E-01,	0,	Heptachlor
595,	1.00E+10,	1.670E+06,	0,	0,	6.200E-03,	0,	Hexachlorobenzen
596,	1.00E+10,	1.670E+06,	0,	0,	5.000E+01,	0,	Hexachloroethane
597,	1.00E+10,	1.670E+06,	0,	0,	9.500E+00,	0,	Nhexane
598,	1.00E+10,	1.670E+06,	0,	0,	5.900E+03,	0,	1hexanol
599,	1.00E+10,	1.670E+06,	0,	0,	5.900E+03,	0,	2hexanone
601,	1.00E+10,	1.670E+06,	0,	0,	0.000E+00,	0,	Isophorone
602,	1.00E+10,	1.670E+06,	0,	0,	8.000E+00,	0,	Lindane
603,	1.00E+10,	1.670E+06,	0,	0,	1.000E+06,	0,	Methonal
605,	1.00E+10,	1.670E+06,	0,	0,	1.300E+04,	0,	Methchloride
606,	1.00E+10,	1.670E+06,	0,	0,	1.400E+01,	0,	Methylcyclo
607,	1.00E+10,	1.670E+06,	0,	0,	1.900E+04,	0,	MethylIso
608,	1.00E+10,	1.670E+06,	0,	0,	1.500E+04,	0,	MMetacrylate
609,	1.00E+10,	1.670E+06,	0,	0,	6.100E+01,	0,	MethylEthylB
610,	1.00E+10,	1.670E+06,	0,	0,	2.460E+01,	0,	2Methylnaptha
611,	1.00E+10,	1.670E+06,	0,	0,	6.100E+01,	0,	MethylPropylB
612,	1.00E+10,	1.670E+06,	0,	0,	0.000E+00,	0,	Naphthalene
614,	1.00E+10,	1.670E+06,	0,	0,	1.070E-05,	0,	4Nitrobenzenamin
615,	1.00E+10,	1.670E+06,	0,	0,	2.090E+03,	0,	Nitrobenzene
616,	1.00E+10,	1.670E+06,	0,	0,	2.500E+03,	0,	2Nitrophenol
617,	1.00E+10,	1.670E+06,	0,	0,	1.160E+04,	0,	4Nitrophenol
618,	1.00E+10,	1.670E+06,	0,	0,	0.000E+00,	0,	NnitroNpropyl
619,	1.00E+10,	1.670E+06,	0,	0,	3.500E+01,	0,	NNitrosodiphen
622,	1.00E+10,	1.670E+06,	0,	0,	9.300E+04,	0,	Phenol
623,	1.00E+10,	1.670E+06,	0,	0,	6.100E+01,	0,	PropylB
624,	1.00E+10,	1.670E+06,	0,	0,	1.000E+06,	0,	PropGlycol
626,	1.00E+10,	1.670E+06,	0,	0,	1.000E+06,	0,	Pyridine
627,	1.00E+10,	1.670E+06,	0,	0,	3.100E+02,	0,	Styrene
628,	1.00E+10,	1.670E+06,	0,	0,	1.070E+03,	0,	1112Tetra
629,	1.00E+10,	1.670E+06,	0,	0,	2.870E+03,	0,	1122Tetra
630,	1.00E+10,	1.670E+06,	0,	0,	0.000E+00,	0,	Tetrachloroethen
631,	1.00E+10,	1.670E+06,	0,	0,	2.300E+01,	0,	2346Tetrachlor
632,	1.00E+10,	1.670E+06,	0,	0,	0.000E+00,	0,	Toluene
634,	1.00E+10,	1.670E+06,	0,	0,	5.700E+01,	0,	124Trichlorb
637,	1.00E+10,	1.670E+06,	0,	0,	0.000E+00,	0,	Trichloroethene

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639,  1.00E+10, 1.670E+06,          0,      0, 1.100E+03,     0,    TriChloFlo
641,  1.00E+10, 1.670E+06,          0,      0, 8.000E+02,     0,    246-Trichlorophnl
642,  1.00E+10, 1.670E+06,          0,      0, 1.750E+03,     0,    123TriChlopr
643,  1.00E+10, 1.670E+06,          0,      0, 5.700E+01,     0,    Trimethbenz
644,  1.00E+10, 1.670E+06,          0,      0, 5.700E+01,     0,    124trimethylb
645,  1.00E+10, 1.670E+06,          0,      0, 4.820E+01,     0,    135Trimeth
646,  1.00E+10, 1.670E+06,          0,      0, 8.800E+03,     0,    Vinyl
647,  1.00E+10, 1.670E+06,          0,      0, 1.060E+02,     0,    Xylene
122,  1.00E+10, 1.670E+06,          0,      0, 0.000E+00,     0,    Mercury
702,  1.00E+10, 1.670E+06,          0,      0, 4.500E-01,     0,    Endosulfan
703,  1.00E+10, 1.670E+06,          0,      0, 8.130E+01,     0,    14Dichloro

-- 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
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,-4.000E+01, 7.000E-01, 2.000E+01,      U-233
141,-4.000E+01, 7.000E-01, 2.000E+01,      U-234
142,-4.000E+01, 7.000E-01, 2.000E+01,      U-235
143,-4.000E+01, 7.000E-01, 2.000E+01,      U-236
144,-4.000E+01, 7.000E-01, 2.000E+01,      U-238
501,-5.880E-02, 5.880E-03, 5.880E-02,      24-D
502,-1.608E-01, 1.608E-02, 1.608E-01,      245-TP
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
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
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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,-4.340E-02, 4.340E-03, 4.340E-02,        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
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
641,-6.360E-01, 6.360E-02, 6.360E-01,        246-Trichlorophnl
642,-1.610E-01, 1.610E-02, 1.610E-01,        123TriChlopr
643,-1.440E+00, 1.440E-01, 1.440E+00,        Trimethbenz
644,-1.440E+00, 1.440E-01, 1.440E+00,        124trimethylb
645,-3.340E+00, 3.340E-01, 3.340E+00,        135Trimeth
646,-3.720E-01, 3.720E-02, 3.720E-01,        Vinyl
647,-8.860E-01, 8.860E-02, 8.860E-01,        Xylene
122,-5.800E+02, 5.800E+01, 5.800E+02,        Mercury
702,-4.080E+00, 4.080E-01, 4.080E+00,        Endosulfan
703,-1.232E+00, 1.232E-01, 1.232E+00,        14DiChloro


-- 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., 6.9


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
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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
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
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
Methchloride	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
246-Trichlorphnl	0.25,	2.70E-01,	2.70E-02,	4.00E-05,	0,	1.30E-04,	0.00E+00,	641
123TriChlopr	0.25,	8.20E-02,	8.20E-03,	3.10E-04,	0,	1.00E-03,	0.00E+00,	642
Trimethbenz	0.25,	2.40E-01,	2.40E-02,	4.80E-05,	0,	1.50E-04,	0.00E+00,	643
124trimethylb	0.25,	2.40E-01,	2.40E-02,	4.80E-05,	0,	1.50E-04,	0.00E+00,	644
135Trimeth	0.25,	3.90E-01,	3.90E-02,	2.10E-05,	0,	6.60E-05,	0.00E+00,	645
Vinyl chloride	0.25,	5.90E+00,	5.90E-01,	2.00E-07,	0,	6.30E-07,	0.00E+00,	646
Xylene	0.25,	4.60E-01,	4.60E-02,	1.60E-05,	0,	5.00E-05,	5.50E+01,	647
Mercury	0.25,	1.00E+00,	1.00E-01,	4.70E-04,	0,	1.00E-02,	1.00E+03,	122
Endosulfan	0.25,	3.30E-01,	3.30E-02,	2.80E-05,	0,	8.90E-05,	5.20E+03,	702
14Dichloro	0.25,	4.10E-01,	4.10E-02,	2.00E-05,	0,	6.30E-05,	8.90E+01,	703

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********** PATHRAE INPUT SUMMARY **********

THERE ARE 99 CONTAMINANTS IN THE RISK FACTOR LIBRARY
NUMBER OF TIMES FOR CALCULATION IS  3
YEARS TO BE CALCULATED ARE ...

  1000.00  1200.00100000.00

THERE ARE  99 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
   0  3X,I2,2X,A22,6X,I2))           0

TIME OF OPERATION OF WASTE FACILITY IN YEARS                 0.
LENGTH OF REPOSITORY (M) 486.
WIDTH OF REPOSITORY (M)  243.
RIVER FLOW RATE (M**3/YR)  4.91E+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)                                6.00E+00
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)                               4.00
THICKNESS OF WASTE IN PITS (M)                              16.00
TOTAL WASTE VOLUME (M**3)  1.910E+06
DISTANCE TO WELL -- X COORDINATE (M)                       150.
DISTANCE TO WELL -- Y COORDINATE (M)                       450.
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.
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FRACTION OF YEAR EXPOSED TO DUST .705
CANISTER LIFETIME (YEARS) 0.
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 CLASS4
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) 1.00E-02
DEGREE OF SOIL SATURATION 1.000
RESIDUAL SOIL SATURATION .000

PERMEABILITY OF VERTICAL ZONE (M/YR) .32
SOIL NUMBER .000
POROSITY OF AQUIFER .25
POROSITY OF UNSATURATED ZONE.25
DISTANCE FROM AQUIFER TO WASTE (M) 7.0
AVERAGE VERTICAL GROUNDWATER VELOCITY (M/YR) 2.50E-02

HORIZONTAL VELOCITY OF AQUIFER (M/YR) 4.20E+00
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
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

VAPORIZATION CONTAMINANT	SKIN VOLATILITY FRACTION	RATE (1/S)	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
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

CONTAMINANT	INPUT LEACH (1/YR)	FINAL LEACH (1/YR)	SOLUBILITY (MG/L)	INPUT INVENTORY (KG)
Antimony	-1.900E+01	2.039E-05	0.000E+00	1.670E+06
Barium	-5.500E+01	7.082E-06	0.000E+00	1.670E+06
Boron	-3.000E+00	1.238E-04	0.000E+00	1.670E+06
Chromium-III	-1.000E+01	3.846E-05	0.000E+00	1.670E+06
Lead	-1.000E+02	3.900E-06	0.000E+00	1.670E+06
Manganese	-2.000E+02	1.952E-06	0.000E+00	1.670E+06
Molybdenum	-2.000E+01	1.938E-05	7.660E+04	1.670E+06
Selenium	-1.500E+01	2.577E-05	0.000E+00	1.670E+06
Strontium	-1.350E+01	2.860E-05	0.000E+00	1.670E+06
Tin	-2.500E+00	1.471E-04	0.000E+00	1.670E+06
Vanadium	-1.000E+02	3.900E-06	0.000E+00	1.670E+06
U-233	-4.000E+01	9.728E-06	0.000E+00	1.670E+06
U-234	-4.000E+01	9.728E-06	0.000E+00	1.670E+06
U-235	-4.000E+01	9.728E-06	0.000E+00	1.670E+06
U-236	-4.000E+01	9.728E-06	0.000E+00	1.670E+06
U-238	-4.000E+01	9.728E-06	0.000E+00	1.670E+06
24-D	-5.880E-02	4.823E-04	6.820E+02	1.670E+06
245-TP(Silvex)	-1.608E-01	1.414E-04	2.000E+02	1.670E+06
Acenaphthene	-9.200E+01	2.419E-06	3.420E+00	1.670E+06
Acenaphthylene	-1.220E+01	1.139E-05	1.610E+01	1.670E+06
Acetone	-4.400E-02	1.951E-03	0.000E+00	1.670E+06
Acentonitrile	-1.540E-03	2.476E-03	1.000E+06	1.670E+06
acetophenone	-9.240E-02	1.571E-03	6.130E+03	1.670E+06
Acrolien	-2.780E-03	2.456E-03	1.200E+04	1.670E+06
Acylonitrle	-4.440E-03	2.431E-03	7.450E+04	1.670E+06
Aldrin	-9.740E+01	1.202E-08	1.700E-02	1.670E+06
Aroclor1221	-1.200E+02	3.251E-06	4.830E+00	1.670E+06
Aroclor1232	-1.500E+01	3.416E-06	4.830E+00	1.670E+06
Benzene	-1.700E+00	2.104E-04	0.000E+00	1.670E+06
Benzoic-Acid	-1.200E-03	2.404E-03	3.400E+03	1.670E+06
Benzyl-Alcohol	-3.130E-02	2.083E-03	4.290E+04	1.670E+06
benzidine	-5.480E+00	6.931E-05	3.220E+02	1.670E+06
Alpha-BHC	-3.520E+00	5.657E-06	8.000E+00	1.670E+06
Beta-BHC	-4.280E+00	5.657E-06	8.000E+00	1.670E+06
Delta-BHC	-4.280E+00	5.657E-06	8.000E+00	1.670E+06
Bromodichloro	-1.080E-02	2.143E-03	3.030E+03	1.670E+06
Bromoform	-2.520E-01	7.072E-05	1.000E+02	1.670E+06
Bromometh	-2.830E-02	2.117E-03	5.200E+03	1.670E+06
butylbenzene	-1.630E+00	4.335E-05	6.130E+01	1.670E+06
Carbazole	-6.780E+00	1.273E-06	1.800E+00	1.670E+06
CarbonDiS	-1.030E-01	8.345E-04	1.180E+03	1.670E+06
Carbontetchl	-2.200E+00	1.658E-04	0.000E+00	1.670E+06
Chlordane	-1.730E+02	3.960E-08	5.600E-02	1.670E+06
Chlorobenzene	-4.380E-01	3.522E-04	4.980E+02	1.670E+06
Chloroform	-6.200E-01	5.032E-04	0.000E+00	1.670E+06
Chlorometh	-2.860E-02	2.113E-03	5.320E+03	1.670E+06
0-ChloroTu	-8.860E-01	2.645E-04	3.740E+02	1.670E+06
m-cresol	-9.560E-02	1.551E-03	2.270E+04	1.670E+06
o-cresol	-1.820E-01	1.155E-03	2.590E+04	1.670E+06
p-cresol	-9.220E-02	1.572E-03	2.150E+04	1.670E+06
Cumene	-1.650E+00	4.335E-05	6.130E+01	1.670E+06
Cyanide	-9.900E+00	3.884E-05	1.000E+06	1.670E+06
DDD	-9.160E+01	6.365E-08	9.000E-02	1.670E+06
DDE	-1.730E+00	2.829E-08	4.000E-02	1.670E+06
Dinbutylphthalat	-1.000E-06	2.500E-03	0.000E+00	1.670E+06
Dibenz[ah]	-3.580E+03	7.284E-10	1.030E-03	1.670E+06
Dibenzofuran	-2.260E+02	1.727E-06	3.100E+00	1.670E+06
Dibromochloro	-1.410E-01	1.314E-03	2.700E+03	1.670E+06
12Dichloro	-7.580E-01	5.657E-05	8.000E+01	1.670E+06
13Dichloro	-1.606E+01	2.409E-05	1.250E+02	1.670E+06
14Dichlorobenzen	-1.232E+00	5.749E-05	8.130E+01	1.670E+06
12cisDichloro	-9.960E-01	3.390E-04	3.500E+03	1.670E+06
12transDichl	-7.600E-02	1.682E-03	3.500E+03	1.670E+06
Dichlorodiflo	-1.370E-02	1.980E-04	2.800E+02	1.670E+06
12Dichlprop	-9.400E-02	1.561E-03	2.800E+03	1.670E+06
Dieldrin	-3.400E+01	1.144E-05	0.000E+00	1.670E+06
Diethylphth	-2.520E-01	7.637E-04	1.080E+03	1.670E+06
12DiMethylB	-4.800E-01	1.556E-04	2.200E+02	1.670E+06
24-Dimethylphe	-2.520E+00	1.460E-04	7.870E+03	1.670E+06

Dimethylphth	-7.420E-02	1.695E-03	4.000E+03	1.670E+06
24Dinitrotoluene	-1.020E-01	1.909E-04	2.700E+02	1.670E+06
26Dinitrotoluene	-8.390E-02	2.489E-04	3.520E+02	1.670E+06
EndosulfanII	-4.080E+00	3.182E-07	4.500E-01	1.670E+06
Endrin	-2.160E+01	1.768E-07	2.500E-01	1.670E+06
Aldehyde	-2.160E+01	1.768E-07	2.500E-01	1.670E+06
Ketone	-2.160E+01	1.768E-07	2.500E-01	1.670E+06
Ethylbenz	-4.080E-01	1.195E-04	1.690E+02	1.670E+06
Ethylchlorid	-4.750E-02	1.917E-03	6.700E+03	1.670E+06
Heptachlor	-4.800E+01	1.273E-07	1.800E-01	1.670E+06
Heptachlor-epoxd	-1.730E+01	1.414E-07	2.000E-01	1.670E+06
Hexachlorobenzen	-1.100E+02	4.384E-09	6.200E-03	1.670E+06
Hexachloroethane	-3.560E+00	3.536E-05	5.000E+01	1.670E+06
Nhexane	-2.980E-01	6.718E-06	9.500E+00	1.670E+06
1hexanol	-2.600E-02	2.143E-03	5.900E+03	1.670E+06
2hexanone	-2.600E-02	2.143E-03	5.900E+03	1.670E+06
Isophorone	-1.700E+00	2.104E-04	0.000E+00	1.670E+06
Lindane	-6.760E+00	5.657E-06	8.000E+00	1.670E+06
Methonal	-2.000E-03	2.468E-03	1.000E+06	1.670E+06
Methchloride	-4.340E-02	1.957E-03	1.300E+04	1.670E+06
Methylcyclo	-1.990E-01	9.900E-06	1.400E+01	1.670E+06
MethylIso	-4.700E-03	2.427E-03	1.900E+04	1.670E+06
MMetacrylate	-2.000E-02	2.216E-03	1.500E+04	1.670E+06
MethylEthylB	-1.650E+00	4.314E-05	6.100E+01	1.670E+06
2Methylnaptha	-5.940E+00	1.740E-05	2.460E+01	1.670E+06
MethylPropylB	-1.650E+00	4.314E-05	6.100E+01	1.670E+06
Naphthalene	-1.900E+01	2.039E-05	0.000E+00	1.670E+06
4Nitrobenzenamin	-3.440E-01	7.567E-12	1.070E-05	1.670E+06
Nitrobenzene	-1.290E-01	1.369E-03	2.090E+03	1.670E+06
2Nitrophenol	-7.100E-01	4.509E-04	2.500E+03	1.670E+06

CONTAMINANT	AQUIFER SORPTION	AQUIFER RETARDATION	VERTICAL SORPTION	VERTICAL RETARDATION
Antimony	1.900E+00	1.468E+01	1.900E+01	1.378E+02
Barium	5.500E+00	4.060E+01	5.500E+01	3.970E+02
Boron	3.000E-01	3.160E+00	3.000E+00	2.260E+01
Chromium-III	1.000E+00	8.200E+00	1.000E+01	7.300E+01
Lead	1.000E+01	7.300E+01	1.000E+02	7.210E+02
Manganese	2.000E+01	1.450E+02	2.000E+02	1.441E+03
Molybdenum	2.000E+00	1.540E+01	2.000E+01	1.450E+02
Selenium	1.500E+00	1.180E+01	1.500E+01	1.090E+02
Strontium	0.000E+00	1.000E+00	1.350E+01	9.820E+01
Tin	2.500E-01	2.800E+00	2.500E+00	1.900E+01
Vanadium	1.000E+01	7.300E+01	1.000E+02	7.210E+02
U-233	7.000E-01	6.040E+00	2.000E+01	1.450E+02
U-234	7.000E-01	6.040E+00	2.000E+01	1.450E+02
U-235	7.000E-01	6.040E+00	2.000E+01	1.450E+02
U-236	7.000E-01	6.040E+00	2.000E+01	1.450E+02
U-238	7.000E-01	6.040E+00	2.000E+01	1.450E+02
24-D	5.880E-03	1.042E+00	5.880E-02	1.423E+00
245-TP(Silvex)	1.608E-02	1.116E+00	1.608E-01	2.158E+00
Acenaphthene	9.200E+00	6.724E+01	9.200E+01	6.634E+02
Acenaphthylene	1.220E+00	9.784E+00	1.220E+01	8.884E+01
Acetone	0.000E+00	1.000E+00	4.400E-02	1.317E+00
Acentonitrile	1.540E-04	1.001E+00	1.540E-03	1.011E+00
acetophenone	9.240E-03	1.067E+00	9.240E-02	1.665E+00
Acrolien	2.780E-04	1.002E+00	2.780E-03	1.020E+00
Acylonitrle	4.440E-04	1.003E+00	4.440E-03	1.032E+00
Aldrin	9.740E+00	7.113E+01	9.740E+01	7.023E+02
Aroclor1221	1.200E+02	8.650E+02	1.200E+02	8.650E+02
Aroclor1232	1.500E+01	1.090E+02	1.500E+01	1.090E+02
Benzene	0.000E+00	1.000E+00	1.700E+00	1.324E+01
Benzoic-Acid	1.200E-04	1.001E+00	1.200E-03	1.009E+00
Benzyl-Alcohol	3.130E-03	1.023E+00	3.130E-02	1.225E+00
benzidine	5.480E-01	4.946E+00	5.480E+00	4.046E+01
Alpha-BHC	3.520E-01	3.534E+00	3.520E+00	2.634E+01
Beta-BHC	4.280E-01	4.082E+00	4.280E+00	3.182E+01
Delta-BHC	4.280E-01	4.082E+00	4.280E+00	3.182E+01
Bromodichloro	1.080E-03	1.008E+00	1.080E-02	1.078E+00
Bromoform	2.520E-02	1.181E+00	2.520E-01	2.814E+00
Bromometh	2.830E-03	1.020E+00	2.830E-02	1.204E+00
butylbenzene	1.630E-01	2.174E+00	1.630E+00	1.274E+01
Carbazole	6.780E-01	5.882E+00	6.780E+00	4.982E+01
CarbonDiS	1.030E-02	1.074E+00	1.030E-01	1.742E+00
Carbontetchl	0.000E+00	1.000E+00	2.200E+00	1.684E+01
Chlordane	1.730E+01	1.256E+02	1.730E+02	1.247E+03
Chlorobenzene	4.380E-02	1.315E+00	4.380E-01	4.154E+00
Chloroform	0.000E+00	1.000E+00	6.200E-01	5.464E+00
Chlorometh	2.860E-03	1.021E+00	2.860E-02	1.206E+00

0-ChloroTu	8.860E-02	1.638E+00	8.860E-01	7.379E+00
m-cresol	9.560E-03	1.069E+00	9.560E-02	1.688E+00
o-cresol	1.820E-02	1.131E+00	1.820E-01	2.310E+00
p-cresol	9.220E-03	1.066E+00	9.220E-02	1.664E+00
Cumene	1.650E-01	2.188E+00	1.650E+00	1.288E+01
Cyanide	9.900E-01	8.128E+00	9.900E+00	7.228E+01
DDD	9.160E+00	6.695E+01	9.160E+01	6.605E+02
DDE	1.730E-01	2.246E+00	1.730E+00	1.346E+01
Dinbutylphthalat	0.000E+00	1.000E+00	1.000E-06	1.000E+00
Dibenz[ah]	3.580E+02	2.579E+03	3.580E+03	2.578E+04
Dibenzofuran	2.260E+01	1.637E+02	2.260E+02	1.628E+03
Dibromochloro	1.410E-02	1.102E+00	1.410E-01	2.015E+00
12Dichloro	7.580E-02	1.546E+00	7.580E-01	6.458E+00
13Dichloro	1.606E+00	1.256E+01	1.606E+01	1.166E+02
14Dichlorobenzen	1.232E-01	1.887E+00	1.232E+00	9.870E+00
12cisDichloro	9.960E-02	1.717E+00	9.960E-01	8.171E+00
12transDichl	7.600E-03	1.055E+00	7.600E-02	1.547E+00
Dichlorodiflo	1.370E-03	1.010E+00	1.370E-02	1.099E+00
12Dichlprop	9.400E-03	1.068E+00	9.400E-02	1.677E+00
Dieldrin	0.000E+00	1.000E+00	3.400E+01	2.458E+02
Diethylphth	2.520E-02	1.181E+00	2.520E-01	2.814E+00
12DiMethylB	4.800E-02	1.346E+00	4.800E-01	4.456E+00
24-Dimethylphe	2.520E-01	2.814E+00	2.520E+00	1.914E+01
Dimethylphth	7.420E-03	1.053E+00	7.420E-02	1.534E+00
24Dinitrotoluene	1.020E-02	1.073E+00	1.020E-01	1.734E+00
26Dinitrotoluene	8.390E-03	1.060E+00	8.390E-02	1.604E+00
EndosulfanII	4.080E+00	3.038E+01	4.080E-01	3.938E+00
Endrin	2.160E+00	1.655E+01	2.160E+01	1.565E+02
Aldehyde	2.160E+01	1.565E+02	2.160E+00	1.655E+01
Ketone	2.160E+01	1.565E+02	2.160E+00	1.655E+01
Ethylbenz	4.080E-02	1.294E+00	4.080E-01	3.938E+00
Ethylchlorid	4.750E-03	1.034E+00	4.750E-02	1.342E+00
Heptachlor	4.800E+00	3.556E+01	4.800E+01	3.466E+02
Heptachlor-epoxd	1.730E+00	1.346E+01	1.730E+01	1.256E+02
Hexachlorobenzen	1.100E+01	8.020E+01	1.100E+02	7.930E+02
Hexachloroethane	3.560E-01	3.563E+00	3.560E+00	2.663E+01
Nhexane	2.980E-02	1.215E+00	2.980E-01	3.146E+00
1hexanol	2.600E-03	1.019E+00	2.600E-02	1.187E+00
2hexanone	2.600E-03	1.019E+00	2.600E-02	1.187E+00
Isophorone	0.000E+00	1.000E+00	1.700E+00	1.324E+01
Lindane	6.760E-01	5.867E+00	6.760E+00	4.967E+01
Methonal	2.000E-04	1.001E+00	2.000E-03	1.014E+00
Methchloride	4.340E-03	1.031E+00	4.340E-02	1.312E+00
Methylcyclo	0.000E+00	1.000E+00	0.000E+00	1.000E+00
MethylIso	4.700E-04	1.003E+00	4.700E-03	1.034E+00
MMetacrylate	2.000E-03	1.014E+00	2.000E-02	1.144E+00
MethylEthylB	1.650E-01	2.188E+00	1.650E+00	1.288E+01
2Methylnaptha	5.940E-01	5.277E+00	5.940E+00	4.377E+01
MethylPropylB	1.650E-01	2.188E+00	1.650E+00	1.288E+01
Naphthalene	1.900E+00	1.468E+01	1.900E+01	1.378E+02
4Nitrobenzenamin	3.440E-02	1.248E+00	3.440E-01	3.477E+00
Nitrobenzene	1.290E-02	1.093E+00	1.290E-01	1.929E+00
2Nitrophenol	7.100E-02	1.511E+00	7.100E-01	6.112E+00

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
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
O-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	6.700E+00	6.700E-01	1.600E-07	5.000E-07
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

***** 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	6.94E-02	50362.8	1.99E-03		4.98E+00
Barium	2.41E-02	144848.5	6.95E-04		3.47E-03
Boron	4.21E-01	8369.1	1.23E-02		6.16E-02
Chromium-III	1.31E-01	26741.3	3.99E-03		
Lead	1.33E-02	262955.7	3.83E-04		
Manganese	6.64E-03	525416.0	1.91E-04		1.36E-03
Molybdenum	6.59E-02	52987.4	1.93E-03		3.87E-01
Selenium	8.77E-02	39864.3	4.50E-03		9.00E-01
Strontium	9.73E-02	34515.3	3.02E-03		5.04E-03
Tin	5.00E-01	7056.8	1.55E-02		2.58E-02
Vanadium	1.33E-02	262955.7	3.87E-04		7.74E-02
U-233	2.75E-02	42451.5	7.93E-04		2.64E-01
U-234	2.93E-02	42471.7	8.46E-04		2.82E-01
U-235	3.31E-02	51627.5	9.54E-04		3.18E-01
U-236	3.30E-02	42592.7	9.53E-04		3.18E-01
U-238	3.31E-02	51627.5	9.55E-04		3.18E-01
24-D	1.64E+00	1039.4	4.71E-02		4.71E+00
245-TP(Silvex)	4.81E-01	1100.8	1.38E-02		1.73E+00
Acenaphthene	8.23E-03	241958.8	2.37E-04		3.95E-03
Acenaphthylene	3.87E-02	32515.4	1.11E-03		1.85E-02
Acetone	6.63E+00	848.6	1.90E-01		2.11E-01
Acentonitrile	8.42E+00	699.1	2.42E-01		
acetophenone	5.34E+00	885.4	1.53E-01		1.53E+00
Acrolien	8.35E+00	703.6	2.40E-01		4.79E+02
Acylonitrle	8.27E+00	709.7	2.37E-01	1.28E-01	5.93E+00
Aldrin	4.09E-05	256131.7	1.17E-06	1.99E-05	3.91E-02
Aroclor1221	1.11E-02	556945.5	3.18E-04	6.36E-04	
Aroclor1232	1.16E-02	75580.1	3.33E-04	6.67E-04	
Benzene	7.16E-01	4779.3	2.05E-02	1.13E-03	5.13E+00
Benzoic-Acid	8.18E+00	697.8	2.35E-01		5.86E-02
Benzyl-Alcohol	7.08E+00	808.4	2.03E-01		2.03E+00
benzidine	2.36E-01	14878.1	6.76E-03	1.55E+00	2.25E+00
Alpha-BHC	1.92E-02	9733.9	5.53E-04	3.48E-03	6.91E-02
Beta-BHC	1.92E-02	11728.6	5.53E-04	9.96E-04	
Delta-BHC	1.92E-02	11728.6	5.52E-04	9.94E-04	
Bromodichloro	7.29E+00	733.1	2.09E-01	1.30E-02	1.05E+01
Bromoform	2.41E-01	1388.0	6.90E-03	5.45E-05	3.45E-01
Bromometh	7.20E+00	797.4	2.06E-01		1.47E+02
butylbenzene	1.47E-01	5728.1	4.23E-03		8.46E-02
Carbazole	4.33E-03	18290.1	1.24E-04	2.49E-06	
CarbonDiS	2.84E+00	918.7	8.14E-02		8.14E-01
Carbontetchl	5.64E-01	6039.3	1.62E-02	1.13E-03	4.04E+00
Chlordane	1.35E-04	454551.7	4.17E-06	1.46E-06	8.33E-03
Chlorobenzene	1.20E+00	1973.8	3.44E-02		1.72E+00
Chloroform	1.71E+00	2057.7	4.91E-02	1.52E-03	4.91E+00
Chlorometh	7.19E+00	798.5	2.06E-01		
0-ChloroTu	9.00E-01	3384.8	2.58E-02		1.29E+00
m-cresol	5.28E+00	895.4	1.51E-01		3.03E+00
o-cresol	3.93E+00	1167.6	1.13E-01		2.25E+00
p-cresol	5.35E+00	884.7	1.53E-01		1.53E+00
Cumene	1.47E-01	5791.1	4.23E-03		4.23E-02
Cyanide	1.32E-01	26478.9	3.79E-03		6.32E+00
DDD	2.16E-04	240909.0	7.20E-06	1.73E-06	
DDE	9.62E-05	6043.0	3.11E-06	1.06E-06	
Dinbutylphthalat	8.50E+00	693.4	2.68E-01		2.68E+00
Dibenz[ah]		> 1000000.0			
Dibenzofuran	5.87E-03	593655.7	1.69E-04		1.69E-01
Dibromochloro	4.47E+00	1038.4	1.28E-01	1.08E-02	6.41E+00
12Dichloro	1.92E-01	2981.7	5.52E-03		6.14E-02
13Dichloro	8.19E-02	42646.4	2.35E-03		2.64E-02
14Dichlorobenzen	1.96E-01	4474.6	5.61E-03	3.03E-05	8.02E-02
12cisDichloro	1.15E+00	3731.3	3.31E-02		1.65E+01
12transDichl	5.72E+00	972.7	1.64E-01		8.20E+00
Dichlorodiflo	6.73E-01	850.0	1.93E-02		9.66E-02
12Dichlprop	5.31E+00	890.4	1.52E-01	5.48E-03	1.69E+00
Dieldrin	3.89E-02	86175.3	1.26E-03	2.02E-02	2.52E+01
Diethylphth	2.60E+00	1388.0	7.45E-02		9.31E-02
12DiMethylB	5.29E-01	2106.1	1.52E-02		7.59E-02
24-Dimethylphe	4.96E-01	8531.1	1.42E-02		7.12E-01
Dimethylphth	5.77E+00	966.0	1.65E-01		1.65E-02
24Dinitrotoluene	6.49E-01	915.6	1.86E-02	5.77E-03	9.31E+00
26Dinitrotoluene	8.47E-01	858.6	2.43E-02		2.43E+01
EndosulfanII	1.08E-03	13899.0	3.11E-05		5.18E-03

Endrin	6.01E-04	57186.7	1.74E-05		5.81E-02
Aldehyde	6.01E-04	62772.3	1.74E-05		5.81E-02
Ketone	6.01E-04	62772.3	1.74E-05		5.81E-02
Ethylbenz	4.06E-01	1879.3	1.17E-02	1.28E-04	1.17E-01
Ethylchlorid	6.52E+00	867.9	1.87E-01		
Heptachlor	4.33E-04	126476.3	1.25E-05	5.62E-05	2.50E-02
Heptachlor-epoxd	4.81E-04	45900.9	1.47E-05	1.33E-04	1.13E+00
Hexachlorobenzen	1.49E-05	289201.7	4.49E-07	7.19E-07	5.61E-04
Hexachloroethane	1.20E-01	9838.9	3.46E-03	1.38E-04	4.94E+00
Nhexane	2.28E-02	1532.9	6.57E-04		1.09E-02
1hexanol	7.29E+00	788.9	2.09E-01		5.23E+00
2hexanone	7.29E+00	788.9	2.09E-01		4.18E+01
Isophorone	7.16E-01	4779.3	2.05E-02	1.95E-05	1.03E-01
Lindane	1.92E-02	18237.6	5.53E-04	6.08E-04	1.84E+00
Methonal	8.40E+00	700.7	2.41E-01		4.82E-01
Methchloride	6.65E+00	852.9	1.91E-01	3.82E-04	3.18E+01
Methylcyclo	3.37E-02	792.5	9.66E-04		1.61E-02
MethylIso	8.25E+00	710.7	2.37E-01		2.96E+00
MMetacrylate	7.54E+00	766.9	2.16E-01		1.54E-01
MethylEthylB	1.47E-01	4825.9	4.21E-03		1.14E-01
2Methylnaptha	5.92E-02	16085.4	1.70E-03		4.25E-01
MethylPropylB	1.47E-01	4825.9	4.21E-03		1.14E-01
Naphthalene	6.94E-02	50362.8	1.99E-03		9.95E-02
4Nitrobenzenamin	2.57E-08	1677.8	7.38E-10	1.48E-11	1.85E-07
Nitrobenzene	4.66E+00	1000.6	1.34E-01		6.68E+01
2Nitrophenol	1.53E+00	2830.5	4.40E-02		7.10E-01

3.2.2.2 Remaining Contaminants of Concern

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PATHRAE-HAZ(PC)  Version 2.3d  January 1997
  Date:  9-11-2012
  Time: 20: 7:14

pWAC - July, 2012 New Proposed Cell in UBCV - HAZ
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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
4Nitrophenol	7.328E+02	7.328E+02	2.872E+03	2.872E+03	2.872E+03	1.266E+01
NnitroNpropyl	7.328E+02	7.328E+02	7.797E+02	7.797E+02	7.797E+02	2.488E+01
NNitrosodiphen	7.330E+02	7.330E+02	7.696E+02	7.696E+02	7.696E+02	2.605E+00
Phenol	7.328E+02	7.328E+02	7.887E+02	7.887E+02	7.887E+02	2.150E+01
PropylB	7.334E+02	7.334E+02	7.334E+02	7.334E+02	7.334E+02	1.525E+00
PropGlycol	7.334E+02	7.334E+02	7.332E+02	7.334E+02	7.334E+02	1.560E+03
Pyridine	7.328E+02	7.328E+02	7.328E+02	7.328E+02	7.328E+02	2.825E+01
Styrene	7.329E+02	7.329E+02	7.329E+02	7.330E+02	7.330E+02	3.358E+00
1112Tetra	7.330E+02	7.330E+02	7.330E+02	7.330E+02	7.330E+02	2.940E+00
1122Tetra	7.328E+02	7.328E+02	7.328E+02	7.328E+02	7.328E+02	6.340E+00
Tetrachloroethen	7.329E+02	7.329E+02	7.329E+02	7.329E+02	7.329E+02	1.273E+00
2346Tetrachlor	7.351E+02	7.351E+02	7.351E+02	7.357E+02	7.357E+02	7.641E-01
Toluene	7.330E+02	7.330E+02	7.329E+02	7.330E+02	7.330E+02	1.106E+00
124Trichlorb	7.339E+02	7.343E+02	7.339E+02	7.343E+02	7.343E+02	8.070E+01
Trichloroethene	7.329E+02	7.329E+02	7.329E+02	7.329E+02	7.329E+02	1.735E+00
TriChloFlo	7.328E+02	7.328E+02	7.328E+02	7.328E+02	7.328E+02	5.498E+00
246-Trichlorphnl	7.337E+02	7.337E+02	7.337E+02	7.337E+02	7.337E+02	1.201E+00
123TriChlopr	7.400E+02	7.400E+02	7.400E+02	7.400E+02	7.400E+02	4.928E-01
Trimethbenz	7.339E+02	7.339E+02	7.339E+02	7.339E+02	7.339E+02	1.077E+00
124trimethylb	7.339E+02	7.339E+02	7.339E+02	7.339E+02	7.339E+02	1.077E+00
135Trimeth	7.333E+02	7.333E+02	7.333E+02	7.333E+02	7.333E+02	1.690E+00
Vinyl-Chloride	7.328E+02	7.328E+02	7.328E+02	7.328E+02	7.328E+02	2.488E+01
Xylene	7.332E+02	7.332E+02	1.113E+03	1.113E+03	1.113E+03	1.981E+00

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**********  Image of Input Files  **********

-- Input File:  ABCDEF.DAT
pWAC - July, 2012 New Proposed Cell in UBCV - HAZ
3,1000.,1200.,100000.
23,0,2
1,2,
0.,486.0,243.0,4.91E+05,1.,476.,0.
1800.,6.,0.,0.,0.,0.,0.315,0.
20,2,0,1,1
```

```
4.0,16.,1.91E+06,150.,450.,1600.,.40,.705,0.90,1.
1.0E-7,8000.,.705,0.,1.0E+00,0.01
240.,5.56E-04,.22,.02,3.0E-4,20.,0.01
4,6.3,.23,0.,1.1E-06,0.01,0.,0.,0.,0.,0.
0,0,0,0,0,0,0
1,0,0,1
0.010,4.2,0.25,7.0,0.025,24.,0.00001,1.,0.,0.25
```

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-- Input File:  BRCDCF.DAT
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
641,246-Trichlorphnl    1.10E-02,1.00E-03,0.00E+00,0.00E+00
642,123TriChlopr        3.00E+01,4.00E-03,0.00E+00,0.00E+00
643,Trimethbenz         0.00E+00,5.00E-02,0.00E+00,0.00E+00
644,124trimethylb       0.00E+00,0.00E+00,0.00E+00,0.00E+00
645,135Trimeth          0.00E+00,1.00E-02,0.00E+00,0.00E+00
646,Vinyl-Chloride      7.20E-01,3.00E-03,0.00E+00,0.00E+00
647,Xylene              0.00E+00,2.00E-01,0.00E+00,0.00E+00
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-- Input File:  INVNTRY.DAT
617,  1.00E+10, 1.670E+06,          0,          0, 1.160E+04,      0,        4Nitrophenol
618,  1.00E+10, 1.670E+06,          0,          0, 0.000E+00,      0,        NnitroNpropyl
619,  1.00E+10, 1.670E+06,          0,          0, 3.500E+01,      0,        NNitrosodiphen
622,  1.00E+10, 1.670E+06,          0,          0, 9.300E+04,      0,        Phenol
623,  1.00E+10, 1.670E+06,          0,          0, 6.100E+01,      0,        PropylB
624,  1.00E+10, 1.670E+06,          0,          0, 1.000E+06,      0,        PropGlycol
626,  1.00E+10, 1.670E+06,          0,          0, 1.000E+06,      0,        Pyridine
627,  1.00E+10, 1.670E+06,          0,          0, 3.100E+02,      0,        Styrene
628,  1.00E+10, 1.670E+06,          0,          0, 1.070E+03,      0,        1112Tetra
629,  1.00E+10, 1.670E+06,          0,          0, 2.870E+03,      0,        1122Tetra
630,  1.00E+10, 1.670E+06,          0,          0, 0.000E+00,      0,        Tetrachloroethen
631,  1.00E+10, 1.670E+06,          0,          0, 2.300E+01,      0,        2346Tetrachlor
632,  1.00E+10, 1.670E+06,          0,          0, 0.000E+00,      0,        Toluene
634,  1.00E+10, 1.670E+06,          0,          0, 5.700E+01,      0,        124Trichlorb
637,  1.00E+10, 1.670E+06,          0,          0, 0.000E+00,      0,        Trichloroethene
639,  1.00E+10, 1.670E+06,          0,          0, 1.100E+03,      0,        TriChloFlo
641,  1.00E+10, 1.670E+06,          0,          0, 8.000E+02,      0,        246-Trichlorophnl
642,  1.00E+10, 1.670E+06,          0,          0, 1.750E+03,      0,        123TriChlopr
643,  1.00E+10, 1.670E+06,          0,          0, 5.700E+01,      0,        Trimethbenz
644,  1.00E+10, 1.670E+06,          0,          0, 5.700E+01,      0,        124trimethylb
645,  1.00E+10, 1.670E+06,          0,          0, 4.820E+01,      0,        135Trimeth
646,  1.00E+10, 1.670E+06,          0,          0, 8.800E+03,      0,        Vinyl
647,  1.00E+10, 1.670E+06,          0,          0, 1.060E+02,      0,        Xylene
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-- Input File:  RQSITE.DAT
617,-8.740E-01, 8.740E-02, 8.740E-01,        4Nitrophenol
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
641,-6.360E-01, 6.360E-02, 6.360E-01,        246-Trichlorophnl
642,-1.610E-01, 1.610E-02, 1.610E-01,        123TriChlopr
643,-1.440E+00, 1.440E-01, 1.440E+00,        Trimethbenz
644,-1.440E+00, 1.440E-01, 1.440E+00,        124trimethylb
645,-3.340E+00, 3.340E-01, 3.340E+00,        135Trimeth
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646,-3.720E-01, 3.720E-02, 3.720E-01,         Vinyl
647,-8.860E-01, 8.860E-02, 8.860E-01,         Xylene

-- 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., 6.9
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
246-Trichlorphnl     0.25,  2.70E-01,  2.70E-02,  4.00E-05,        0,  1.30E-04,  0.00E+00,      641
123TriChlopr         0.25,  8.20E-02,  8.20E-03,  3.10E-04,        0,  1.00E-03,  0.00E+00,      642
Trimethbenz          0.25,  2.40E-01,  2.40E-02,  4.80E-05,        0,  1.50E-04,  0.00E+00,      643
124trimethylb        0.25,  2.40E-01,  2.40E-02,  4.80E-05,        0,  1.50E-04,  0.00E+00,      644
135Trimeth           0.25,  3.90E-01,  3.90E-02,  2.10E-05,        0,  6.60E-05,  0.00E+00,      645
Vinyl-Chloride       0.25,  5.90E+00,  5.90E-01,  2.00E-07,        0,  6.30E-07,  0.00E+00,      646
Xylene               0.25,  4.60E-01,  4.60E-02,  1.60E-05,        0,  5.00E-05,  5.50E+01,      647
1


**********  PATHRAE INPUT SUMMARY  **********

THERE ARE 99 CONTAMINANTS IN THE RISK FACTOR LIBRARY
NUMBER OF TIMES FOR CALCULATION IS  3
YEARS TO BE CALCULATED ARE ...

  1000.00  1200.00100000.00

THERE ARE  23 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
   0  3X,I2,2X,A22,6X,I2))            0

TIME OF OPERATION OF WASTE FACILITY IN YEARS                  0.
LENGTH OF REPOSITORY (M)                                    486.
WIDTH OF REPOSITORY (M)                                     243.
RIVER FLOW RATE (M**3/YR)                                     4.91E+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)                                 6.00E+00
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)                                4.00
THICKNESS OF WASTE IN PITS (M)                               16.00
TOTAL WASTE VOLUME (M**3)                                     1.910E+06
DISTANCE TO WELL -- X COORDINATE (M)                        150.
DISTANCE TO WELL -- Y COORDINATE (M)                        450.
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
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ANNUAL ADULT BREATHING RATE (M**3/YR)	8000.
FRACTION OF YEAR EXPOSED TO DUST	.705
CANISTER LIFETIME (YEARS)	0.
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)	1.00E-02
DEGREE OF SOIL SATURATION	1.000
RESIDUAL SOIL SATURATION	.000
PERMEABILITY OF VERTICAL ZONE (M/YR)	.32
SOIL NUMBER	.000
POROSITY OF AQUIFER	.25
POROSITY OF UNSATURATED ZONE	.25
DISTANCE FROM AQUIFER TO WASTE (M)	7.0
AVERAGE VERTICAL GROUNDWATER VELOCITY (M/YR)	2.50E-02
HORIZONTAL VELOCITY OF AQUIFER (M/YR)	4.20E+00
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)
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
246-Trichlorphnl	1.100E-02	1.000E-03	0.000E+00	0.000E+00	1.000E+10
123TriChlopr	3.000E+01	4.000E-03	0.000E+00	0.000E+00	1.000E+10
Trimethbenz	0.000E+00	5.000E-02	0.000E+00	0.000E+00	1.000E+10
124trimethylb	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.000E+10
135Trimeth	0.000E+00	1.000E-02	0.000E+00	0.000E+00	1.000E+10
Vinyl-Chloride	7.200E-01	3.000E-03	0.000E+00	0.000E+00	1.000E+10
Xylene	0.000E+00	2.000E-01	0.000E+00	0.000E+00	1.000E+10

CONTAMINANT	VOLATILITY FRACTION	VAPORIZATION RATE (1/S)	SKIN ABSORPTION (M/HR)
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
246-Trichlorphnl	0.000E+00	0.000E+00	0.000E+00
123TriChlopr	0.000E+00	0.000E+00	0.000E+00
Trimethbenz	0.000E+00	0.000E+00	0.000E+00
124trimethylb	0.000E+00	0.000E+00	0.000E+00
135Trimeth	0.000E+00	0.000E+00	0.000E+00
Vinyl-Chloride	0.000E+00	0.000E+00	0.000E+00
Xylene	0.000E+00	0.000E+00	0.000E+00

CONTAMINANT	INPUT LEACH (1/YR)	FINAL LEACH (1/YR)	SOLUBILITY (MG/L)	INPUT INVENTORY (KG)
4Nitrophenol	-8.740E-01	3.792E-04	1.160E+04	1.670E+06
NnitroNpropyl	-3.000E-01	8.562E-04	0.000E+00	1.670E+06
NNitrosodiphen	-6.540E-01	2.475E-05	3.500E+01	1.670E+06
Phenol	-2.800E-01	8.954E-04	9.300E+04	1.670E+06
PropylB	-1.650E+00	4.314E-05	6.100E+01	1.670E+06
PropGlycol	-2.000E-03	2.468E-03	1.000E+06	1.670E+06
Pyridine	-1.380E-02	2.297E-03	1.000E+06	1.670E+06
Styrene	-1.820E+00	1.977E-04	3.100E+02	1.670E+06
1112Tetra	-3.180E-01	7.567E-04	1.070E+03	1.670E+06
1122Tetra	-1.580E-01	1.243E-03	2.870E+03	1.670E+06
Tetrachloroethen	-7.200E+00	5.310E-05	0.000E+00	1.670E+06
2346Tetrachlor	-2.490E+02	1.568E-06	2.300E+01	1.670E+06
Toluene	-6.000E+00	6.345E-05	0.000E+00	1.670E+06
124Trichlorb	-1.440E+00	4.031E-05	5.700E+01	1.670E+06
Trichloroethene	-2.600E+00	1.417E-04	0.000E+00	1.670E+06
TriChloFlo	-2.680E-01	7.779E-04	1.100E+03	1.670E+06
246-Trichlorphnl	-6.360E-01	4.931E-04	8.000E+02	1.670E+06
123TriChlopr	-1.610E-01	1.231E-03	1.750E+03	1.670E+06
Trimethbenz	-1.440E+00	4.031E-05	5.700E+01	1.670E+06
124trimethylb	-1.440E+00	4.031E-05	5.700E+01	1.670E+06
135Trimeth	-3.340E+00	3.409E-05	4.820E+01	1.670E+06
Vinyl-Chloride	-3.720E-01	7.395E-04	8.800E+03	1.670E+06
Xylene	-8.860E-01	7.496E-05	1.060E+02	1.670E+06

CONTAMINANT	AQUIFER SORPTION	AQUIFER RETARDATION	VERTICAL SORPTION	VERTICAL RETARDATION
4Nitrophenol	8.740E-02	1.629E+00	8.740E-01	7.293E+00
NnitroNpropyl	3.000E-02	1.216E+00	3.000E-01	3.160E+00
NNitrosodiphen	6.540E-02	1.471E+00	6.540E-01	5.709E+00
Phenol	2.800E-02	1.202E+00	2.800E-01	3.016E+00
PropylB	1.650E-01	2.188E+00	1.650E+00	1.288E+01
PropGlycol	2.000E-04	1.001E+00	2.000E-03	1.014E+00
Pyridine	1.380E-03	1.010E+00	1.380E-02	1.099E+00
Styrene	1.820E-01	2.310E+00	1.820E+00	1.410E+01
1112Tetra	3.180E-02	1.229E+00	3.180E-01	3.290E+00
1122Tetra	1.560E-02	1.112E+00	1.560E-01	2.123E+00
Tetrachloroethen	0.000E+00	1.000E+00	7.200E+00	5.284E+01
2346Tetrachlor	2.490E+01	1.803E+02	2.490E+02	1.794E+03
Toluene	0.000E+00	1.000E+00	6.000E+00	4.420E+01
124Trichlorb	1.440E-01	2.037E+00	1.440E+00	1.137E+01
Trichloroethene	0.000E+00	1.000E+00	2.600E+00	1.972E+01
TriChloFlo	2.680E-02	1.193E+00	2.680E-01	2.930E+00
246-Trichlorphnl	6.360E-02	1.458E+00	6.360E-01	5.579E+00
123TriChlopr	1.610E-02	1.116E+00	1.610E-01	2.159E+00
Trimethbenz	1.440E-01	2.037E+00	1.440E+00	1.137E+01
124trimethylb	1.440E-01	2.037E+00	1.440E+00	1.137E+01
135Trimeth	3.340E-01	3.405E+00	3.340E+00	2.505E+01
Vinyl-Chloride	3.720E-02	1.268E+00	3.720E-01	3.678E+00
Xylene	8.860E-02	1.638E+00	8.860E-01	7.379E+00

	BIOACCUMULATION FACTORS			
CONTAMINANT	SOIL-PLANT Bv	SOIL-PLANT Br	FORAGE-MILK Fm (D/L)	FORAGE-MEAT Ff (D/KG)

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
246-Trichlorphnl	2.700E-01	2.700E-02	4.000E-05	1.300E-04
123TriChlopr	8.200E-02	8.200E-03	3.100E-04	1.000E-03
Trimethbenz	2.400E-01	2.400E-02	4.800E-05	1.500E-04
124trimethylb	2.400E-01	2.400E-02	4.800E-05	1.500E-04
135Trimeth	3.900E-01	3.900E-02	2.100E-05	6.600E-05
Vinyl-Chloride	5.900E+00	5.900E-01	2.000E-07	6.300E-07
Xylene	4.600E-01	4.600E-02	1.600E-05	5.000E-05

***** 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
4Nitrophenol	1.29E+00	2789.2	3.70E-02		5.97E-01
NnitroNpropyl	2.91E+00	1539.2	8.35E-02	5.85E-01	
NNitrosodiphen	8.42E-02	2654.1	2.42E-03	1.18E-05	
Phenol	3.05E+00	1476.2	8.74E-02		2.91E-01
PropylB	1.47E-01	4825.9	4.21E-03		1.14E-01
PropGlycol	8.40E+00	700.7	2.41E-01		1.20E-02
Pyridine	7.81E+00	744.1	2.24E-01		2.24E+02
Styrene	6.72E-01	5272.1	1.93E-02		9.64E-02
1112Tetra	2.57E+00	1595.9	7.38E-02	1.92E-03	2.46E+00
1122Tetra	4.23E+00	1085.7	1.21E-01	2.43E-02	6.06E+00
Tetrachloroethen	1.81E-01	18639.3	5.18E-03	1.09E-05	8.64E-01
2346Tetrachlor	5.33E-03	654021.6	1.53E-04		5.11E-03
Toluene	2.16E-01	15615.3	6.19E-03		7.74E-02
124Trichlorb	1.37E-01	5129.7	3.94E-03	1.14E-04	3.94E-01
Trichloroethene	4.82E-01	7047.3	1.38E-02	6.36E-04	2.77E+01
TriChloFlo	2.65E+00	1438.4	7.59E-02		2.53E-01
246-Trichlorphnl	1.68E+00	2164.5	4.82E-02	5.30E-04	4.82E+01
123TriChlopr	4.19E+00	1101.4	1.21E-01	3.64E+00	3.03E+01
Trimethbenz	1.37E-01	5129.7	3.94E-03		7.88E-02
124trimethylb	1.37E-01	5129.7	3.94E-03		
135Trimeth	1.16E-01	9261.5	3.33E-03		3.33E-01
Vinyl-Chloride	2.52E+00	1766.0	7.21E-02	5.19E-02	2.40E+01
Xylene	2.55E-01	3384.8	7.32E-03		3.66E-02

APPENDIX G

COST ESTIMATES FOR ON-SITE AND OFF-SITE DISPOSAL ALTERNATIVES

CONTENTS

FIGURES

TABLES

ACRONYMS

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EMDF	Environmental Management Disposal Facility
EMWMF	Environmental Management Waste Management Facility
EPA	U.S. Environmental Protection Agency
ETTP	East Tennessee Technology Park
FY	Fiscal Year
LLW	low-level (radioactive) waste
M	million
NNSS	Nevada National Security Site
OMB	Office of Management and Budget
ORR	Oak Ridge Reservation
RCRA	Resource Conservation and Recovery Act of 1976
RAWP	Remedial Action Work Plan
RDR	Remedial Design Report
RI/FS	Remedial Investigation/Feasibility Study
S&M	surveillance and maintenance
TSCA	Toxic Substances Control Act of 1976
U.S.	United States
WAC	waste acceptance criteria
WBS	Work Breakdown Structure

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, waste would be disposed of in a newly constructed on-site disposal facility at ORR referred to as the Environmental Management Disposal Facility (EMDF). Under the Off-site Disposal Alternative, waste would be disposed of at existing off-site facilities.

CERCLA waste will be generated from environmental restoration activities on the ORR and associated sites. Separate projects are responsible for transport of waste to the new disposal facility for the On-site Disposal Alternative or to a centrally located transfer station for the Off-site Disposal Alternative.

Candidate waste streams addressed under these disposal alternatives are low-level (radioactive) waste (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 Toxic Substances Control Act of 1976 (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 are design and construction of the disposal cells and supporting facilities, operation and management of the disposal cells, capping and closure, and postclosure monitoring and maintenance. Major cost elements of the Off-site Disposal Alternative are transportation of waste to the off-site facilities and fees for disposal. Waste volumes estimated to be generated and disposed are key to determining the cost for both 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.

No contingency was added to either the On-site or Off-site Disposal Alternative cost estimates. Uncertainties regarding waste volume estimates, technologies and process options that will be used for final designs; and unknowns that could pose risks that would increase costs; or opportunities that could decrease costs are accounted for in the cost accuracy range for CERCLA feasibility studies of -30% to +50% of the calculated estimate.

For the On-site Disposal Alternative, a cost estimate was developed for construction of the EMDF on the ORR at a site in East Bear Creek Valley near EMWMF.

Table G-1 summarizes the cost in 2012 dollars and present worth project cost for the On-site and Off-site Disposal Alternatives.

Table G-1. On-site and Off-site Disposal Alternatives Cost Estimates

Alternative	Cost in 2012 Dollars ($ Ms)	Present Worth Cost* ($ Ms)
On-site Disposal		
EMDF	708	499
Off-site Disposal		
Existing Off-site Facilities	1992	1408

*Based on real discount rate of 2.0%

1.1 ALTERNATIVE DESCRIPTIONS

A summary description of the On-site and Off-site Disposal Alternatives that were developed for analysis in the RI/FS is 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 ORR. The scope of actions for this alternative includes early actions (i.e., pre-design investigations); design and construction of all facilities; design support during construction, quality assurance, quality controls, receiving waste, meeting the waste acceptance criteria (WAC); unloading the waste and placing it into the disposal cells; decontaminating any containers, equipment, or vehicles leaving the site; and managing the waste and the disposal cells during construction, operations, closure, and postclosure.

The envisioned on-site EMDF would consist of an engineered waste disposal facility (i.e., landfill) 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. The EMDF is estimated to be operational for approximately 23 years (i.e., early Fiscal Year [FY] 2020 through FY 2042). Support facilities required for initial operations would include those needed for staging of waste, receiving and unloading waste, and decontamination of equipment. Siting near the EMWMF would allow many of the support facilities already constructed for the EMWMF to be shared with the EMDF (see Sect. 6.2.2.5 of the RI/FS). The conceptual design of the EMDF would provide a disposal capacity of approximately 2.5 million[1] (M) yd^3.

The representative process option for the On-site Disposal Alternative is construction of an engineered waste disposal facility for on-site disposal of radioactive or mixed wastes and implementing long-term institutional controls for this EMDF. Key elements of the proposed disposal facility include a dike constructed of clean fill material to contain the waste laterally, a multilayer liner with a double leachate collection detection system to isolate the waste from groundwater, a facility underdrain beneath the landfill to intercept and drain upwelling groundwater, upgradient geomembrane-lined diversion ditch with shallow French drain to divert upgradient surface water and shallow perched groundwater 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 this alternative. The conceptual site layout plan for the EMDF is shown on Figure G-1.

[1] A projected disposal capacity need of approximately 2.5M yd^3 is based on an assumed allowance of 28% uncertainty applied to waste volume estimates as described in Chapter 2 of the RI/FS.

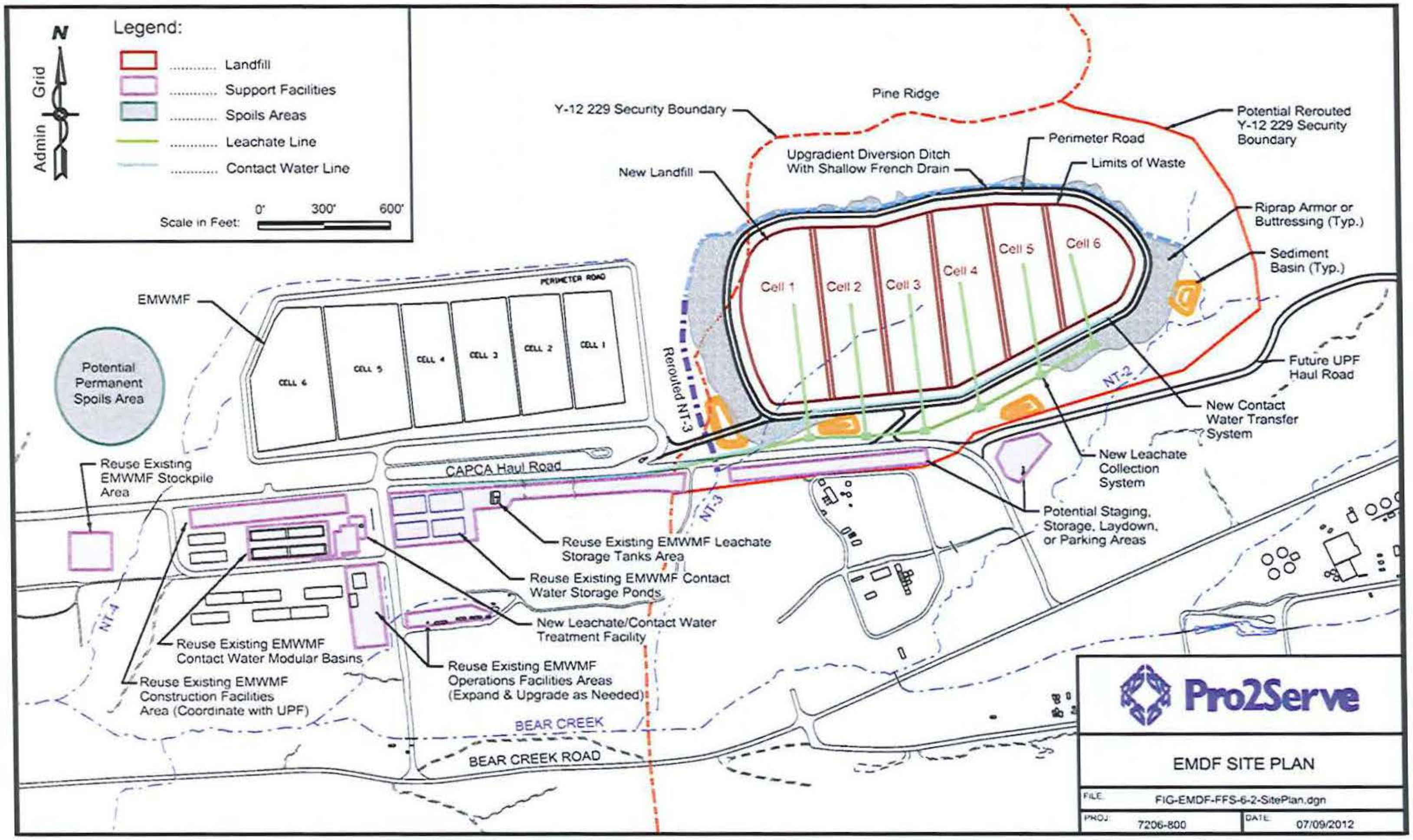


Figure G–1. On-site EMDF Conceptual Site Layout Plan

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 estimates, it is assumed that all non-classified LLW and LLW/TSCA waste and classified LLW waste would be shipped to Nevada National Security Site (NNSS) in Nye County, Nevada. Any unclassified LLW/RCRA (mixed) waste would be shipped for treatment and disposal at Energy*Solutions*, Clive, Utah. Classified mixed waste would be treated by the generator to meet the NNSS WAC prior to shipment to NNSS. 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 rail followed by truck transport to NNSS (transload facility in Kingman, AZ). All classified waste shipments to NNSS would be by truck transport. The waste-volume estimates for the Off-site Disposal Alternative are approximately 2,147,407 yd^3 destined for NNSS and 42,942 yd^3 destined for Energy*Solutions*. For purposes of the cost estimate, it is assumed that all waste and material types would be placed into intermodal containers before shipment.

2. PROJECT SCHEDULES

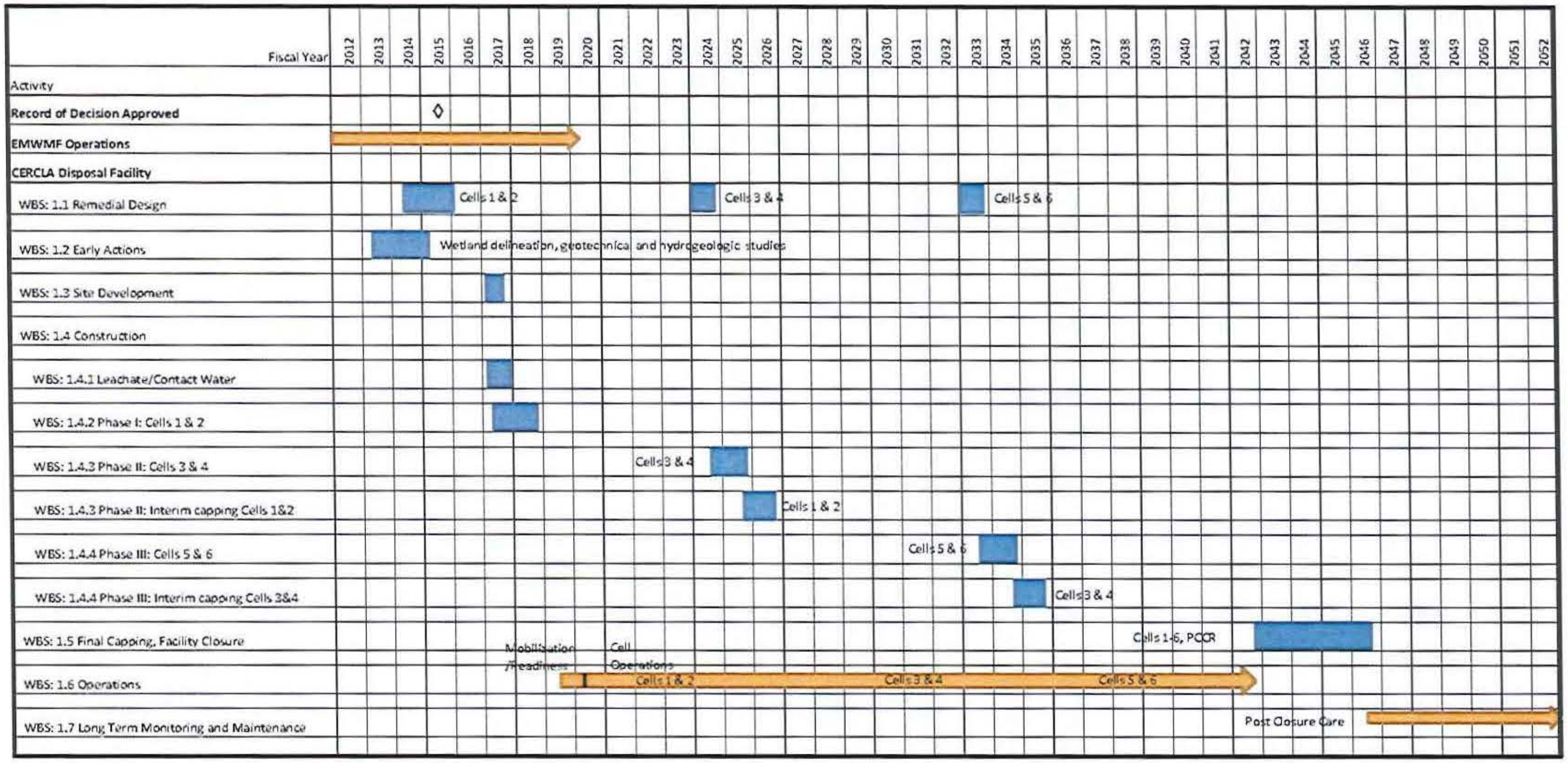
Project schedules for the On- and Off-site Disposal Alternatives are based on the estimated future waste-generation rates. It is assumed that waste would be disposed of on-site or off-site in the same year it is generated. The schedule for the Off-site Disposal Alternative is directly linked to the as-generated waste volume estimate.

Figure G-2 shows the project schedule for the On-site Disposal Alternative. Operation of the on-site disposal facility would be expected to continue through FY 2042 with closure activities completed in FY 2046. Long-term surveillance and maintenance (S&M) and monitoring would continue after facility closure.

3. ELEMENTS COMMON TO THE ON- AND OFF-SITE DISPOSAL ALTERNATIVES

Key elements common to the On- and Off-site Disposal Alternatives affecting cost estimates include contractual mechanism, assumption about no costs for involvement of an integrating contractor, assumption about excluding cost of the United States (U.S.) Department of Energy (DOE) activities, and assumptions regarding responsibilities of the waste generators. Costs for off-site shipment of waste not meeting the on-site disposal facility WAC or shipped off-site due to other project-specific factors are excluded for both disposal alternatives (see Sect. 2.1.3 of the RI/FS).

For purposes of the cost estimates for both alternatives, it is assumed that integrating contractor overhead costs would not be applicable for the design, construction, operation, or management of the project. Costs for DOE activities are excluded from the cost estimates for both disposal alternatives. No cost contingency was added to either the On-site or Off-site Disposal Alternative cost estimate.



WBS = Work Breakdown Structure

Figure G-2. On-site Disposal Alternative Schedule

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 the East Tennessee Technology Park (ETTP) rail siding for off-site shipment; and interim storage, if required, for waste not meeting the disposal facilities' WAC. Because these costs are not within the scope of the disposal alternatives, and would not represent a discriminating element between the alternatives because of comparable expense, costs associated with these activities and materials are not included in the cost estimates, except for purchase and loading waste containers for transport to off-site facilities. For classified waste and hazardous waste to be treated at the disposal facility, purchase and single use of containers is assumed. Costs for purchase of containers for shipment to off-site disposal facilities are included in the off-site disposal cost estimate because the costs are a discriminator between the On-site and Off-site Disposal Alternatives.

4. ON-SITE DISPOSAL ALTERNATIVE COST ESTIMATE

This chapter provides the key assumptions for the On-site Disposal Alternative cost estimate, the basis for the estimate, and summary results.

4.1 ON-SITE DISPOSAL ALTERNATIVE COST-ESTIMATE ASSUMPTIONS

A cost estimate was prepared for the On-site Disposal Alternative with a proposed EMDF sited in East Bear Creek Valley immediately east of EMWMF (see Figure G-1). This section provides the conditions and assumptions for the on-site EMDF. Elements common to both the On-site and Off-site Disposal Alternative (see Sect. 3 above) are not included in the On-site Disposal Alternative cost estimate.

The On-site Disposal Alternative would be implemented and managed by a prime contractor to the United States (U.S.) Department of Energy (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; 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, leachate treatment, site monitoring; final capping and closure of the landfill; postclosure monitoring and maintenance; and management of all aspects and phases of the project. A Cost Engineering Estimating System project value file for materials and labor was used to develop the estimate. No allowance is included for overtime during any phase of the project.

The key assumptions for the On-site Disposal Alternative cost estimate are as follows:

- Costs for DOE activities are not included.
- All costs are presented in 2012 dollars and present worth.
- Assumed EMWMF capacity is filled in early FY 2020. The EMDF would have an operational lifespan of approximately 23 years from early FY 2020 through FY 2043.
- 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 the EMDF 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.

- 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 Sect. 4.2.3. 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 and 2 and future disposal cells. Construction of the first phase would be implemented so that the EMDF is ready to receive waste in early FY 2020.
- Phase II construction would include the construction of two waste disposal cells (Cells 3 and 4) and the interim capping of Cells 1 and 2. This construction would occur simultaneously with the operation of the existing disposal cells.
- Phase III construction would include the construction of two waste disposal cells (Cells 5 and 6) and the interim capping of Cells 3 and 4. This construction would occur simultaneously with the operation of the existing disposal cells. The Phase III construction cost estimate also includes interim capping of Cells 5 and 6 after the cells are filled.
- The EMDF would be closed with a final cap that would be placed at the conclusion of operation in Cells 5 and 6 including an interim cap on Cells 5 and 6 placed as part of Phase III construction. (Cells 5 and 6 may not require the geomembrane portion of the interim cap if the landfill is closed shortly after operations cease, but the vent layer and associated geotextile would be required regardless of schedule. All layers of the interim cap are included in the Phase III construction cost estimate.)
- The new disposal facility would be a stand-alone facility. Complete self-supporting infrastructure (e.g., access roads, utilities, disposal cells, leachate collection, decontamination facilities, staging, truck scales, etc.) would be constructed or shared with EMWMF (see Sect. 6.2.2.5 of the RI/FS).
- Waste would be transported to the EMDF on a dedicated Haul Road and not over state maintained roadways.
- All on-site waste shipments would satisfy U.S. Department of Transportation (DOT) requirements.
- The 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.
- Leachate and contact water treatment would be conducted at the on-site disposal facility by a newly constructed treatment plant; disposal of secondary waste would be in the EMDF. The treatment facility would be constructed prior to opening the EMDF landfill. Operation of the treatment facility would continue 10 years after disposal operations cease.
- Waste would not be highly radioactive and, therefore, would not require personnel shielding or special handling.
- Operations costs (except for treatment plant operations) are based on actual EMWMF operations data.

- The long-term monitoring and maintenance for the EMDF would continue after closure of the facility. A perpetual care fee of $1M per year for each year of operation of the EMDF would be paid into an escrow account to be used for long-term monitoring and maintenance.

4.2 BASIS OF ESTIMATE FOR THE ON-SITE DISPOSAL ALTERNATIVE

The key components of the On-site Disposal Alternative cost estimate are early actions; remedial design; site development and construction; operations; final capping and facility closure; and long-term monitoring and maintenance.

4.2.1 Early Actions

Early actions to support remedial design include construction of new groundwater monitoring wells and surface water weirs, upgrading existing down-gradient groundwater monitoring wells (if required), groundwater monitoring, hydrogeological and geotechnical investigation, and wetland delineation activities. These early actions would be completed prior to issuance of the draft Remedial Design Report (RDR)/ Remedial Action Work Plan (RAWP).

4.2.2 Remedial Design

Remedial design for the On-site Disposal Alternative includes development of a Remedial Design Report/Remedial Action Work Plan (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, etc., required to construct and operate the new disposal facility. In addition, remedial design includes preparation of design documents for site development activities. Procurement activities (captured in WBS 1.8, Project Management) include development and issuance of Request for Proposals for the different phases of facility design and construction.

4.2.3 Site Development and Construction

Site development activities described in Sect. 6.2.2.3 of the RI/FS 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; relocating the Y-12 National Security Complex 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.

Construction activities would include construction of the disposal facility and construction of a leachate/contact water treatment facility described in Sect. 6.2.2.4, Sect. 6.2.2.6, and Sect. 6.2.2.7 of the RI/FS. Construction of six disposal cells of the facility would be in three phases (two cells in each phase - Phases I, II, and III). An interim cover system (interim cap) would be installed for all Phases of the cells construction.

4.2.3.1 Material and Labor Pricing

The site development and construction estimates are based on preliminary bills of materials developed for each anticipated activity. 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.

4.2.3.2 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.

4.2.3.3 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 cost 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.

4.2.3.4 Indirect Markups

Indirect markups for construction have been applied according to guidelines provided by the DOE Oak Ridge Office. Indirect markups for fixed price construction used in the estimates cover expenses incurred by the subcontractor such as Overhead (e.g., home office support, General and Administrative 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. Table G-2 provides a breakdown of the 28% indirect markup prior to compounding.

Table G–2. Indirect Markups for Fixed-Price Construction

Activity	Markup (%)
Overhead	10
Profit	10
Bond	1
General contractor's markup for work performed by subcontractors	5

4.2.4 Operations

It is assumed that all operations activities would be performed by a prime contractor to DOE. Operations activities would consist of waste receipt and inspection, 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, leachate collection and management, equipment maintenance, support facility (e.g., roads and buildings) maintenance, and record keeping. Treatment of waste to meet the disposal-facility WAC would remain the responsibility of the waste generator and is not included in this alternative. Disposal facility operations costs (except for waste treatment facility operation costs) are based on actual EMWMF operations cost data.

Collected wastewater from the leachate collection system would be treated at a newly constructed wastewater treatment facility. The new facility would contain conventional unit operations for a range of target contaminants. These unit operations would be expected to include chemical precipitation, clarification, sand filtration, neutralization, and ion exchange for removal of uranium and other contaminants. Treated effluent would be discharged to Bear Creek in accordance with applicable or relevant and appropriate requirements.

4.2.5 Final Capping and Facility Closure

Final capping and facility closure would include placement of the final cover system, removal of support facilities, and site restoration (see Sect. 6.2.8 of the RI/FS).

4.2.6 Long-term Monitoring and Maintenance

Long-term monitoring and maintenance would include post-closure operation of the leachate/contact water treatment facility for 10 years followed by demolition and disposal of the facility. Also included is a perpetual care fund ($23M or $1M per year of facility operation) that would be paid into an escrow account to be used for long-term facility S&M and monitoring after the facility is closed.

4.2.7 Present Worth

Present worth cost for the cost estimates were calculated based on U.S. Environmental Protection Agency (EPA) guidance (EPA 2000) using a real discount rate of 2.0% according to published 2012 Discount rates for Office of Management and Budget (OMB) Circular No. A-94 (OMB 2012). The present worth cost is based on discounting cost in 2012 dollars over the period of activity as determined by the project schedule.

4.3 PROJECT WORK BREAKDOWN STRUCTURE

The project WBS for the On-site Disposal Alternative is presented on Figure G-3.

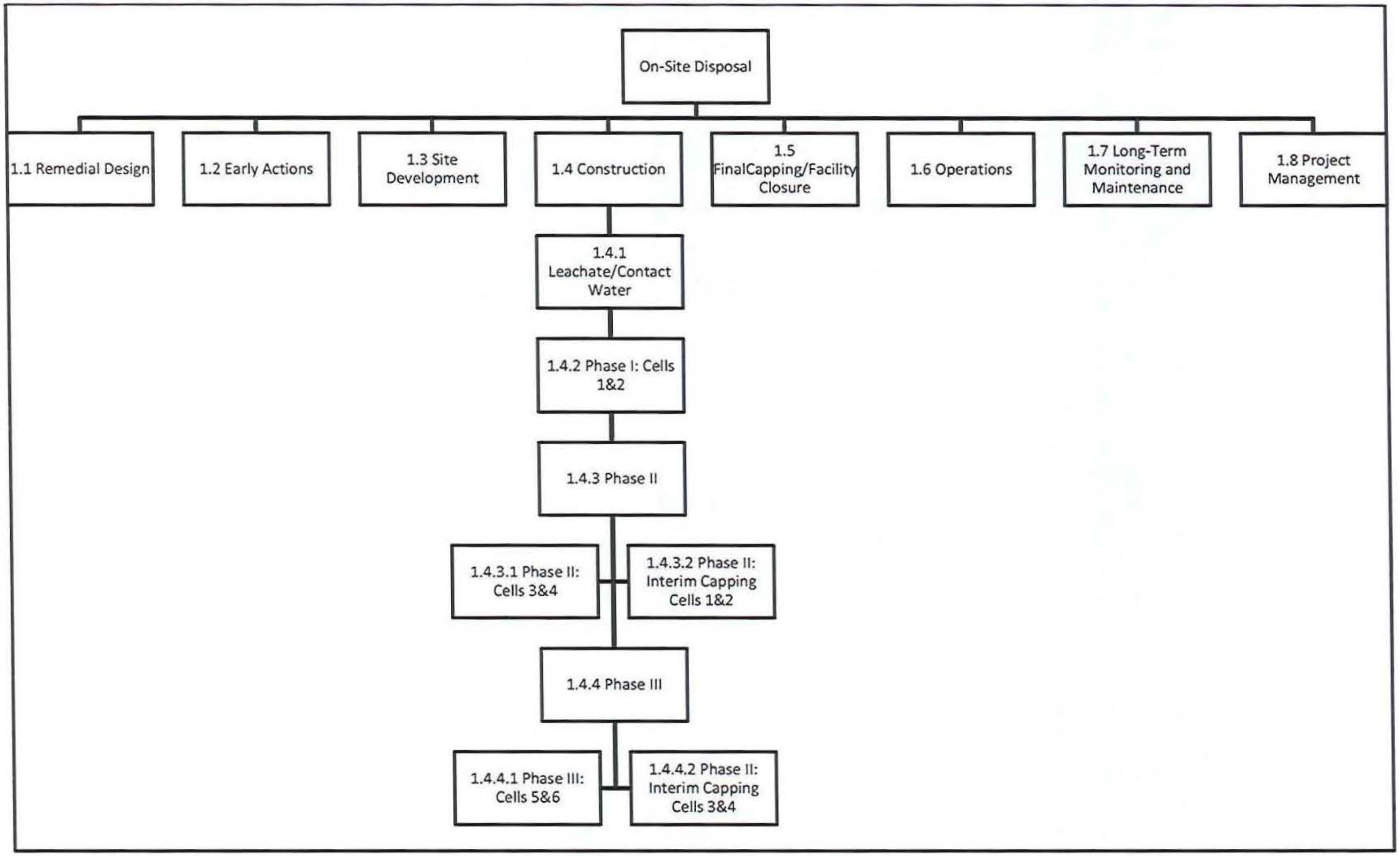


Figure G-3. On-site Disposal Alternative Work Breakdown Structure

4.4 SUMMARY COST DATA

Table G-3 provides summary project cost estimates for the On-site Disposal Alternative for the proposed EMDF site.

Table G–3. Summary Cost Estimate for the On-site Disposal Alternative

Project Cost Item	Cost in 2012 Dollars ($ Ms)
Capital Cost	
Remedial Design	6
Early Actions (Site Characterization)	3
Site Development	6
Construction (includes cells, interim capping, and leachate/contact water treatment facility)	147
Capping and Closure	58
Project Management (includes construction management and procurement)	20
Total Capital Cost	**240**
Operations Cost	
Disposal Facility Operations	429
Long-Term Monitoring & Maintenance	39
Total Operations Cost	**468**
Total Project Cost	**708**
Total Project Cost (present worth)*	**499**

*Present worth based on real discount rate of 2.0%
Note: All costs are rounded

5. OFF-SITE DISPOSAL ALTERNATIVE COST ESTIMATES

This section provides the key assumptions for the Off-site Disposal Alternative cost estimates, the basis for the estimates, and the summary results.

5.1 OFF-SITE DISPOSAL ALTERNATIVE COST-ESTIMATE CONDITIONS AND ASSUMPTIONS

A cost estimate was conducted 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.

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 Sect. 3 of this Appendix).

Figures G-4 and G-5 show the off-site disposal activities and responsible entities for waste shipments to NNSS and Energy*Solutions*.

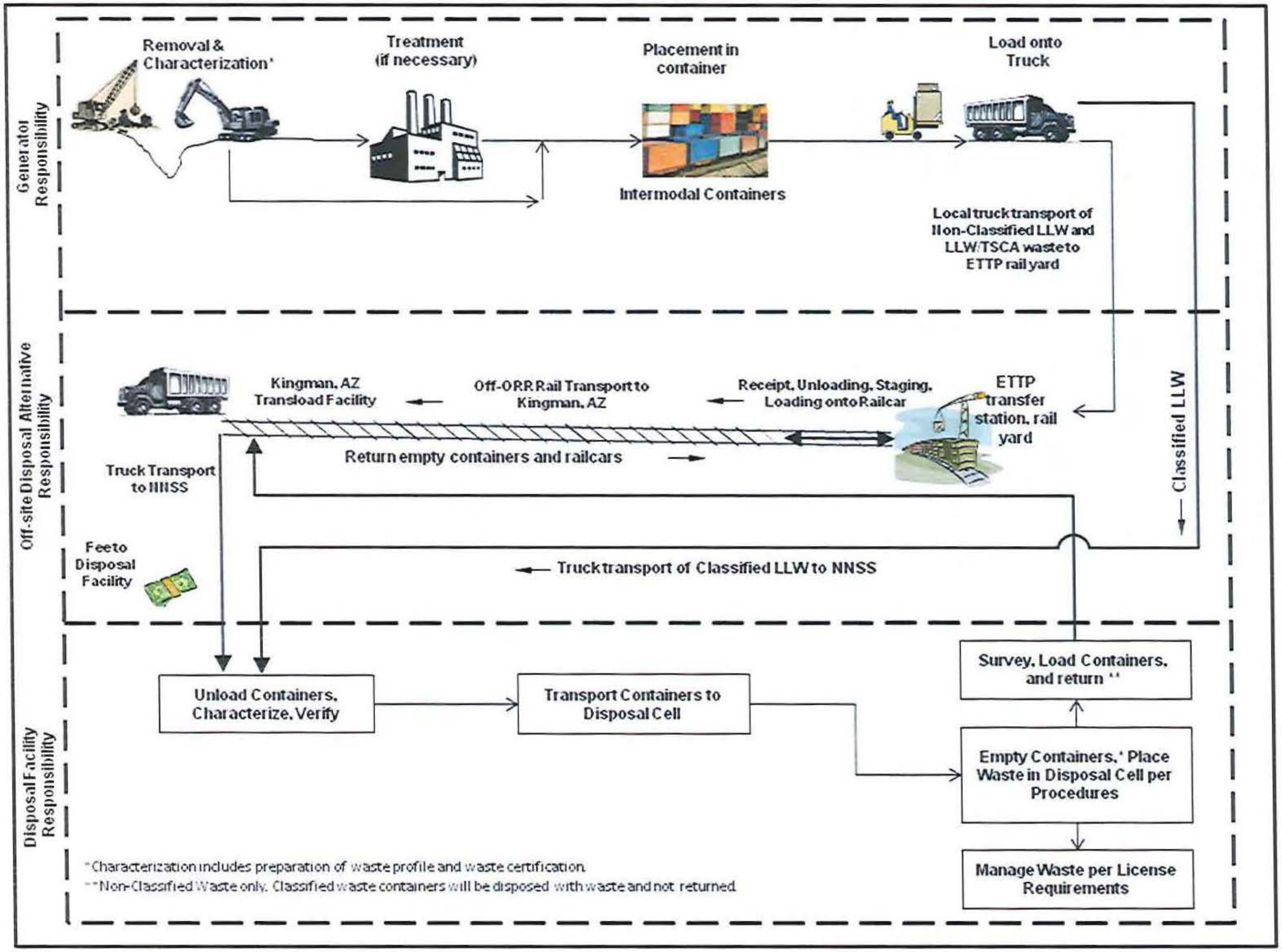


Figure G-4. Schematic of Responsibilities for Waste Shipments to NNSS for Off-site Disposal Alternative

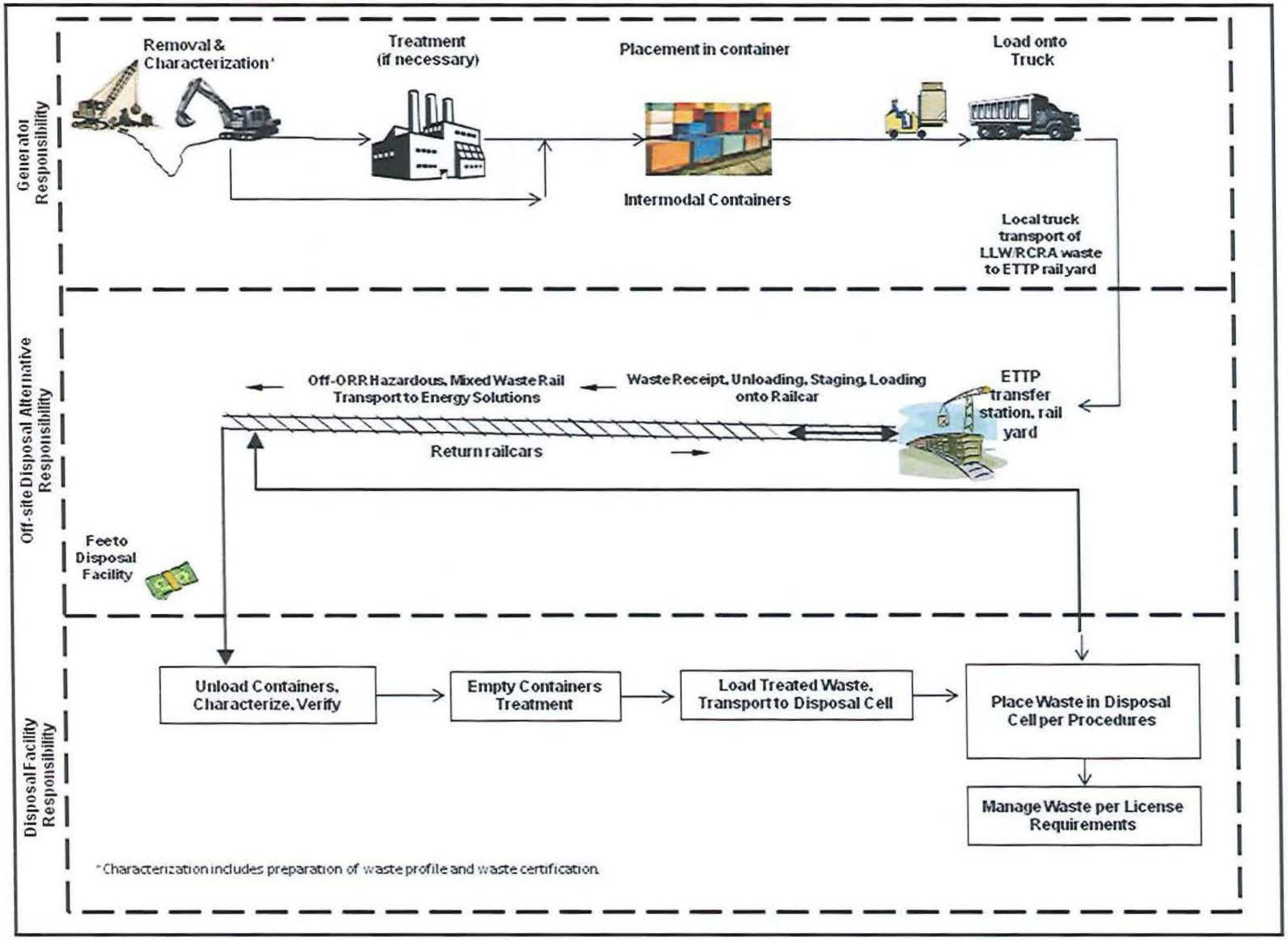


Figure G-5.Schematic of Responsibilities for Waste Shipments to EnergySolutions for Off-site Disposal Alternative

Table G-4 shows the estimated volumes expected to be disposed of at NNSS and Energy*Solutions*. Transportation and treatment/disposal costs are based on these estimated volumes.

The key assumptions for the Off-site Disposal Alternative cost estimate are as follows:

- All non-classified LLW and LLW/TSCA waste and all classified LLW would be disposed at the NNSS facility in Nye County, NV.
- The NNSS WAC allows for the use of returnable intermodal containers.
- All LLW/RCRA (mixed) waste would be treated and disposed at the Energy*Solutions* facility in Clive, Utah.
- All classified mixed waste would be treated by the generator to meet the NNSS WAC prior to shipment to NNSS.
- All non-classified waste shipped to NNSS or Energy*Solutions* would be transported in intermodal containers from the individual remedial sites to the Technology Park rail siding, loaded onto railcars, and shipped by :
  - Rail to Kingman, AZ transload facility followed by truck transport to NNSS (two intermodal containers per truckload for debris and one intermodal container per truckload for soil), or
  - Rail to Energy*Solutions*.
- Each intermodal would contain approximately 11 yd^3 of debris waste or 15 yd^3 of soil waste and each railcar will carry eight intermodal debris containers or six intermodal soil containers.
- Intermodal containers would be purchased and reused for all non-classified, non-RCRA hazardous waste shipment.
- All intermodal containers would include a plastic liner for each shipment.
- Intermodal container design life is 10 years.
- Intermodal containers would be purchased for all classified and LLW/RCRA (mixed) waste shipments (non-returnable containers).
- Macroencapsulation is the assumed waste treatment for LLW/RCRA (mixed) waste disposed at Energy*Solutions*. The waste treatment fee for macroencapsulation includes waste disposal.
- Waste treatment/disposal fees for Energy*Solutions* 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.
- All shipments will satisfy DOT requirements.
- 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.)

Table G–4. As-generated Waste Volume Estimate (FY 2020 - FY 2042) by Waste Type, Material Type, and Disposal Facility for Off-site Disposal Alternative with 28%[2] Uncertainty

Off-site Disposal Facility	Waste Type	Material type	Volume (yd^3)
NNSS (Non-Classified)	LLW	Debris	1,500,618
	LLW and LLW/TSCA	Soil	638,472
		NNSS (Non-Classified) TOTAL	**2,139,090**
NNSS (Classified)	LLW	Debris	7,612
NNSS (Classified, Mixed)	LLW	Debris	705
		NNSS (Classified) TOTAL	**8,317**
Energy*Solutions*	LLW/RCRA	Debris	27,616
		Soil	15,326
		Energy*Solutions* TOTAL	**42,942**
		TOTAL	**2,190,349**

5.2 BASIS OF ESTIMATE FOR THE OFF-SITE DISPOSAL ALTERNATIVE

The key components of the Off-site Disposal Alternative cost estimate are those costs associated with transportation and treatment/disposal. Costs calculated for the Off-site Disposal Alternative estimates are situation-specific rates based on privatized cost estimates, and include no allowance for involvement of an integrating contractor. Table G-5 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. Transportation costs include purchase cost for intermodal containers for all waste shipments. Intermodal containers used for LLW would be reused as many times as possible during an assumed design life of 10 years. Intermodal containers for classified and mixed low-level (radioactive) waste are considered single use. Treatment/disposal fees used in the cost estimate for macroencapsulation of LLW/RCRA waste are based on the fee structure of an existing mixed waste disposal contract between DOE and Energy*Solutions*.

Fuel surcharges that may be incurred during transportation of the waste to the disposal facilities are not included in the estimate. 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.

[2] The actual assumed uncertainty is 27.9798%; 28% is a rounded value.

Table G–5. Transportation and Treatment/Disposal Costs Used for Off-site Disposal Alternative

Transportation Costs*		
Rail from ETTP Railyard to Kingman, AZ or Clive, UT	$25,440	Per railcar (8 debris intermodals per railcar)
Rail from ETTP Railyard to Kingman, AZ or Clive, UT	$22,482	Per railcar (6 soil intermodals per railcar)
Truck transport from Kingman, AZ 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, AZ)	$370	Per intermodal
Container purchase (classified and LLW/RCRA waste shipments)	$6,300	Per intermodal
Container liner purchase	$545	Per intermodal per trip
Truck transport to NNSS for classified waste	$15,887	Per truckload (2 intermodals per truckload for classified debris waste)
Treatment/Disposal Costs*		
Treatment and Disposal of LLW/RCRA (mixed waste) (macroencapsulation)	$3,406	Per yd^3
Surcharge of 4% on waste received during winter months (Dec - Feb)	$136	Per yd^3
NNSS disposal access fee rate	$14.51	Per ft^3

**All rates are in 2012 dollars*

5.3 PRESENT WORTH

The present worth calculation approach for the Off-site Disposal Alternative using a real discount rate of 2.0% is the same used for the On-site Disposal Alternative estimate as described in Section 4.2.7 of this Appendix.

5.4 SUMMARY COST DATA

Table G-6 provides the summary cost estimates for the Off-site Disposal Alternative.

Table G–6. Summary Cost Estimate for the Off-site Disposal Alternative

Project Cost Item	Cost in 2012 Dollars ($ Ms)
Capital Cost	
Total Capital Cost	**0**
Operations Cost	
Transportation and Packaging	1,003
Treatment/Disposal	989
Long-Term Monitoring and Maintenance	0
Total Operations Cost	**1,992**
Total Project Cost	**1,992**
Total Project Cost (present worth)*	**1,408**

Note: All costs are in 2012 dollars unless otherwise noted and all costs are rounded.
*Present worth based on real discount rate of 2.0%

6. REFERENCES

EPA 2000. *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study*, EPA-540-4-00-002, July 2000.

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NNSA 2008. Memorandum from the National Nuclear Security Administration, *Request for Fiscal Year 2009 Preliminary Mixed and Low-Level Radioactive Waste Forecasts and Transmittal of the NNSA-Nevada Site Office Program Management Strategy for Disposal Operations*, July 15, 2008.