OAK RIDGE RESERVATION

Annual Site Environmental Report

2018

DOE/ORO-2512

Oak Ridge Reservation

Annual Site Environmental Report 2018

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Oak Ridge Reservation Annual Site Environmental Report 2018

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Appendices

Acronyms and Abbreviations

A	ACHP	Advisory Council on Historic Preservation
	ACM	asbestos-containing material
	AFV	alternative fuel vehicle
	ALARA	as low as reasonably achievable
	aMSL	above mean sea level
	ANSI	American National Standards Institute
	ANSI/HPS	ANSI Health Physics Society (standard)
	AOC	area of concern
	AOEC	Agent Operations Eastern Command (NNSA OST)
	ARAP	aquatic resource alteration permit
	ASER	*Oak Ridge Reservation Annual Site Environmental Report*
	AWQC	ambient water quality criterion
B	BCG	biota concentration guide
	BCK	Bear Creek kilometer
	BFK	Brushy Fork kilometer
	BMAP	Biological Monitoring and Abatement Program
	BRW	bedrock well
C	C&D	construction and demolition
	CAA	Clean Air Act
	CAP-88	Clean Air Act Assessment Package (software)
	CCR	climate change resiliency
	CEQ	Council on Environmental Quality
	CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
	CEUSP	Consolidated Edison Uranium Solidification Project
	CFR	*Code of Federal Regulations*
	CFTF	Carbon Fiber Technology Facility
	CH	contact-handled
	CNF	Central Neutralization Facility
	COC	contaminant of concern
	CPU	central processing unit
	CRK	Clinch River kilometer
	CROET	Community Reuse Organization of East Tennessee
	CWA	Clean Water Act
	CWTS	Chromium Water Treatment System (ETTP)
	CX	categorical exclusion
	CY	calendar year

D	D&D	decontamination and decommissioning
	DCA	dichloroethane
	DCE	dichloroethene/dichloroethylene
	DCS	derived concentration standard
	DNAPL	dense nonaqueous phase liquid
	DOE	US Department of Energy
	DOE ORO	DOE Oak Ridge Office
	DOI	US Department of Interior
	DOT	US Department of Transportation
	DPT	direct push technology
E	EC&P	environmental compliance and protection
	ED	effective dose
	EFK	East Fork Poplar Creek kilometer
	EFPC	East Fork Poplar Creek
	EISA	Energy Independence and Security Act
	EM	environmental management
	EMS	environmental management system
	EMWMF	Environmental Management Waste Management Facility
	EO	executive order
	EPA	US Environmental Protection Agency
	EPCRA	Emergency Planning and Community Right-to-Know Act
	EPEAT	Electronic Product Environmental Assessment Tool
	E-Plan	Emergency response information system
	EPSD	Environmental Protection Services Division (UT-Battelle)
	EPT	ephemeroptera, plecoptera, and trichoptera (taxa)
	ES&H	environment, safety, and health
	ESS	Environmental Surveillance System (ORNL)
	ETTP	East Tennessee Technology Park
	EU	exposure unit
	EUI	energy use intensity
	EV	electric vehicle
F	FCK	First Creek kilometer
	FFA	Federal Facility Agreement for the Oak Ridge Reservation
	FFCA	Federal Facilities Compliance Agreement
	FFK	Fifth Creek kilometer
	FWS	US Fish and Wildlife Service
	FY	fiscal year
G	GHG	greenhouse gas
	GI	green infrastructure
	GI/LID	green infrastructure/low impact development
	GP	guiding principle
	GSF	gross square feet

H

HAP	hazardous air pollutant
HFIR	High Flux Isotope Reactor
HPSB	high-performance sustainable building
HQ	hazard quotient
HVC	Hardin Valley Campus

I

ID	identification (number)
IDMS	Integrated Document Management System (UT-Battelle)
ISMS	Integrated Safety Management System
ISO	International Organization for Standardization
Isotek	Isotek Systems LLC

L

LCD	liquid crystal display
LEED	Leadership in Energy and Environmental Design
LID	low impact development
LLW	low-level waste

M

MARSAME	*Multi-Agency Radiation Survey and Assessment of Materials and Equipment Manual*
MARSSIM	*Multi-Agency Radiation Survey and Site Investigation Manual*
MBK	Mill Branch kilometer
MCK	McCoy Branch kilometer
MCL	maximum contaminant level
MDF	Manufacturing Demonstration Facility
MEI	maximally exposed individual
MEK	Melton Branch kilometer
MIK	Mitchell Branch kilometer
MOA	memorandum of agreement
MSL	mean sea level
MT	meteorological tower (when followed by a numeral as in “MT2”)

N

NAAQS	National Ambient Air Quality Standards
NCRP	National Council on Radiation Protection and Measurement
NEPA	National Environmental Policy Act
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NHPA	National Historic Preservation Act
NNSA	National Nuclear Security Administration
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List (EPA)
NPS	US National Park Service
NRC	US Nuclear Regulatory Commission
NRCS	Natural Resources Conservation Service
NRHP	National Register of Historic Places
NSF-ISR	NSF International Strategic Registrations, Ltd.

	NTRC	National Transportation Research Center
	NWSol	North Wind Solutions, LLC
O	ODS	ozone-depleting substance
	OMP	operational monitoring plan
	OREM	DOE Oak Ridge Office of Environmental Management
	ORGDP	Oak Ridge Gaseous Diffusion Plant
	ORISE	Oak Ridge Institute for Science and Education
	ORNL	Oak Ridge National Laboratory
	ORO	Oak Ridge Office (DOE)
	ORR	Oak Ridge Reservation
	ORR-PCB-FFCA	Oak Ridge Reservation Polychlorinated Biphenyl Federal Facilities Compliance Agreement
	ORSSAB	Oak Ridge Site Specific Advisory Board
	ORWMA	Oak Ridge Wildlife Management Area
	OS	DOE Office of Science
	OST	Office of Secure Transportation
P	P2	pollution prevention
	P2/WMin	pollution prevention/waste minimization
	PAM	perimeter air monitoring (station)
	PCB	polychlorinated biphenyl
	PCE	tetrachloroethene
	PEMS	Predictive Emissions Monitoring System
	PHEV	plug-in hybrid electric vehicle
	PM	particulate matter
	PM_{10}	particulate matter with an aerodynamic diameter $\leq 10\ \mu m$
	$PM_{2.5}$	fine particulate matter with an aerodynamic diameter $\leq 2.5\ \mu m$
	PS	performance specification
	PWTC	Process Waste Treatment Complex
Q	QA	quality assurance
	QAS	quality assurance system
	QC	quality control
	QMS	quality management system
R	R&D	research and development
	RA	remedial action
	rad-NESHAPs	National Emission Standards for Hazardous Air Pollutants for radionuclides
	RATA	relative accuracy test audit
	RCRA	Resource Conservation and Recovery Act
	RCW	recirculating cooling water
	RH	remote-handled
	RI	remedial investigation

	RI/FS	remedial investigation/feasibility study
	RICE	reciprocating internal combustion engine
	RMP	risk management plan
	ROD	record of decision
	RSI	Restoration Services, Inc.
S	S&M	surveillance and maintenance
	SAP	sampling and analysis plan
	SARA	Superfund Amendments and Reauthorization Act
	SBMS	Standards-Based Management System (UT-Battelle)
	SC	DOE Office of Science
	SCI	sustainable campus initiative
	SCS	Soil Conservation Service
	SD	storm water outfall/storm drain
	SDWA	Safe Drinking Water Act
	SHPO	State Historic Preservation Office (Tennessee)
	SNS	Spallation Neutron Source
	SODAR	sonic detection and ranging
	SOF	sum of fractions
	SOP	state operating permit
	SPCC	spill prevention, control, and countermeasures (plan)
	SPMD	semipermeable membrane device
	STP	sewage treatment plant
	SVOC	semivolatile organic compound
	SWMU	solid waste management unit
	SWPP	storm water pollution prevention
	SWPPP	Storm Water Pollution Prevention Plan
	SWSA	solid waste storage area
T	TCA	trichloroethane
	TCE	trichloroethene/trichloroethylene
	TDEC	Tennessee Department of Environment and Conservation
	TMDL	total maximum daily load
	TRI	toxic (chemical) release inventory
	TRO	total residual oxidant
	TRU	transuranic
	TSCA	Toxic Substances Control Act
	TSS	total suspended solids
	TVA	Tennessee Valley Authority
	TWPC	Transuranic Waste Processing Center
	TWRA	Tennessee Wildlife Resources Agency
U	UMC	unneeded materials and chemicals
	UNW	unconsolidated well
	USC	United States Code

	USDA	US Department of Agriculture
	UST	underground storage tank
	UT	University of Tennessee
	UT-Dallas	University of Texas at Dallas
V	VC	vinyl chloride
	VOC	volatile organic compound
W	WBK	Walker Branch kilometer
	WCK	White Oak Creek kilometer
	WIPP	Waste Isolation Pilot Plant
	WOC	White Oak Creek
	WOD	White Oak Dam
	WQC	water quality criterion
	WQPP	water quality protection plan
	WRRP	Water Resources Restoration Program
	WSR	waste services representatives
Y	Y-12	Y-12 National Security Complex
	Y-12 Complex	Y-12 National Security Complex
Z	ZPR	Zero-power Reactor

Units of Measure and Conversion Factors*

Units of measure and their abbreviations

acre	acre	micrometer	µm
becquerel	Bq	millicurie	mCi
British thermal unit	Btu	milligram	mg
centimeter	cm	milliliter	mL
curie	Ci	millimeter	mm
day	day	million	M
degrees Celsius	°C	million gallons per day	MGD
degrees Fahrenheit	°F	millirad	mrad
disintegrations per minute	dpm	millirem	mrem
foot	ft	milliroentgen	mR
gallon	gal	millisievert	mSv
gallons per minute	gal/min	minute	min
gram	g	nanogram	ng
gray	Gy	nephelometric turbidity unit	NTU
gross square feet	gsf	parts per billion	ppb
hectare	ha	parts per million	ppm
hour	h	parts per trillion	ppt
inch	in.	picocurie	pCi
joule	J	pound	lb
kilocurie	kCi	pound mass	lbm
kilogram	kg	pounds per square inch	psi
kilometer	km	pounds per square inch gage	psig
kilowatt	LF	quart	qt
linear feet	kW	rad	rad
liter	L	roentgen	R
megajoule	MJ	roentgen equivalent man	rem
megawatt	MW	second	s
megawatt-hour	MWh	sievert	Sv
meter	m	standard unit (pH)	SU
metric tons	MT	ton, short (2,000 lb)	ton
microcurie	µCi	yard	yd
microgram	µg	year	yr

Quantitative prefixes

exa	$\times 10^{18}$	atto	$\times 10^{-18}$
peta	$\times 10^{15}$	femto	$\times 10^{-15}$
tera	$\times 10^{12}$	pico	$\times 10^{-12}$
giga	$\times 10^{9}$	nano	$\times 10^{-9}$
mega	$\times 10^{6}$	micro	$\times 10^{-6}$
kilo	$\times 10^{3}$	milli	$\times 10^{-3}$
hecto	$\times 10^{2}$	center	$\times 10^{-2}$
deka	$\times 10^{1}$	decic	$\times 10^{-1}$

*Due to differing permit reporting requirements and instrument capabilities, various units of measurement are used in this report. The provided list of units of measure and conversion factors is intended to help readers make approximate conversions to other units as needed for specific calculations and comparisons.

Unit conversions

Unit	Conversion	Equivalent	Unit	Conversion	Equivalent
		Length			
in.	× 2.54	cm	cm	× 0.394	in.
ft	× 0.305	m	m	× 3.28	ft
mile	× 1.61	km	km	× 0.621	mile
		Area			
acre	× 0.405	ha	ha	× 2.47	acre
ft^2	× 0.093	m^2	m^2	× 10.764	ft^2
$mile^2$	× 2.59	km^2	km^2	× 0.386	$mile^2$
		Volume			
ft^3	× 0.028	m^3	m^3	× 35.31	ft^3
qt (US liquid)	× 0.946	L	L	× 1.057	qt (US liquid)
gal	× 3.7854118	L	L	× 0.264172051	gal
		Concentration			
ppb	× 1	µg/kg	µg/kg	× 1	ppb
ppm	× 1	mg/kg	mg/kg	× 1	ppm
ppb	× 1	µg/L	µg/L	× 1	ppb
ppm	× 1	mg/L	mg/L	× 1	ppm
		Weight			
lb	× 0.4536	kg	kg	× 2.205	lb
lbm	× 0.45356	kg	kg	× 2.2046226	lbm
ton, short	× 907.1847	kg	kg	× 0.00110231131	ton, short
		Temperature			
°C	°F = (9/5)°C + 32	°F	°F	°C = (5/9) (F–32)	°C
		Activity			
Bq	$\times 2.7 \times 10^{-11}$	Ci	Ci	$\times 3.7 \times 10^{10}$	Bq
Bq	× 27	pCi	pCi	× 0.037	Bq
mSv	× 100	mrem	mrem	× 0.01	mSv
Sv	× 100	rem	rem	× 0.01	Sv
nCi	× 1,000	pCi	pCi	× 0.001	nCi
mCi/km^2	× 1	nCi/m^2	nCi/m^2	× 1	mCi/km^2
dpm/L	$\times 0.45 \times 10^{9}$	$\mu Ci/cm^3$	$\mu Ci/cm^3$	$\times 2.22 \times 10^{9}$	dpm/L
pCi/L	$\times 10^{-9}$	µCi/mL	µCi/mL	$\times 10^{9}$	pCi/L
pCi/m^3	$\times 10^{12}$	$\mu Ci/cm^3$	$\mu Ci/cm^3$	$\times 10^{12}$	pCi/m^3

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Executive Summary

Overview

The Oak Ridge Reservation (ORR), located in Roane and Anderson Counties in East Tennessee about 40 km (25 mi) west of Knoxville, is managed by the US Department of Energy (DOE). ORR is one of DOE's most complex sites. Established in the early 1940s as part of the Manhattan Project to enrich uranium and pioneer methods for producing and separating plutonium, ORR continued those activities until the mid-1980s. Today ORR comprises three major facilities with thousands of employees performing every mission in the DOE portfolio: energy research, environmental restoration, national security, nuclear fuel supply, reindustrialization, science education, basic and applied research in areas important to US security, and technology transfer. Scientists at the Oak Ridge National Laboratory (ORNL), DOE's largest science and energy laboratory, conduct leading-edge research in advanced materials, neutron scattering, nuclear programs (including isotope production), and high-performance computing. The Y-12 National Security Complex (Y-12 or Y-12 Complex) is vital to maintaining the safety, security, and effectiveness of the US nuclear weapons stockpile and reducing the global threat posed by nuclear proliferation and terrorism. The East Tennessee Technology Park (ETTP), a former uranium enrichment complex, is being transitioned to a clean, revitalized industrial park.

ORR is managed by three DOE Program Secretarial Offices and their management, operating, and support contractors. This calendar year 2018 *Oak Ridge Reservation Annual Site Environmental Report* (ASER) contains detailed and complex information furnished to the DOE ORR integrating contractor by other contractors including UT-Battelle, LLC; Consolidated Nuclear Security, LLC; UCOR, an AECOM-led partnership with Jacobs; North Wind Solutions, LLC; Oak Ridge Associated Universities; and Isotek Systems, LLC.

Safety is of paramount importance at all DOE facilities, and DOE's signature integrated safety management system (ISMS) integrates safety in all aspects of work at its facilities. Safety, as defined in ISMS, encompasses protection of the public, the worker, and the environment and includes all safety, health, and environmental disciplines: radiation protection, fire protection, nuclear safety, environmental protection, waste management, and environmental management.

Three key chapters of this report were prepared for DOE in strict accordance with applicable federal, state, and local regulations. Chapter 3 was written by UCOR, the lead environmental management contractor for ETTP; Chapter 4 was developed by Consolidated Nuclear Security, LLC, which manages and operates the Y-12 Complex; and Chapter 5 was written by UT-Battelle, LLC, which manages ORNL. These contractors are also responsible for independently carrying out the various DOE missions at the three major ORR facilities. They manage and implement environmental protection programs through environmental management systems that adhere to International Organization for Standardization standard 14001, *Environmental Management Systems*, and are integrated with ISMS to provide unified strategies for managing resources. Chapters 3, 4, and 5 include detailed information on the contractors' environmental management systems.

DOE operations on ORR have the potential to release a variety of constituents to the environment via atmospheric, surface water, and groundwater pathways. Some of these constituents, such as particles from diesel engines, are common at many types of facilities while others, such as radionuclides, are unique to specialized research and production activities like those conducted on ORR. Any releases are highly regulated and carefully monitored. DOE is committed to enhancing environmental stewardship and managing the impacts its operations may have on the environment. It encourages the public to participate in matters related to ORR's environmental impact on the community by soliciting citizens' input on matters of significant public interest through various communications. DOE also offers public access to information on all of its Oak Ridge environmental, safety, and health activities.

The ASER is prepared for DOE according to the requirements of DOE Order 231.1B, *Environment, Safety, and Health Reporting*. The ASER includes data on the environmental performance of each of the major DOE ORR contractors and describes significant accomplishments in pollution prevention and sustainability programs that reduce all types of waste and pollutant releases to the environment. DOE has published an annual environmental report with consolidated data on overall ORR performance and status since the mid-1970s. The ASER is a key component of DOE's effort to keep the public informed about environmental conditions across DOE and National Nuclear Security Administration sites. The report is written to enhance readability, and it references other sections and chapters as well as other reports throughout to avoid redundancy.

2018 Impacts

In 2018, DOE ORR operations resulted in minimal impact to the public and the environment. Permitted discharges to air and water were well below regulatory standards, and potential radiation doses to the public from activities on the reservation were significantly less than the 100 mrem standard established for DOE sites in DOE Order 458.1, *Radiation Protection of the Public and the Environment*.

The maximum radiation dose a hypothetical off-site individual could have received from DOE activities on ORR in 2018 was estimated to be 0.2 mrem from air pathways, 0.2 mrem from water pathways (drinking water, fish consumption, swimming, recreation, and other uses), and 2 mrem from consumption of wildlife harvested on ORR. This is about 3 percent of the DOE 100 mrem standard for all pathways and is significantly less than the 300 mrem annual average dose to people in the United States from natural or background radiation.

Environmental Monitoring

Each year extensive environmental monitoring is conducted across ORR. Site-specific environmental protection programs are carried out at ORNL, the Y-12 Complex, and ETTP. ORR-wide environmental surveillance programs, which include locations and media both on and off the reservation, are carried out to enhance and supplement data from site-specific efforts. In 2018, thousands of samples and measurements of air, water, direct radiation, vegetation, fish, and wildlife collected from across the reservation were analyzed for both radioactive and nonradioactive contaminants. Sample media, locations, frequencies, and parameters were selected based on environmental regulations and standards, public and environmental exposure pathways, public concerns, and measurement capabilities. Chapters 2 through 7 of this report summarize the environmental protection and surveillance programs on ORR. These extensive sampling and monitoring efforts demonstrate DOE's commitment to ensuring safety; protecting human health; complying with regulations, standards, DOE Orders, and "as low as reasonably achievable" principles; reducing the risks associated with past, present, and future operations; and improving cost-effectiveness.

Compliance with Environmental Regulations

Federal, state, and local government agencies including the US Environmental Protection Agency (EPA) and the Tennessee Department of Environment and Conservation (TDEC) monitor ORR for compliance with applicable environmental regulations. These agencies issue permits, review compliance reports, participate in monitoring programs, and inspect facilities and operations. Compliance with environmental regulations and DOE orders ensures activities do not adversely impact the public or the environment.

Compliance with applicable regulations during 2018 for the three major ORR sites is summarized as follows:

- Y-12 had three environmental violations in 2018.
- ETTP had no environmental violations, issues, or findings in 2018.
- ORNL had no environmental violations, issues, or findings in 2018.

Chapter 2 provides a detailed summary of ORR environmental compliance during 2018. Chapters 3, 4, and 5 discuss each site's compliance status for the year.

Cleanup, Pollution Prevention, and Site Sustainability

Numerous cleanup, pollution prevention, and sustainability programs across ORR embody efforts to achieve enduring sustainability in facilities, operations, and organizational culture. These programs promote energy and water conservation, building efficiency, sustainable landscaping, green transportation, sustainable acquisition, and waste minimization, which in turn decrease the life cycle costs of programs and projects and reduce risks to the environment. While implementing their work in 2018, ORR contractors achieved a high level of excellence in pollution prevention and sustainability programs as described in Chapters 3, 4, and 5.

Cleanup Operations in 2018

ORR has played key roles in America's defense and energy research. However, past waste disposal practices, operational and industrial practices, changing standards, and unintentional releases have left land and facilities contaminated with radioactive elements, mercury, asbestos, polychlorinated biphenyls, and industrial wastes. The DOE Environmental Management program is responsible for cleaning up these sites, and numerous cleanup projects are under way at the reservation's three main facilities.

ETTP achievements included completing the demolition of ETTP's Central Neutralization Facility, which once treated the site's industrial wastewater. Demolition of ETTP's K-633 Test Loop Facility, one of several radiologically contaminated facilities in ETTP's Poplar Creek area, was also completed during 2018. Deactivation of Building K-1037 and the K-1200 Centrifuge Complex continued to prepare these structures for safe demolition in the next couple of years.

Y-12 achievements in 2018 included characterization of nine facilities in the Y-12 Biology Complex. In 2018, 3.1 tons of elemental mercury were removed from column exchange equipment in the Alpha-4 Building, and 9,477 feet of process piping, 22 tanks, and four heat exchangers were tapped, drained, and deactivated. Twenty-one of the aforementioned tanks were demolished and removed from the site for disposal. Ground was broken in 2018 for the Outfall 200 Mercury Treatment Facility. This facility will be capable of treating 3,000 gallons of water per minute and will include a 2-million-gallon storage tank to handle storm water peak flow conditions. Early site preparation will ensure construction begins in 2019. Buildings 9743-2 and 9770-2 were demolished during 2018. Mobilization began in 2018 for the demolition of the remaining buildings in the Biology Complex.

At ORNL, achievements included removal of combustible material and asbestos from Building 7500, also known as the Homogeneous Reactor Experiment. Cleanup achievements also included characterization and disposal of 74 waste items that were added to the Molten Salt Reactor Experiment's waste handling plan in 2014, and workers completed the successful Reactive Gas Removal System pumpdown of fuel drain tanks and a fuel flush tank. Significant progress was made in fiscal year 2018 to advance the design and safety basis document package for the uranium-233 processing phase in support of the DOE review and approval process. ORNL's Liquid and Gaseous Waste Operations received several important upgrades during fiscal year 2018 as a follow-up to an engineering evaluation and extended life study issued in 2016.

Environmental Management Waste Management Facility operations collected, analyzed, and disposed of approximately 3.19 million gallons of leachate treated by the Liquid and Gaseous Waste Operations facility. Characterization for the proposed Environmental Management and Disposal Facility began in February 2018 with the installation of 16 water sampling wells.

Transuranic Waste Processing Center achievements included completion of 56 contact-handled transuranic shipments to the Waste Isolation Pilot Plant (WIPP). To date, approximately 72 percent of the contact-handled transuranic waste and 46 percent of the remote-handled transuranic waste have been dispositioned at WIPP. Key progress for the Sludge Project in 2018 included receiving vendor proposals for the sludge mobilization system, the slurry mixing and characterization tank, and the sludge test area construction. The contract for testing the mobilization measurements instrumentation was also awarded.

Pollution Prevention and Sustainability in 2018

The three main ORR sites made significant strides in sustainability and pollution prevention in 2018, and highlights are summarized below.

- Y-12 achieved a 9.0 percent reduction in energy use intensity from the fiscal year 2015 baseline, in line with meeting the DOE site sustainability plan reduction goal of 25 percent by fiscal year 2025, and also achieved a 66 percent reduction in water use. Greenhouse gas emissions were reduced by 55 percent during 2018, and 91.5 percent of construction and demolition materials were diverted from the landfill.
- ORNL implemented 25 new pollution prevention projects and ongoing reuse/recycle projects during 2018, eliminating more than 4 million kg of waste. ORNL also achieved a 61 percent reduction in water use intensity from fiscal years 1985 through 2018, in compliance with the Executive Order 13693 reduction goal of 36 percent by 2025; a 32 percent decrease in petroleum consumption; and an increase, to 25, in the number of alternative use vehicles. ORNL has seen a cumulative reduction of 31.6 percent in energy used since 2003.
- ETTP carbon dioxide emissions have surpassed the targeted 40 percent reduction outlined in Executive Order 13693. The total reduction of greenhouse gas emissions to date, starting with the 2008 baseline year, is 58.6 percent. In 2018, ETTP received an exceptional electronics stewardship award from the Green Electronics Council for the use of Electronic Product Environmental Assessment Tool (EPEAT) methods. Other significant 2018 accomplishments at ETTP included diversion of approximately 156 tons of rubble through reuse, saving approximately 1,100 cubic yards of landfill space; recognition of the K-1401 Treatability Study Team for optimizing waste disposition efforts, saving $9.4 million; and the reuse of a contaminated manipulator from Building 3028, which saved $75,000.

The Office of Environmental Management also continued planning for capital asset projects that will further advance ORR cleanup objectives. These include the aforementioned mercury treatment facility at Y-12, the new disposal facility that will accept debris from future cleanup at Y-12 and ORNL, and the new sludge treatment facility at the Transuranic Waste Processing Center.

1. Introduction to the Oak Ridge Reservation

The concept of a Secret City is both mystifying and intriguing. It was here, and in supporting locations, that humankind leapt from candlepower to nuclear power in a single generation. In the Secret City an engineering marvel materialized that changed the world, helped bring an end to World War II, and launched the use of diagnostic tools such as magnetic resonance imaging and nuclear medicine that are saving thousands of lives from many types of cancer. Today, the Secret City exists in two parts: the commercial city of Oak Ridge and the Oak Ridge Reservation (ORR), which is a federally owned site in Anderson and Roane Counties in eastern Tennessee.

The ORR site covers 52 square miles of land used for commercial and industrial activities as well as streams, lakes, and woodlands teeming with deer, wild turkey, raccoon, squirrels, and rabbits; birds of prey such as eagles, osprey, great horned owls, and red tail and sparrow hawks; and wildlife predators including coyotes and bobcats. ORR is home to two major US Department of Energy (DOE) operating components: the Oak Ridge National Laboratory (ORNL) and the Y-12 National Security Complex (Y-12 Complex or Y-12). Other facilities on ORR include the East Tennessee Technology Park (ETTP), the site of a former gaseous diffusion plant that has undergone significant environmental cleanup and transitioned to a private sector business and industrial park; the Oak Ridge Institute for Science and Education (ORISE) South Campus, which includes training facilities, laboratories, and support facilities; several smaller, government-owned, contractor-operated facilities involved in environmental cleanup; and the government-owned, government-operated Agent Operations Eastern Command (AOEC) of the National Nuclear Security Administration (NNSA) Office of Secure Transportation (OST). Personnel seeking entrance to ORR must have proper credentials in accordance with current access security requirements.

President Franklin D. Roosevelt received the famous Einstein-Szilard letter in 1939 informing him that German scientists were working on a nuclear weapon. In utmost secrecy, he formed the agencies leading up to the Manhattan Project. Then, on June 28, 1941, the President signed Executive Order 8807 that ultimately funded the Manhattan Project. The super-secret code name Manhattan Project gave no indication of the classified activities it concealed. Originally established in New York City's Manhattan District on the 18th floor of an office building at 270 Broadway in June of 1942, the headquarters of the Manhattan Project moved to Oak Ridge, Tennessee in the late summer of 1943. Here scientists began using the gaseous diffusion process to enrich uranium and pioneered methods for producing and separating plutonium. ORR's mission continues to evolve as it adapts to meet the changing basic and applied research and national security needs of the United States.

Due to different permit reporting requirements and instrument capabilities, this report uses various units of measurement. The lists of units of measure and conversion factors on pages xxvii and xxviii are included to help readers convert numeric values presented herein as needed for specific calculations and comparisons.

1.1 Background

The ORR Annual Site Environmental Report (ASER) presents a summary of environmental data that characterizes environmental performance, lists environmental occurrences reported during the year, confirms compliance with environmental standards and requirements, and highlights significant environmental program activities. The ASER meets the requirements of DOE Order 231.1B, *Environment, Safety, and Health Reporting*, and its Attachments 1, 2, 3, 4, and 5 (DOE 2012) regarding the preparation of an integrated annual site environmental report.

Summary results presented in this report are based on data collected before and continuing through 2018. Not all results of the environmental monitoring associated with ORR are reported here, and this is not intended as a comprehensive monitoring report. Data collected for other site and regulatory purposes, such as environmental restoration and remedial investigation reports, waste management characterization sampling data, and environmental permit compliance data, are presented in other documents that have been prepared in accordance with applicable laws, regulations, policies, and guidance. These data are referenced herein as appropriate.

Environmental monitoring of ORR activities consists primarily of effluent monitoring and environmental surveillance. Effluent monitoring involves the collection and analysis of samples or measurements of liquid and gaseous effluents at the points of their release to the environment. These measurements allow the quantification and official reporting of contaminant levels, assessment of public exposures to radiation (see Appendix E) and chemicals (see Appendix F), and demonstration of compliance with applicable standards and permit requirements. Environmental surveillance consists of direct measurement, collection, and analysis of samples taken from the site and its environs, exclusive of effluents. These surveillance activities provide information on contaminant concentrations in air, water, groundwater, soil, foods, biota, and other media. Other environmental surveillance data support environmental compliance and, when combined with data from effluent monitoring, also support chemical and radiation dose and exposure assessments of the potential effects of ORR operations, if any, on the local environment.

1.2 History of the Area around the Oak Ridge Reservation

Native Americans first inhabited the ORR area during the Woodland Period (c. 1000 BC to AD 1000). Descendants of these early dwellers, whose ancestors were Neolithic and Stone Age people, still lived in the East Tennessee region when European settlers arrived in the late 1700s. The Cherokee people were dominant in the area following wars with the Shawnee and Creek. The early European settlers of the ORR area lived on farms or in four small communities named Elza, Robertsville, Scarboro, and Wheat. All but Elza were founded shortly after the Revolutionary War. About a thousand families inhabited the area in the early 1940s.

The area that became ORR was selected in 1942 for the Manhattan Project, in part, because the Clinch River provided abundant water, the terrain featured linear and partitioned ridges, nearby Knoxville was a good source of labor, and the Tennessee Valley Authority (TVA) could supply ample amounts of needed electricity. Families that had occupied homes and farms for generations received orders to vacate within just a few weeks. The federal government's acquisition of property immediately affected more than three thousand individuals. According to data from the US Department of Agriculture’s National Agricultural Statistics Service, the average farm real estate value in 1942 for the 48 contiguous states was $34 per acre. Some property owners were paid this amount for their land, and others were paid less. Many felt they were poorly compensated, especially for their homes.

The site’s wartime name was Clinton Engineering Works. Although it was not shown on any map, the workers’ city on the reservation’s northern edge, named Oak Ridge, grew to a population of 75,000, becoming the fifth largest city in Tennessee. To the south of the residential area, an electromagnetic method at the Y-12 Complex separated uranium-235 from natural uranium. The K-25 gaseous diffusion plant was built on the reservation’s western edge. Near the reservation’s southwest corner, about 16 km (10 mi) from the Y-12 Complex, a third facility—known as X-10 or Clinton Laboratories—housed the experimental graphite reactor. X-10 served as a pilot scale facility for the larger plutonium production facilities built at Hanford, Washington.

Two years after World War II ended, Oak Ridge shifted to civilian control under the authority of the US Atomic Energy Commission. In 1959 the city was incorporated and the community adopted a city manager and city council form of government.

The missions of the three major ORR installations have continued to evolve and operations have adapted to meet America's changing defense, energy, and research needs. Section 1.4 describes their current missions, as well as the missions of several smaller DOE facilities and activities on ORR.

1.3 Site Description

1.3.1 Location and Population

Situated in the Great Valley of East Tennessee between the Cumberland and Great Smoky Mountains, ORR borders the Clinch River (see Figures 1.1 and 1.2). The Cumberland Mountains are 16 km (10 mi) to the northwest and the Great Smoky Mountains are 51 km (31.6 mi) to the southeast. ORR encompasses about 13,055 ha (33,259 acres) of mostly contiguous land in Anderson and Roane Counties owned by the federal government, and ORR is under the management of DOE. According to the US Census Bureau, the estimated population of the 10-county region surrounding ORR is 999,791 and, as reported in *US Department of Energy FY2017│Economic Impact in Tennessee*, ORR employs about 3 percent of the region's labor force. The 2018 US census population estimate for the official nine-county Knoxville metropolitan statistical area is 883,309. Other municipalities within about 30 km (18.6 mi) of the reservation include Oliver Springs, Clinton, Rocky Top, Lenoir City, Farragut, Kingston, and Harriman.

Knoxville, the major metropolitan area nearest Oak Ridge, is about 40 km (25 mi) to the east and had a population of about 187,500 according to the 2018 US census population estimate. Except for the city of Oak Ridge, the land within 8 km (5 mi) of ORR is semirural and is used primarily for residences, small farms, and cattle pasture. Fishing, hunting, boating, water skiing, and swimming are popular recreational activities in the area.

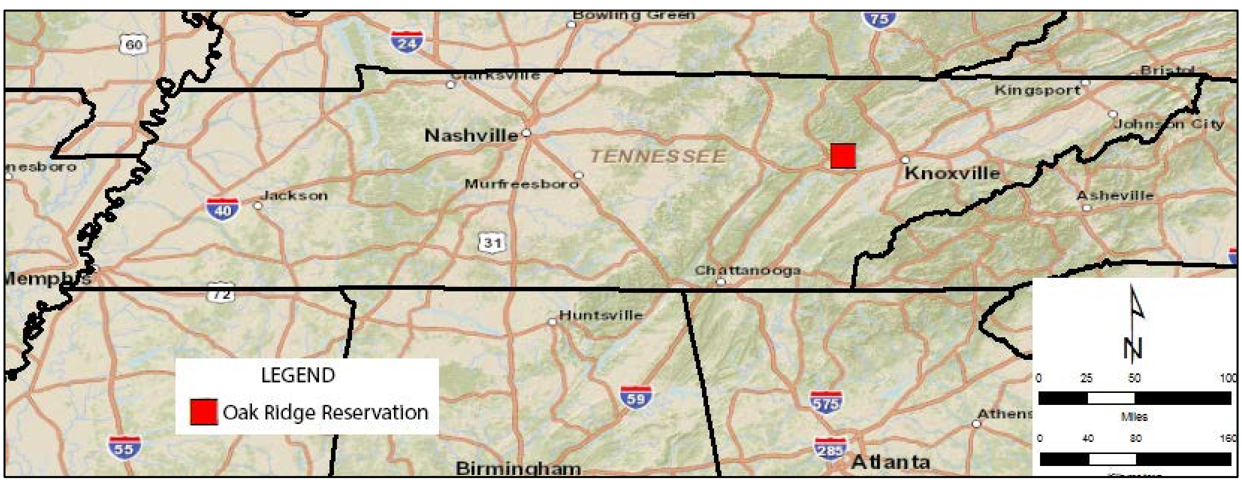


Figure 1.1. Location of the Oak Ridge Reservation in Tennessee

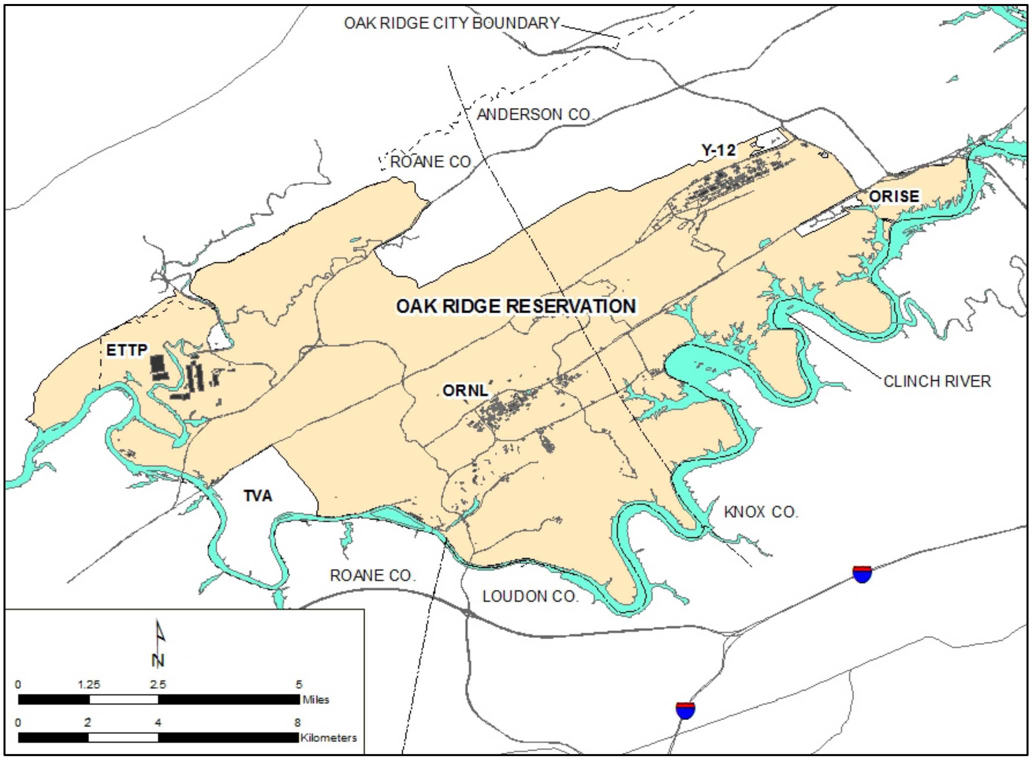


Figure 1.2. Map of the Oak Ridge Reservation

1.3.2 Climate

Although it features significant temperature changes between summer and winter, the climate of the Oak Ridge region qualifies as humid subtropical. The 30-year mean temperature for 1981–2010 was 14.7°C (58.5°F). The average high temperature for the Oak Ridge area in 2018 was 20.6°C (69.1°F). January temperatures were coldest in 2018, averaging 0.4°C (32.8°F). July was the warmest month, with average temperatures of 24.7°C (76.5°F). Monthly summaries of temperature averages, extremes, and 2018 values are provided in Appendix B, Table B.1.

Average annual precipitation in the Oak Ridge area for the 30-year period from 1981 to 2010 was 1,337.5 mm (52.64 in.), including about 21.3 cm (8.4 in.) of snowfall (NOAA 2011). Total precipitation during 2018 as measured at meteorological tower (MT)2 was 1,559.8 mm (61.39 in.), which is 5 percent above the 30-year average. Monthly summaries of precipitation averages, extremes, and 2018 values can also be found in Appendix B, Table B.1.

The average annual wind data recovery rates (a measure of acceptable data) across locations used for modeling during 2018 stood at 99.2 percent for wind sensors at the ORNL sites (towers MT2, MT3, MT4, and MT10). All other MT2, MT3, and MT4 instrument recoveries were well above 90 percent for both quarterly and annual values.

In 2018 wind speeds at ORNL Tower C/D (MT2), measured at 15 m (49 ft) above ground level, averaged 0.94 m/s (2.2 mph). This value remained unchanged for winds at 60 m (198 ft) above ground level. The local ridge-and-valley terrain reduces average wind speeds at valley bottoms, resulting in frequent periods of calm or near calm conditions, particularly during clear early morning hours in weak synoptic weather environments. Wind direction frequencies with respect to precipitation hours for the ORR towers may be reviewed **here** under the heading 2018 Annual Precipitation Wind Roses−Oak Ridge Reservation.

Detailed information on the climate of the Oak Ridge area is available in *Oak Ridge Reservation Physical Characteristics and Natural Resources* (Parr and Hughes 2006) and in Appendix B of this report. An in-depth analysis of wind patterns for ORR conducted from 2009 to 2011 and documented in *Wind Regimes in Complex Terrain in the Great Valley of Eastern Tennessee* (Birdwell 2011) is available online **here**.

1.3.3 Regional Air Quality

The US Environmental Protection Agency (EPA) Office of Air Quality Planning and Standards set national ambient air quality standards (NAAQS) for key principal pollutants, also known as criteria pollutants. These key pollutants are sulfur dioxide, carbon monoxide, nitrogen dioxide, lead, ozone, particulate matter with an aerodynamic diameter less than or equal to 10 µm (PM_{10}), and fine particulate matter with an aerodynamic diameter less than or equal to 2.5 µm ($PM_{2.5}$). EPA evaluates NAAQS based on ambient, or outdoor, levels of the criteria pollutants. Areas that satisfy NAAQS are classified as attainment areas, and areas that exceed NAAQS for a particular pollutant are considered non-attainment areas for that pollutant.

ORR is located in Anderson and Roane Counties. As of August 30, 2017, EPA designated Anderson, Knox, Blount, and Roane Counties as attainment areas for the $PM_{2.5}$ air quality standard. The greater Knoxville and Oak Ridge area is a NAAQS attainment area for all other criteria pollutants for which EPA has made attainment designations.

1.3.4 Surface Water

The ORR area is composed of a series of drainage basins or troughs containing numerous small streams that feed the Clinch River. Surface water on ORR drains into a series of tributaries, streams, or creeks in different watersheds. Each of these watersheds drains into the Clinch River, which in turn flows into the Tennessee River. On December 31, 2018, the Tennessee Valley Authority declared 2018 the wettest year on record for the Tennessee Valley region with 67.1 inches of precipitation, surpassing a previous record of 65.1 inches set in 1973. This conclusion is based on 129 years of collected weather data.

The largest of the ORR drainage basins is Poplar Creek, which receives drainage from a 352 km^2 (136 mi^2) area including the northwestern sector of ORR. Flow is from northeast to southwest, roughly through the center of ETTP, and the creek discharges directly into the Clinch River.

East Fork Poplar Creek, which discharges into Poplar Creek east of ETTP, originates within the Y-12 Complex and flows northeast along the south side of the complex. Bear Creek also originates within the Y-12 Complex and flows southwest. Bear Creek is affected by storm water runoff, groundwater infiltration, and tributaries that drain former waste disposal sites in the Bear Creek Valley Burial Grounds Waste Management Area and the current Environmental Management Waste Management Facility (EMWMF).

Both the Bethel Valley and Melton Valley portions of ORNL are in the White Oak Creek drainage basin, which has an area of 16.5 km^2 (6.4 mi^2). The headwaters of White Oak Creek originate on Chestnut Ridge, north of ORNL and near the Spallation Neutron Source site. The creek flows west along the southern boundary of the developed area of the ORNL site, then flows southwest through a gap in Haw Ridge to the western portion of Melton Valley, forming a confluence with Melton Branch. The headwaters of Melton Branch originate in Melton Valley east of the High Flux Isotope Reactor complex, and the area of the drainage basin is about 3.8 km^2 (1.47 mi^2). The waters of White Oak Creek enter White Oak Lake, an impoundment formed by White Oak Dam. Water flowing over White Oak Dam enters the Clinch River after passing through the White Oak Creek embayment area.

1.3.5 Geological Setting

ORR is in the Tennessee portion of the Valley and Ridge Physiographic Province, which is part of the southern Appalachian fold-and-thrust belt. Thrust faulting, associated fracturing of the rock, and differential erosion rates created a series of parallel valleys and ridges that trend southwest to northeast.

Two geologic units on ORR, the Knox Group and the Maynardville Limestone of the Upper Conasauga Group, consist of dolostone and limestone, respectively, and make up the most significant water-bearing hydrostratigraphic units in the Valley and Ridge Province (Zurawski 1978) and on ORR. Composed of moderately soluble minerals, these bedrock formations are prone to dissolution as slightly acidic rainwater and percolating recharge water come in contact with the mineral surfaces. This dissolution increases fracture apertures and can, under some circumstances, form caverns and extensive solution conduit networks. This hydrostratigraphic unit is locally known as the Knox Aquifer. A combination of fractures and solution conduits in the aquifer control flow over substantial areas and large quantities of water may move long distances. Active groundwater flow can occur at substantial depths (91.5 to 122 m, or 300 to 400 ft) in the Knox Aquifer. The Knox Aquifer is the primary source of groundwater (base flow) for many streams, and most large springs on ORR receive discharge from the Knox Aquifer. Yields of some wells penetrating larger solution conduits exceed 3,785.4 L/min (1,000 gal/min). The high productivity of the Knox Aquifer results from the combination of its abundant and sometimes large solution conduit systems and frequently thick overburden soils that promote recharge and storage of groundwater.

The remaining geologic units on ORR (the Rome Formation, the Conasauga Group below the Maynardville Limestone, and the Chickamauga Group) are composed predominantly of shale, siltstones, and sandstones with a subordinate and locally variable amount of carbonate bedrock. These formations are primarily composed of insoluble minerals such as clays and quartz that were derived from ancient continental erosion. Groundwater occurs in and moves through fractures in these bedrock units. Groundwater availability in such settings depends on the abundance and interconnectedness of fractures and the connection of fractures to sources of recharge, such as alluvial soils along streams, which can provide some sustained infiltration. The shale and sandstone formations are the poorest aquifers in the Valley and Ridge Province (Zurawski 1978). Well yields are generally low in the Rome, Conasauga, and Chickamauga bedrock formations except in localized areas where carbonate beds may provide greater groundwater storage than adjacent clastic bedrock. Detailed information on ORR groundwater hydrology and flow is available in *Oak Ridge Reservation Physical Characteristics and Natural Resources* (Parr and Hughes 2006).

1.3.6 Natural, Cultural, and Historic Resources

The ORR has an exceptional variety of natural, cultural, and historic resources. Ongoing efforts continue to focus on preserving the rich diversity of these resources.

1.3.6.1 Wetlands

Wetlands occur across ORR at low elevations, primarily in riparian zones of headwater streams and receiving streams and in the Clinch River embayments, as shown in Figure 1.3. Surveys of wetland resources presented in *Identification and Characterization of Wetlands in the Bear Creek Watershed* (Rosensteel and Trettin 1993), *Wetland Survey of the X-10 Bethel Valley and Melton Valley Groundwater Operable Units at Oak Ridge National Laboratory, Oak Ridge, Tennessee* (Rosensteel 1996), and *Wetland Survey of Selected Areas in the Oak Ridge Y-12 Plant Area of Responsibility, Oak Ridge, Tennessee* (Rosensteel 1997) serve as references to support wetland assessments for upcoming projects and activities.

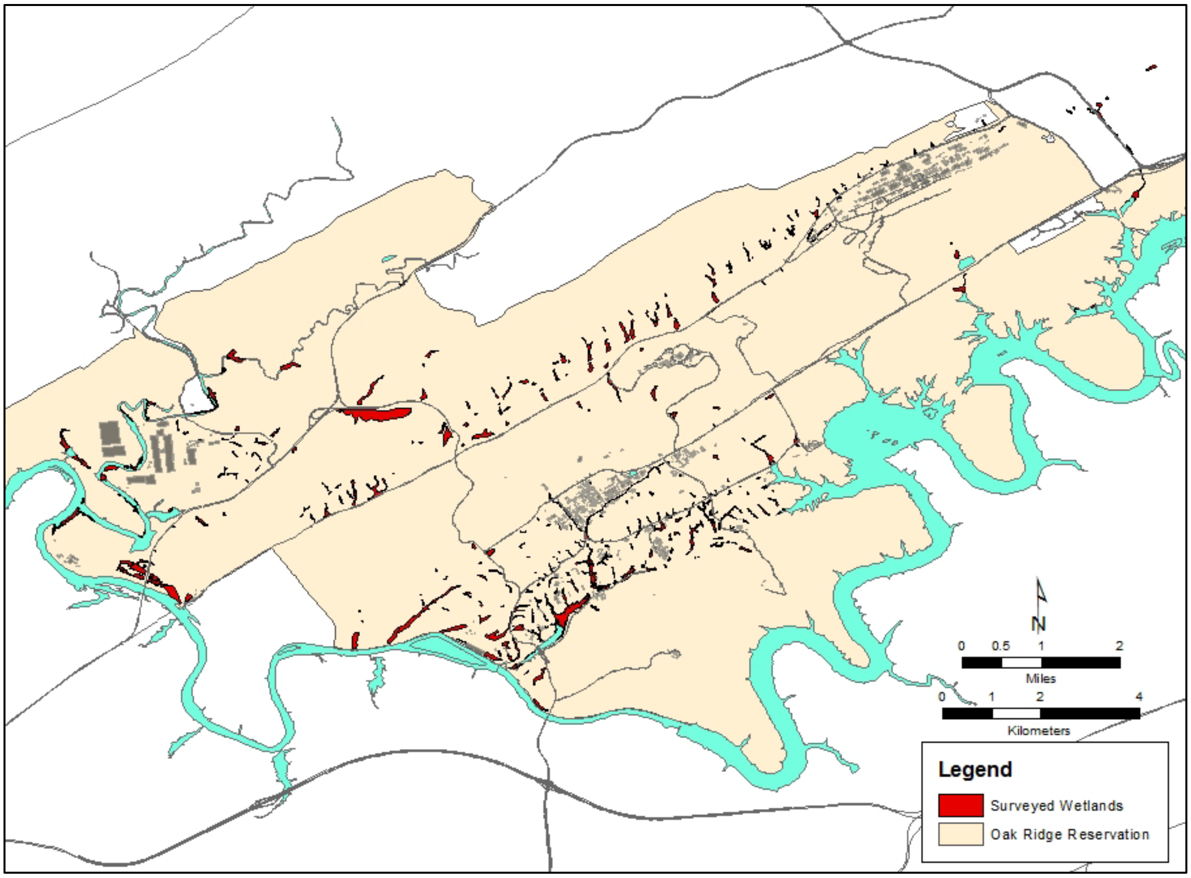


Figure 1.3. Location of Oak Ridge Reservation wetlands

About 243 ha (600 acres) of wetlands have been identified on ORR; most are classified as forested palustrine, scrub/shrub, and emergent wetlands. Wetlands identified to date range from several square meters at small seeps and springs to about 10 ha (25 acres) at White Oak Lake. In 2017, wetlands were delineated in the Copper Ridge Borrow Area and 294 Power Line Area. The Tennessee Department of Environment and Conservation's (TDEC's) wetland mitigation aquatic resource alteration permits (ARAPs), required by Section 401 of the Clean Water Act, entail monitoring restored or created wetland mitigation sites for five years. Activities and conditions in and around ORNL wetlands are verified by site inspections when appropriate (see Chapter 5, Section 5.8.11).

Wetland mitigation efforts that began in 2013 and 2014 as part of the Uranium Processing Facility project at the Y-12 Complex were completed in 2017. Details of this activity are provided in Chapter 4, Section 4.5.8.4. The work was performed under an approved US Army Corps of Engineers Section 404 permit and an ARAP issued by TDEC. Monitoring in accordance with these permits began following the completion of mitigation activities. The wetland mitigation carried out under these permits resulted in a more than 3:1 net increase in total wetland area. Annual monitoring of the remediated wetland sites through 2018 revealed that, in general, the wetlands are responding as intended and have shown remarkable wetland plant coverage over the past few years. The wetland soil bank was undoubtedly key to the restoration effort. Some wetlands have extensive open water areas, and deeper-water species of plants were added at these sites in 2018. Additional actions to lower the water level are to be considered in 2019.

1.3.6.2 Wildlife and Endangered Species

Animals listed as species of concern by state, federal, or international organizations and known to have occurred on the reservation (excluding the Clinch River bordering the reservation) are listed, along with their status, in Table 1.1. Some of these, such as hellbender, have been seen only once or a few times; others, including wood thrush, are comparatively common and widespread on ORR. As of July 2016, Tennessee had 93 species listed under the federal Endangered Species Act (75 endangered and 18 threatened). The complete Tennessee Threatened and Endangered List−New Rules is found **here**.

Table 1.1. Animal species of special concern reported on the Oak Ridge Reservation[a]

Scientific name	Common name	Status[b]		
		Federal	State	PIF[c]
	FISH			
Phoxinus tennesseensis	Tennessee dace		NM	
	AMPHIBIANS AND REPTILES			
Crytobranchus alleganiensis	Hellbender		T	
Hemidactylium scutatum	Four-toed salamander		NM	
	BIRDS			
	Bitterns and Herons			
Ixobrychus exilis	Least bittern		NM	
Egretta caerulea	Little blue heron		NM	
Nycticorax nycticorax	Black-crowned night heron		NM	
Mycteria americana	Wood stork	T		
	Kites, Hawks, Eagles, and Allies			
Haliaeetus leucocephalus	Bald eagle	MC[d]		
	Grouse, Turkey, and Quail			
Bonasa umbellus	Ruffed grouse			RC
Colinus virginianus	Northern bobwhite			RC
	Goatsuckers			
Caprimulgus carolinensis	Chuck-will's-widow			RC
Caprimulgus vociferus	Eastern whip-poor-will			RC
	Swifts			
Chaetura pelagica	Chimney swift			RC
	Kingfishers			
Megaceryle alcyon	Belted kingfisher			RC
	Woodpeckers			
Melanerpes erythrocephalus	Red-headed woodpecker			RC
Colaptes auratus	Northern flicker			RC
	Tyrant Flycatchers			
Contopus virens	Eastern wood-pewee			RC
Empidonax virescens	Acadian flycatcher			RC
	Swallows			
Progne subis	Purple martin			RC
Hirundo rustica	Barn swallow			RC

Table 1.1. Animal species of special concern reported on the Oak Ridge Reservation[a] (continued)

Scientific name	Common name	Status[b]		
		Federal	State	PIF[c]
	Kinglets, Gnatcatchers, and Thrushes			
Hylocichla mustelina	Wood thrush		NM	RC
	Shrikes			
Lanius ludovicianus	Loggerhead shrike		NM	
	Wood Warblers			
Vermivora chrysoptera	Golden-winged warbler		T	RC
Setophaga cerulea	Cerulean warbler		NM	RC
Setophaga discolor	Prairie warbler			RC
Mniotilta varia	Black-and-white warbler			RC
Protonotaria citrea	Prothonotary warbler			RC
Geothlypis formosa	Kentucky warbler			RC
Cardellina canadensis	Canada warbler			RC
Icteria virens	Yellow-breasted chat			RC
	Tanagers			
Piranga rubra	Summer tanager			RC
	Towhees, Sparrows, and Allies			
Pipilo erythrophthalmus	Eastern towhee			RC
Spizella pusilla	Field sparrow			RC
Ammodramus savannarum	Grasshopper sparrow			RC
Ammodramus henslowii	Henslow's sparrow		T	RC
Melospiza Georgiana	Swamp sparrow			RC
	Finches and Allies			
Spinus tristis	American goldfinch			RC
	MAMMALS			
Myotis grisescens	Gray bat	E	E	
Myotis lucifugus	Little brown bat		T	
Myotis sodalist	Indiana bat[e]	E	E	
Myotis septentrionalis	Northern long-eared bat	T		
Myotis leibii	Eastern small-footed bat		NM	
Perimyotis subflavus	Tri-colored bat		T	
Corynorhinus rafinesquii	Rafinesque's Big-eared bat		NM	
Sorex dispar	Long-tailed shrew		NM	

[a] Land and surface waters of the Oak Ridge Reservation (ORR) exclusive of the Clinch River, which borders ORR.
[b] Status codes:
E = endangered
T = threatened
MC = of management concern
NM = in need of management
RC = regional concern
[c] Partners in Flight (PIF) is an international organization devoted to conserving bird populations in the Western Hemisphere.
[d] The bald eagle was federally delisted effective August 9, 2007.
[e] A single specimen was captured in a mist net bordering the Clinch River in June 2013.

Birds, fish, and aquatic invertebrates are the most thoroughly surveyed animal groups on ORR. Nevertheless, the only federally listed animal species observed on ORR in recent years are mammals. Gray bats were seen over the Clinch River bordering ORR in 2003 and over a pond on ORR in 2004. Three gray bats were mist-netted outside a cave on ORR in 2006. Several gray bats and one Indiana bat were caught in mist nets bordering the Clinch River in June and July 2013. Northern long-eared bats, recently federally listed as threatened, are known to be present on ORR; their calls have been identified in various acoustic surveys of the reservation, and in 2013 their presence was confirmed when a number were captured in mist nets (McCracken et al. 2015).

Two-hundred thirty-two species of birds have been recorded on ORR and its boundary waters: the 228 species documented by Roy et al. (2014) plus the cackling goose (*Branta hutchinsii*), purple gallinule (*Porphyrio martinicus*), American bittern (*Botaurus lentiginosus*) and federally threatened wood stork (*Mycteria Americana*). Most of these species are protected under the Migratory Bird Treaty Act and Executive Order 13186, Responsibilities of Federal Agencies to Protect Migratory Birds. DOE's updated memorandum of understanding on migratory birds with the US Fish and Wildlife Service (FWS) (DOE-FWS 2013) strengthens migratory bird conservation on ORR through enhanced collaboration between DOE and FWS.

Breeding bird surveys conducted at 79 points along nine routes on ORR in 2014 provided data for the Partners in Flight Program. Seven public nature walks on ORR during 2018, which involved a total of 129 participants, included wildlife habitat surveillance, winter tree identification, woodcock and falconry observation, a bird nature walk, frog calls monitoring, a reptiles and amphibians inventory, and a wildflower walk. In past years ORR has been nominated for the Presidential Migratory Bird Federal Stewardship Award. A technical manuscript, *Oak Ridge Reservation Bird Records and Population Trends* (Roy et al. 2014), documents all known ORR bird records since 1950, as well as population trends for 32 species of birds.

Several state-listed bird species such as the golden-winged warbler, cerulean warbler, and little blue heron are uncommon migrants or visitors to the reservation. The cerulean warbler, listed by the state as in need of management, often appears during the breeding season on ORR but is currently listed as a potential breeding bird on the reservation (Roy et al. 2014) as its actual breeding status is still uncertain. The bald eagle (shown in Figure 1.4), which was removed from the federal list of threatened and endangered species on August 9, 2007, is a year-round resident in Tennessee, though it can be difficult to find on the reservation from September through November. One bald eagle nest was confirmed on the reservation in 2018. This nest was first observed in 2011 and has remained active every year since.

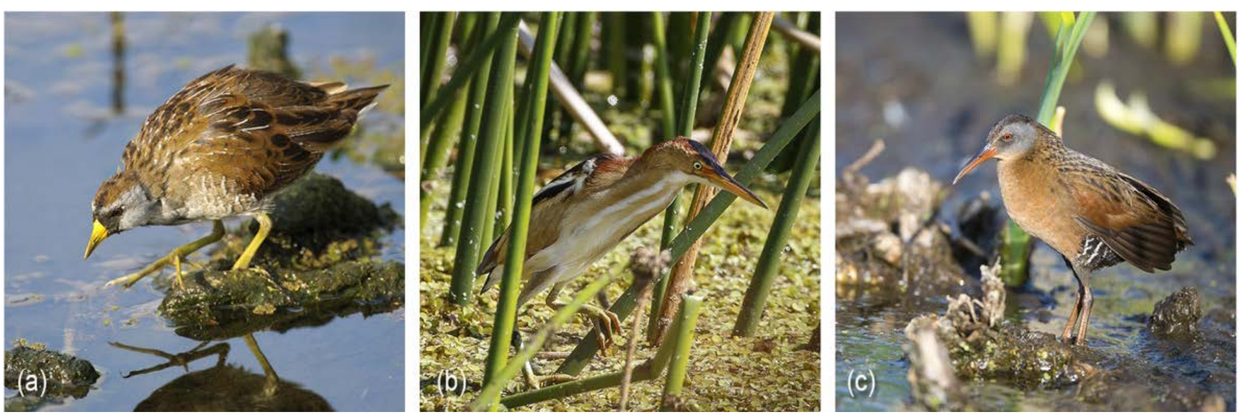
More than two dozen eaglets fledged in East Tennessee during 2017, according to bald eagle information published by the East Tennessee State University College of Arts and Sciences Biological Sciences department. More than 50 sightings in Roane and Anderson counties were reported to eBird during calendar year 2018.

Other species such as the wood thrush and barn swallow are migrants and are known to nest on the reservation. The golden-winged warbler (*Vermivora chrysoptera*), listed by the state as threatened, was sighted once (in May 1998) on the reservation, as was the Lincoln's sparrow (*Melospiza lincolnii*) (no listed status) in May 2014. Barn owls were documented nesting on the reservation in 2018.

Source: Jason Richards, ORNL photographer

Figure 1.4. Bald eagle nest on the Oak Ridge Reservation

With many northern lakes freezing solid during the winter of 2013–2014, white-winged scoters (*Melanitta fusca*) and red-necked grebes (*Podiceps grisegena*) made rare appearances in East Tennessee in February and March of 2014, though they were recorded locally only on boundary waters of the reservation. Other uncommon birds for ORR recorded in recent years include several species associated with wetland habitats. The sora, least bittern, and Virginia rail, shown in Figure 1.5, were observed at the K1007 P1 pond at ETTP in 2013 and were likely attracted to high quality wildlife habitat established through recent restoration efforts. The sora, seen as recently as December 2016, is a fairly common migrant throughout Tennessee but is seldom seen on ORR. The least bittern is an uncommon migrant and summer resident in Tennessee. The Virginia rail, most recently observed in October 2013, was previously known on ORR only through historic records from the early 1950s (Roy et al. 2014). FWS lists all three of these species as of management concern. The least bittern is also deemed in need of management by the State of Tennessee, as shown in Table 1.1.



Source: Stock images courtesy of iStock.

Figure 1.5. Interesting bird species sighted on the Oak Ridge Reservation in recent years: (a) sora, (b) least bittern, and (c) Virginia rail

One fish species, the spotfin chub (*Erimonax monachus*), which is listed as threatened by both the state and the federal government, has been sighted and collected in the city of Oak Ridge and may be present on ORR. The tangerine darter (*Percina aurantiaca*), a species listed by the state as in need of management, has also been recorded in close proximity to ORR. The lake sturgeon (*Acipenser fulvescens*), state-listed as endangered, is known to inhabit the adjacent Clinch River. The Tennessee dace, listed by the state as in need of management, appears in the Bear Creek watershed, tributaries to the lower East Fork watershed, and Ish Creek. The Tennessee dace also occurs in some sections of Grassy Creek upstream of Scientific Ecology Group, Inc. and International Technology Corporation at Clinch River kilometer 23, south of west Bear Creek Road near Grassy Creek sampling point 1.9.

1.3.6.3 Threatened and Endangered Plants

Four plant species known to be on ORR (spreading false foxglove, Appalachian bugbane, tall larkspur, and butternut) have been under review for listing at the federal level and were previously listed under the C2 candidate designation. FWS now informally refers to these as special concern species.

The State of Tennessee lists 17 plant species occurring on ORR as endangered, threatened, or of special concern; these are included in Table 1.2. Appalachian bugbane is no longer listed by Tennessee and does not have official federal status; therefore, it does not appear in Table 1.2. An additional 10 threatened, endangered, or special concern species occur in the area and, although currently unconfirmed on ORR, may be present. These are also included in Table 1.2. Other plant populations currently under study on ORR may be added to the table in future years.

The latest Tennessee Rare Plant List was published in October 2016. The 2012 Tennessee Rare Plant List reduced the number of state-protected species on ORR by six, and the 2016 Tennessee Rare Plant List reduced this number by an additional two species: the Tennessee coneflower (*Echinacea tennesseensis*) and Egget's sunflower (*Helianthus eggertii*).

Table 1.2. Vascular plant species listed by state or federal agencies and sighted/reported on or near the Oak Ridge Reservation, 2017

Species	Common name	Habitat on ORR	Status code[a]
	Currently known to be or previously reported on ORR		
Aureolaria patula	Spreading false foxglove	River bluff	FSC, S
Berberis canadensis	American barberry	Rocky bluff	S
Bolboschoenus fluviatilis	River bulrush	Wetland	S
Delphinium exaltatum	Tall larkspur	Barrens and woodlands	FSC, E
Diervilla lonicera	Northern bush-honeysuckle	Rocky river bluff	T
Draba ramosissima	Branching whitlow-grass	Limestone cliff	S
Elodea nuttallii	Nuttall waterweed	Pond, embayment	S
Eupatorium godfreyanum	Godfrey's thoroughwort	Dry woods edge	S
Fothergilla major	Mountain witch-alder	Woods	T
Helianthus occidentalis	Naked-stem sunflower	Barrens	S
Juglans cinerea	Butternut	Lake shore	FSC, T
Juncus brachycephalus	Small-head rush	Open wetland	S
Liparis loeselii	Fen orchid	Forested wetland	T
Panax quinquifolius	American ginseng	Rich woods	S, CE
Platanthera flava var. herbiola	Tuberculed rein-orchid	Forested wetland	T
Spiranthes lucida	Shining ladies'-tresses	Boggy wetland	T
Thuja occidentalis	Northern white cedar	Rocky river bluffs	S

Table 1.2. Vascular plant speciies listed by state or federal agencies and sighted/reported on or near the Oak Ridge Reservation, 2018 (continued)

Species	Common name	Habitat on ORR	Status code[a]
Rare plants that occur near and could be present on ORR			
Agalinis auriculata	Earleaf false foxglove	Calcareous barren	FSC, E
Allium burdickii or A. tricoccom[b]	Ramps	Moist woods	S, CE
Lathyrus palustris	Marsh pea	Moist meadows	S
Liatris cylindracea	Slender blazing star	Calcareous barren	T
Lonicera dioica	Mountain honeysuckle	Rocky river bluff	S
Meehania cordata	Heartleaf meehania	Moist calcareous woods	T
Pedicularis lanceolata	Swamp lousewort	Calcareous wet meadow	S
Pseudognaphalium helleri	Heller's catfoot	Dry woodland edge	S
Pycnanthemum torrei	Torrey's mountain-mint	Calcareous barren edge	S
Solidago ptarmicoides	Prairie goldenrod	Calcareous barren	E

[a] Status codes:
CE = Status due to commercial exploitation
E = Endangered in Tennessee
FSC = Federal Special Concern; formerly designated as C2. See Federal Register, February 28, 1996.
S = Special concern in Tennessee
T = Threatened in Tennessee

[b] Ramps have been reported near ORR, but there is not sufficient information to determine which of the two species is present or whether the occurrence may have been the result of planting. Both species of ramps have the same state status.

Acronyms: ORR = Oak Ridge Reservation

1.3.6.4 Historical and Cultural Resources

Efforts continue to preserve ORR's rich prehistoric and historic cultural resources. Compliance with the National Historic Preservation Act is maintained in conjunction with National Environmental Policy Act (NEPA) compliance. The scope of proposed actions is reviewed in accordance with the *Cultural Resource Management Plan, DOE Oak Ridge Reservation, Anderson and Roane Counties, Tennessee* (DOE 2001). ORR has 168 facilities that were eligible for inclusion on the National Register of Historic Places (NRHP), a National Park Service program to identify, evaluate, and protect historic and archeological resources in the US, as well as numerous facilities that were not eligible for NHRP inclusion. Artifacts of historical or cultural significance are identified prior to demolition and catalogued in a database to aid in the historic interpretation. The reservation contains more than 45 known prehistoric sites (primarily burial mounds and archeological evidence of former structures), more than 250 historic pre-World War II structures, 32 cemeteries, and several historically significant structures from the Manhattan Project era.

The National Defense Authorization Act of 2015, passed by Congress and signed into law on December 19, 2014, included provisions authorizing the Manhattan Project National Historical Park. An agreement by the Secretaries of Energy and Interior established the Manhattan Project National Historical Park on November 10, 2015. The Park includes facilities and lands in Los Alamos, New Mexico and Hanford, Washington, as well as Oak Ridge. On ORR, the National Park includes the X-10 Graphite Reactor, Buildings 9731 and 9204-3 at the Y-12 Complex, and the K-25 Building Site at ETTP.

The X-10 Graphite Reactor building has been on the NRHP since 1966, and has been open for public access in various ways since that time. Enhancing access and improving the visitor experience are important DOE objectives as it moves forward in implementing the National Park.

Although Buildings 9731 and 9204-3 at the Y-12 National Security Complex are eligible for listing on the NRHP, at present neither is available for regular public access. Occasional public access to both facilities occurred as recently as Nov. 12, 2015, when DOE facilitated public tours of both buildings to celebrate the establishment of the National Park. By developing the National Park, DOE aims to enhance safe access to these buildings while protecting the agency's mission capabilities.

DOE will fulfill the objective of enabling safe access to the former site of the K-25 Building. The National Park Service will aid in historic interpretation of the site, although the K-25 Building site is already undergoing extensive historic interpretation activities separate and independent from the National Park. DOE launched the K-25 Virtual Museum as part of the activities to establish the Park. The online exhibit, which details the history of the K-25 Gaseous Diffusion Plant through narrative and photographs, can be viewed **here**.

Seven historic ORR properties are listed individually in the NRHP:

- Freels Bend Cabin
- Graphite Reactor
- New Bethel Baptist Church and Cemetery
- Oak Ridge Turnpike Checking Station
- George Jones Memorial Baptist Church and Cemetery
- Bear Creek (Scarboro) Road Checking Station
- Bethel Valley Road Checking Station

Although not yet included on the NRHP, an area known as the Wheat Community African Burial Grounds was dedicated in June 2000, and a memorial monument was erected.

A memorandum of agreement signed in 2012 between DOE Oak Ridge Office, the State Historic Preservation Officer, the Advisory Council on Historic Preservation, the City of Oak Ridge, and the East Tennessee Preservation Alliance ensures consistent interpretation of site historic properties at ETTP. The memorandum of agreement is being implemented through planning for a History Center that will highlight the historic aspects of ETTP and of the communities that were displaced during the construction of the site.

Two site-wide programmatic agreements among the DOE Oak Ridge Office, the State Historic Preservation Officer, and the Advisory Council on Historic Preservation concerning management of historical and cultural properties at ORNL and at Y-12 have been enforced since their respective approvals.

1.4 Oak Ridge Sites

The Oak Ridge Reservation includes a number of sites critical to the mission of DOE. Eight of these sites are described in the following pages: the Oak Ridge National Laboratory, the Y-12 National Security Complex, the East Tennessee Technology Park, the Environmental Management Waste Management Facility, the Oak Ridge Environmental Research Park, the Oak Ridge Institute for Science and Education, the National Nuclear Security Administration Office of Secure Transportation Agent Operations Eastern Command, and the Transuranic Waste Processing Center Sludge Buildout Facility.

1.4.1 Oak Ridge National Laboratory

ORNL (shown in Figure 1.6) is managed for DOE by UT-Battelle, LLC, a partnership between the University of Tennessee and Battelle Memorial Institute. The largest science and energy national laboratory in the DOE system, ORNL conducts basic and applied research to deliver transformative solutions to compelling problems in energy and security. The laboratory is home to several of the world's top supercomputers and is a leading neutron science and nuclear energy research facility that includes the Spallation Neutron Source and the High Flux Isotope Reactor. ORNL hosts a DOE leadership computing facility, home of the Summit supercomputer; one of DOE's nanoscience centers, the Center for Nanophase Materials Sciences; one of DOE's energy research centers; and the Bio-Energy Science Center. UT-Battelle, LLC also manages the US International Thermonuclear Experimental Reactor project for DOE.

Formerly known as X-10, ORNL was established in 1943 to support the Manhattan Project. From an early focus on chemical technology and reactor development, ORNL's research and development portfolio broadened to include programs supporting DOE missions in scientific discovery and innovation, clean energy, and nuclear security. Today ORNL employs about 4,400 workers, and the laboratory's extensive capabilities in scientific discovery and innovation are applied to the delivery of mission outcomes for DOE and other sponsors.

Figure 1.6. Aerial view of the Oak Ridge National Laboratory

During fiscal year (FY) 2018, DOE remained focused on disposing of a significant inventory of uranium-233 stored in Building 3019 at ORNL. This special nuclear material requires strict safeguards and security controls to protect against access. The objectives of the Uranium-233 Project are to address safeguards and security requirements, eliminate safety and nuclear criticality concerns, and safely dispose of the material. DOE has successfully resolved the concerns associated with the disposition of the Consolidated Edison Uranium Solidification Project material, which originated from a 1960s research and development test of thorium and uranium fuel at Consolidated Edison's Indian Point 1 Nuclear Plant in New York. Isotek Systems, LLC manages activities at the Building 3019 complex for DOE and is responsible for activities associated with processing, down-blending, and packaging the DOE inventory of uranium-233 stored in the complex.

UCOR is the DOE ORR cleanup contractor. The scope of UCOR activities at ORNL includes long-term surveillance, maintenance, and management of inactive waste disposal sites, structures, and buildings such as former reactors and isotope production facilities. Other UCOR activities include groundwater monitoring, transuranic waste storage, and operation of the liquid low-level and process waste systems and the off-gas collection and treatment system.

Seventy-four waste items added to the Molten Salt Reactor Experiment Facility waste handling plan in 2014 were characterized and disposed of during 2018. Workers completed the pumpdown of the Reactive Gas Removal System fuel drain and fuel flush tanks.

The ORNL Liquid and Gaseous Waste Operations lifecycle was extended during FY 2018 through building and infrastructure upgrades.

1.4.2 Y-12 National Security Complex

The Y-12 Complex (shown in Figure 1.7) was originally constructed as part of the World War II Manhattan Project and began operations in November 1943. The first site mission was the separation of uranium-235 from natural uranium by an electromagnetic separation process. At its peak in 1945, more than 22,000 workers were employed at the Y-12 site.

Today, as part of the NNSA Nuclear Security Enterprise, the Y-12 Complex is the nation's only source of enriched uranium nuclear weapons components and provides enriched uranium for the US Navy. The Y-12 Complex is a leader in materials science and precision manufacturing and serves as the main storage facility for the nation's supply of enriched uranium. The Y-12 Complex also supports efforts to reduce the risk of nuclear proliferation and performs complementary work for other government agencies.

In December 2017, UCOR (the cleanup contractor for ORR) issued the *Construction Execution/ Management Plan, Outfall 200 Mercury Treatment Facility at the Y-12 Nuclear Security Complex, Oak Ridge, Tennessee* (UCOR 2017). The goal of the Mercury Treatment Facility is to reduce the mercury concentration in water exiting the Y-12 Complex. The west end Y-12 storm drain system discharges to Upper East Fork Poplar Creek at Outfall 200. Mercury from historic operations is present at Outfall 200 where storm water enters Poplar Creek.

Three lines of investigation were developed for East Fork Poplar Creek: to examine potential downstream sources such as bank soil and sediment control, to study the ecology and investigate how differences in food chain processes may influence the uptake of mercury in fish, and to investigate the water chemistry and flow characteristics of the creek and their influence. In support of mercury cleanup efforts, research and technology development activities focused on the major factors influencing the accumulation of mercury in fish, which are the major route of both human and wildlife exposure.

The Mercury Treatment Facility is designed to treat up to 3,000 gallons of storm water per minute. It includes a 2-million-gallon storage tank to collect storm water during peak flow conditions of up to 40,000 gallons per minute. The stored water can then be treated after storm flow subsides. Captured storm water will be piped to a treatment facility located on an available site east of Outfall 200. Mercury treatment will be accomplished using chemical precipitation, clarification, and media filtration. Treated water will be discharged back into Upper East Fork Poplar Creek. The *Mercury Remediation Technology Development for Lower East Fork Poplar Creek−2017 Progress Report* (ORNL 2018) provided details of each study area and findings. DOE's Oak Ridge Office of Environmental Management (OREM) began site preparation on the Mercury Treatment Facility in 2018. Construction of the facility is expected to begin in 2019.

Figure 1.7. Aerial view of the Y-12 National Security Complex

At the end of FY 2018, the Y-12 Complex had achieved five of its 10 established environmental targets, and the remaining targets were carried into future years. Highlights include the following; further details and additional successes are presented in other sections of this report.

- **Clean Air:** The Y-12 Complex finalized implementation of a new Title V air operating permit.
- **Energy Efficiency:** Implementation of five Energy Savings Performance Contract energy conservation measures began in FY 2014 for projects to improve lighting, chilled water, air compressors, and the Y-12 Complex steam system. Significant progress was made on the effort to obtain Leadership in Energy and Environmental Design (LEED) certification on the Uranium Processing Facility Construction Support Building. A Silver Certification was awarded, with the additional credit points required for obtaining a Gold Certification pending occupancy.
- **Hazardous Materials:** A project to disposition and ship more than 60 items of legacy mixed waste per Site Treatment Plan milestones was completed in 2018, and FY 2018 priorities for unneeded materials and chemicals were completed to disposition them in the Development High Head Area.

- **Reduce, Reuse, Recycle, and Buy Green:** The Y-12 Complex completed a project to improve the Destruction and Recycling Facility and to install a drum crusher in one facility to reduce the quantity of empty drum waste.
- **Mercury Removal:** More than 3 tons of mercury were removed from column exchange equipment at Alpha-4. Approximately 9,477 feet of piping, 22 tanks, and four heat exchangers were tapped, drained, and deactivated during 2018. Twenty-one of the 22 tanks were demolished and removed from the site.

In FY 2018, the Y-12 Complex implemented 96 pollution prevention initiatives resulting in a reduction of more than 62.7 million lb of waste and cost efficiencies of more than $5 million. Also in 2018, the Y-12 Complex diverted 51.6 percent of municipal and 91.5 percent of construction and demolition waste from landfill disposal through reuse and recycle. The Y-12 Complex diverted more than 2.3 million lb of municipal materials from landfill disposal through source reduction, reuse, and recycling in FY 2018. In addition, more than 60.1 million lbs of construction and demolition materials were diverted from landfill disposal in FY 2018. Also in FY 2018, more than 3,200 lbs of waste generation prevention was realized by transferring materials for on-site reuse, and more than 2.78 million lbs of materials were diverted from landfills into viable recycle processes.

The Y-12 Complex achieved a 9 percent reduction in energy intensity during 2018. Specific initiatives that helped reduce energy consumption at the Y-12 Complex include:

- Completing a new, more-efficient Air Compressor Plant at the end of FY 2016
- Continuing to upgrade light fixtures
- Replacing steam with natural gas
- Upgrading chillers with new high-efficiency variable speed modes; retrofitting existing chillers with efficient controls; replacing constant-speed chilled water pumps with a variable-speed type; and replacing tower pumps, steam controls, and control valves
- Replacing Cooling Towers

Sustainability goals and performance status for the Y-12 Complex are listed in Chapter 4, Table 4.1.

Buildings 9743-2 and 9770-2 of the Biology Complex were demolished in 2018.

1.4.3 East Tennessee Technology Park

ETTP (see Figure 1.8), originally named K-25, is the site of the nation’s first gaseous diffusion uranium enrichment plant. It was established as part of the World War II Manhattan Project. Additional uranium enrichment facilities K-29, K-31, and K-33 were built adjacent to K-25 during the Cold War, and these facilities formed a complex officially known as the Oak Ridge Gaseous Diffusion Plant. Uranium enrichment operations at the site ceased in 1986, and restoration and decontamination and decommissioning activities began soon after in preparation for ultimate conversion of the site to a private-sector industrial park, to be called the Heritage Center. Reindustrialization of the site began in 1996, when it was renamed the East Tennessee Technology Park. Today restoration of the environment, decontamination and decommissioning of facilities, disposition of wastes, and reindustrialization are the major activities at the site.

In 2018, ETTP landlord contractor functions and the majority of the ETTP cleanup program actions were managed by UCOR. During that year ETTP had no National Pollutant Discharge Elimination System permit noncompliances, no Clean Air Act noncompliances, and no reportable releases of hazardous substances or extremely hazardous substances, as defined by the Emergency Planning and Community Right-to-Know Act of 1986. The annualized levels of chromium and lead during 2018 were below the indicated annual standards. Demolition of the K-633 Test Loop Facility began in February and concluded in June 2018. Decontamination and demolition of the K-1314 UF_6 cylinder sandblast and repaint facility was completed in April 2018. Demolition of the Toxic Substances Control Act (TSCA) Incinerator began in June 2018 and concluded in September 2018. Samples collected during rainfall events at these demolition sites did not exhibit any screening level exceedances. Final sampling conducted on December 31, 2018 resulted in no exceedances.

Figure 1.8. Aerial view of East Tennessee Technology Park

In 2017, a proposed plan to build an airport on the ETTP site reached a major milestone with the completion of a master plan, which was submitted to the Federal Aviation Administration for approval. Metropolitan Knoxville Airport Authority is leading the project. During 2018, officials have continued to work on locating the proposed airport near the former K-25 site at ETTP, and the master plan was reviewed by the Federal Aviation Administration. The corporate planes most likely to use the airport include the Beechcraft King Air 350, Cessna 500, and Cirrus SF-50 Vision Jet.

1.4.4 Environmental Management Waste Management Facility

The Environmental Waste Management Facility, or EMWMF (shown in Figure 1.9), is located in eastern Bear Creek Valley near the Y-12 Complex and is managed by UCOR. EMWMF was built for the disposal of waste resulting from CERCLA cleanup actions on ORR. The original design was for the construction, operation, and closure of a projected 1.3 million m^3 (1.7 million yd^3) disposal facility. The approved capacity was subsequently increased to 1.8 million m^3 (2.4 million yd^3) to maximize use of the footprint designated in a 1999 record of decision. The facility currently consists of six disposal cells.

Figure 1.9. Aerial view of the Environmental Management Waste Management Facility

EMWMF is an engineered landfill that accepts low-level, mixed low-level, and hazardous wastes from CERCLA cleanup activities on ORR that meet specific waste acceptance criteria developed in accordance with agreements with state and federal regulators. Waste types that qualify for disposal include soil, dried sludge and sediment, solidified waste, stabilized waste, building debris, scrap equipment, and secondary waste such as personal protective equipment, all of which must meet land disposal restrictions. In addition to the solid waste disposal facility, EMWMF operates a leachate collection system. In FY 2018 the facility collected, analyzed, and disposed of approximately 3.9 million gallons of leachate. The leachate is treated at the ORNL Liquids and Gaseous Treatment Facility, which is also operated by UCOR. The Oak Ridge Reservation landfills disposed of 39,990 yd^3 of waste during 2018.

During FY 2018 the EMWMF received 6,305 waste shipments, accounting for 73,510 tons, from cleanup projects at ETTP, ORNL, and Y-12. EMWMF will reach its capacity before OREM completes its cleanup at Y-12 and ORNL. Planning continued throughout FY 2018 for a new facility, the Environmental Management Disposal Facility, which will provide the additional disposal capacity needed to complete the cleanup at Oak Ridge. The public comment period for this new facility closed on December 10, 2018.

1.4.5 Oak Ridge Environmental Research Park

DOE established the Oak Ridge Environmental Research Park (see Figure 1.10) in 1980. Managed for DOE by UT-Battelle, LLC, the research park serves as an outdoor laboratory to evaluate the environmental consequences of energy use and development and the strategies to mitigate those effects. Its large blocks of forest and diverse communities of vegetation offer unparalleled resources for ecosystem-level and large-scale research. Major national and international collaborative research initiatives use it to address issues such as multiple stress interactions, biodiversity, sustainable development, tropospheric air quality, global climate change, innovative power conductors, solar radiation monitoring, ecological recovery, and monitoring and remediation.

Field sites at the research park provide maintenance and support facilities that permit sophisticated and well-instrumented environmental experiments. These facilities include elaborate monitoring systems that enable users to precisely and accurately measure environmental factors for extended periods. Because the park is under the jurisdiction of the federal government, public access is restricted and experimental sites and associated equipment are therefore not disturbed.

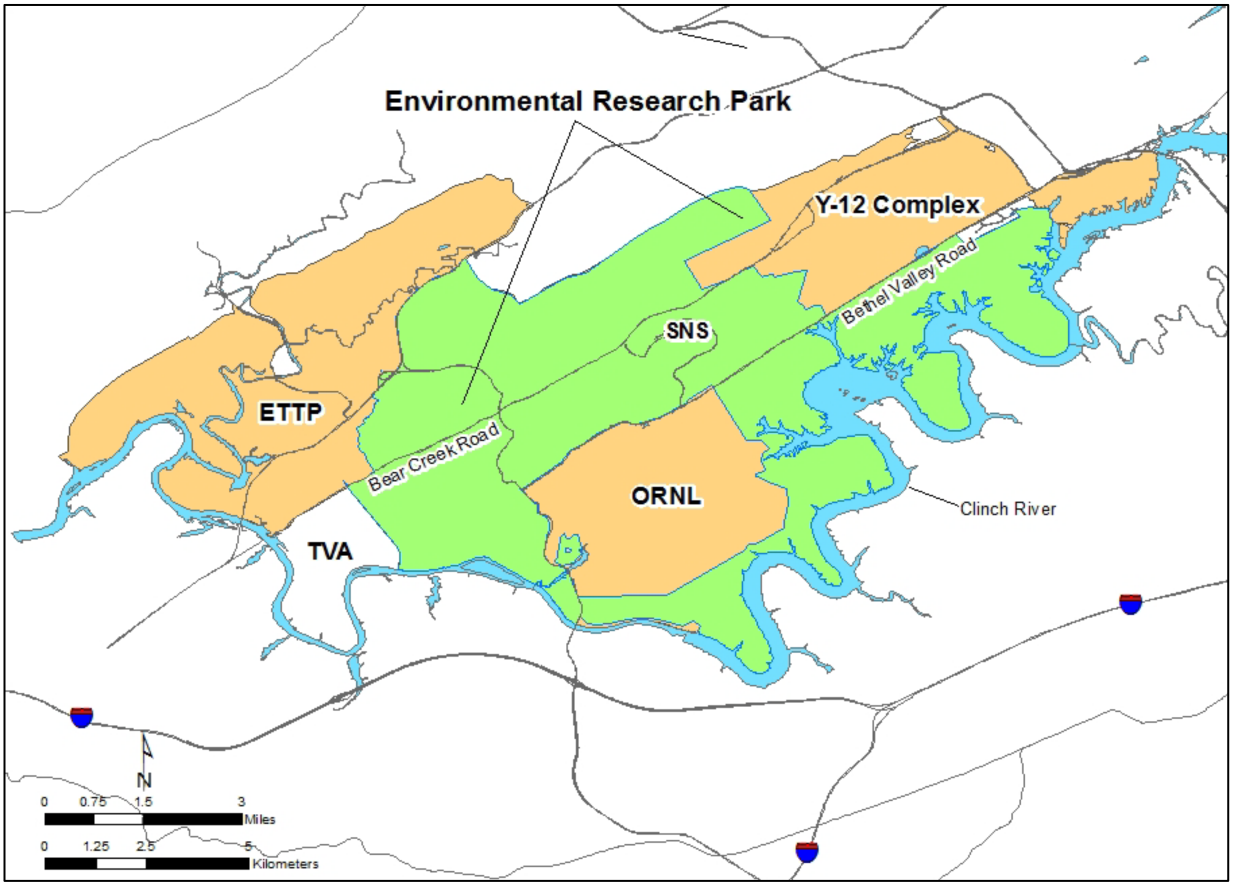


Figure 1.10. Location of the Oak Ridge Environmental Research Park

National recognition of the research park's value has led to its use in both regional- and continental-scale research projects. Research park sites offer opportunities for aquatic and terrestrial ecosystem analyses of topics such as biogeochemical cycling of pollutants resulting from energy production, landscape alterations, ecosystem restoration, wetland mitigation, and forest and wildlife management.

1.4.6 Oak Ridge Institute for Science and Education

ORISE is managed for DOE by Oak Ridge Associated Universities. The ORISE mission is to develop people and solutions to strengthen our nation's competitive advantage in science. ORISE accomplishes its mission by recruiting and preparing the next generation of our nation's scientific workforce; promoting sound scientific and technical investment decisions through independent peer reviews; facilitating and preparing for the medical management of radiation incidents in the US and abroad; evaluating health outcomes in workers exposed to chemical and radiological hazards on the job; and ensuring public confidence in environmental cleanup through independent environmental assessments. ORISE creates opportunities for collaboration through partnerships with other DOE facilities, federal agencies, academia, and industry consistent with DOE objectives and the ORISE mission.

ORISE is in an area on the southeastern border of ORR that was part of an agricultural experiment station owned by the federal government from the late 1940s to the mid-1980s and, until 1981, was operated by the University of Tennessee. The site houses offices, laboratories, and storage areas for ORISE program offices and support departments.

1.4.7 National Nuclear Security Administration Office of Secure Transportation, Agent Operations Eastern Command

Beginning in 1947, DOE and its predecessor agencies moved nuclear weapons, weapons components, special nuclear materials, and other important national security assets by commercial and government modes of transportation. In the late 1960s, worldwide terrorism and acts of violence prompted a review of procedures for safeguarding these materials. As a result, a comprehensive new series of regulations and equipment was developed to enhance the safety and security of these materials in transit. Modified and redesigned transport equipment was created to incorporate features that more effectively enhance self-protection and deny unauthorized access to the materials. Also during this time, the use of commercial transportation systems was abandoned and a totally federal operation was implemented. The organization responsible for this mission within DOE NNSA is the Office of Secure Transportation (OST).

The NNSA OST AOEC Secure Transportation Center and Training Facility is located on ORR. Situated on about 723 ha (1,786 acres), it operates under a user permit agreement with DOE Oak Ridge Office. NNSA OST AOEC implements its assigned mission transportation operations, maintains applicable fleet and escort vehicles, and continues extensive training activities for its federal agents.

1.4.8 TWPC Sludge Buildout Facility

The Transuranic Waste Processing Center (TWPC) is located on an approximately 10.5-ha (26-acre) tract of land in the Melton Valley area of ORNL about 120 feet west of the existing Melton Valley Storage Tanks. North Wind Solutions, LLC manages the TWPC for DOE. TWPC's mission is to receive transuranic waste for processing, treatment, repackaging, and shipment to DOE's Waste Isolation Pilot Plant near Carlsbad, New Mexico.

Transuranic waste consists of materials and debris that are contaminated with elements that have a higher atomic mass and are listed after uranium on the periodic table. The majority of Oak Ridge's inventory of transuranic materials originated from previous research and isotope production missions at ORNL. Waste determined to be non-transuranic (e.g., low-level radioactive waste or mixed low-level waste) is shipped to the Nevada National Security Site or other approved facilities.

Key progress for the project during FY 2018 included the following actions:

- Received vendor proposals for the sludge mobilization system, the Slurry Mixing and Characterization Tank, and the Sludge Test Area Construction
- Awarded the contract for testing of the Mobilization Measurement Instrumentation
- Completed development of documents pertaining to the Integrated System Test Plan, Simulant Strategy, Slurry Mixing and Characterization Tank/Mobilization Measurement Instrumentation, Flowsheet and Material Balance, Project Management Plan, Risk Management Plan, and Code of Record
- Conducted quarterly Safety Design Integration Team meetings

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2. Compliance Summary and Community Involvement

DOE operations on ORR must conform to environmental standards established by federal and state statutes and regulations including Executive Orders, DOE orders, contract-based standards, and compliance and settlement agreements. The US Environmental Protection Agency (EPA) and the Tennessee Department of Environment and Conservation (TDEC) are the principal regulating agencies that issue permits, review compliance reports, participate in joint monitoring programs, inspect facilities and operations, and oversee compliance with applicable regulations.

Environmental concerns or problems identified during routine operations or during ongoing self-assessments of compliance status require reporting or discussions with the respective regulatory agencies. The following sections summarize the major environmental statutes and their 2018 status for DOE operations on ORR. Note that the DOE Reindustrialization Program has leased several facilities at ETTP and the Oak Ridge Science and Technology Park to private entities over the past several years. This report does not discuss the compliance status of these lessee operations.

Due to different permit reporting requirements and instrument capabilities, this report uses various units of measurement. The lists of units of measure and conversion factors on pages xxvii and xxviii are included to help readers convert numeric values presented herein as needed for specific calculations and comparisons.

2.1 Laws and Regulations

Table 2.1 is a summary of the principal environmental standards applicable to DOE activities on ORR, their 2018 status, and the sections in this report that provide more detailed information.

Table 2.1. Applicable environmental laws and regulations and 2018 status

Regulatory program description	2018 status	Report sections
The Clean Air Act and corollary State of Tennessee requirements regulate the release of air pollutants through permits and air quality limits. Emissions of airborne radionuclides are regulated by EPA via National Emission Standards for Hazardous Air Pollutants for radionuclides authorization. Greenhouse gas emissions inventory tracking and reporting are regulated by EPA and DOE internal oversight.	In 2018 all activities on ORR were conducted in accordance with Clean Air Act requirements.	3.3.5 4.3.3 5.3.3
The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) provides a regulatory framework for remediation of the release or threat of release of hazardous substances from past practices on ORR.	ORR was placed on the EPA National Priorities List in 1989. The ORR Federal Facility Agreement, initiated in 1992 between EPA, TDEC, and DOE, established the framework and schedule for developing, implementing, and monitoring remedial actions on ORR. The on-site CERCLA Environmental Management Waste Management Facility (EMWMF) is operated by UCOR for DOE. Located in Bear Creek Valley, EMWMF is used for disposal of waste resulting from CERCLA cleanup actions on ORR. EMWMF is an engineered landfill that accepts low-level radioactive, hazardous, asbestos, and polychlorinated biphenyl (PCB) wastes (and combinations of these wastes) in accordance with specific waste acceptance criteria under an agreement with state and federal regulators. No notices of violations were issued for CERCLA-related ORR actions during 2018.	3.3.11 4.3.7 5.3.8 3.3.2
The Clean Water Act seeks to protect and improve surface water quality by establishing surface water standards enabled by a system of permits. Wastewater discharges are regulated by National Pollutant Discharge Elimination System (NPDES) permits issued by TDEC.	Discharges to surface water at each of the three major ORR sites are governed by NPDES permits. All three major ORR sites achieved a compliance rate of 100% in 2018. There were no permit noncompliances in 2018. See Appendix D for more information.	3.3.6 4.3.4 5.3.4
The Energy Independence and Security Act (EISA) § 438 establishes requirements for federal agencies to reduce storm water runoff from development projects to protect water resources.	A variety of storm water management techniques, referred to as green infrastructure or low impact design practices, have been implemented on ORR to comply with EISA. The site sustainability plans and associated reporting provide data on sustainability projects and support EISA § 438 compliance.	4.2.6.3 5.2.1.5

Table 2.1. Applicable environmental laws and regulations and 2018 status (continued)

Regulatory program description	2018 status	Report sections
The Emergency Planning and Community Right-to-Know Act, also referred to as the Superfund Amendments and Reauthorization Act Title III, requires reporting emergency planning information, hazardous chemical inventories, and environmental releases of certain toxic chemicals to federal, state, and local authorities.	In 2018 DOE facilities on ORR were operated in accordance with emergency planning and reporting requirements. ETTP, Y-12, and ORNL had no reportable releases of hazardous substances or extremely hazardous substances, as defined by the Emergency Planning and Community Right-to-know Act, in 2018.	3.3.14 4.3.9 5.3.10
The National Environmental Protection Act (NEPA) requires consideration of how federal actions may impact the environment and an examination of alternatives to the actions. NEPA also requires that decisions include public input and involvement through scoping and review of NEPA documents.	During 2018, DOE planning and decision-making activities at ETTP, Y-12, and ORNL were conducted via site-level procedures that provide requirements for project reviews and NEPA compliance. Fifty environmental reviews were completed at Y-12 during 2018. One new environmental evaluation was completed at ETTP in 2018. At ORNL, 91 environmental evaluations were completed during 2018.	3.3.4 4.3.2 5.3.2
The National Historic Preservation Act provides protection for the nation's historic resources by establishing a comprehensive national historic preservation policy.	ORR has several facilities eligible for inclusion in the National Register of Historic Places. Proposed activities are reviewed to determine potential adverse effects on these properties, and methods to avoid or minimize harm are identified. During 2018, activities on ORR were conducted in compliance with National Historic Preservation Act requirements.	3.3.4 4.3.2 5.3.2
ORR Protection of Wetlands Programs are implemented to minimize the destruction, loss, or degradation of ORR wetlands and to preserve and enhance their beneficial value.	Surveys to determine the presence of wetlands are conducted as needed for projects or programs through NEPA and other reviews. Wetland protection on ORR is conducted in accordance with 10 *CFR* 1022 and Executive Order 11990, *Protection of Wetlands.*	1.3.6.1 4.5.8.4
	Annual monitoring of remediated wetland sites through 2018 revealed that the wetlands are responding as intended. Also in 2018, a reassessed wetland near Building 2519 was determined to have previously identified boundaries.	5.3.12
The Resource Conservation and Recovery Act (RCRA) governs the generation, storage, handling, and disposal of hazardous wastes. RCRA also regulates underground storage tanks containing petroleum and hazardous substances, universal waste, and recyclable used oil.	Y-12, ORNL, and ETTP are defined as large-quantity generators of hazardous waste because each generates more than 1,000 kg of hazardous waste per month. Each site is also regulated as a handler of universal waste. In addition, several permits have been issued for hazardous waste management units on ORR.	3.3.9 4.3.6 5.3.6

Table 2.1. Applicable environmental laws and regulations and 2018 status (continued)

Regulatory program description	2018 status	Report sections
The Safe Drinking Water Act establishes minimum drinking water standards and monitoring requirements.	The City of Oak Ridge supplies potable water to the facilities on ORR and is responsible for meeting all regulatory requirements for drinking water. Sampling results in 2018 for residual chlorine levels, bacterial constituents, and disinfectant by-products in ORR's water system were all within acceptable limits.	3.3.8 4.3.5 5.3.5
The Toxic Substances Control Act regulates the manufacture, use, and distribution of a number of toxic chemicals.	PCB waste generation, transportation, disposal, and storage at ORR are regulated under EPA identification numbers TN1890090003 and TN0890090004. ETTP operated five PCB waste storage areas at ETTP in 2018. These five PCB storage areas were in RCRA-permitted facilities that meet the PCB regulations for long-term storage when PCB waste is being stored for longer than 30 days, which may be necessary for PCB radioactive waste. In 2018, UT-Battelle, LLC operated nine PCB storage areas and one PCB waste storage area was operated at a UT-Battelle, LLC facility in the Y-12 Complex. The ORR PCB Federal Facilities Compliance Agreement between EPA and DOE continues to provide a mechanism to address legacy PCB-use issues across ORR. The agreement specifically addresses the unauthorized use of PCBs, storage and disposal of PCB waste, PCB spill cleanup and decontamination, PCBs mixed with radioactive materials, PCB research and development, and ORR records and reporting requirements. EPA is updated annually on the status of DOE actions regarding management and disposition of legacy PCBs covered by the ORR PCB Federal Facilities Compliance Agreement.	3.3.13 4.3.8 5.3.9
The Bald and Golden Eagle Protection Act (16 US Code 668-668d) protects bald and golden eagles by prohibiting, except under certain specified conditions, the taking or possession of and commerce in such birds. The act imposes criminal and civil penalties for any such actions.	Bald eagles are known to frequent ORR year-round. The one active bald eagle nest on ORR is protected in accordance with this act. Eaglets have been successfully fledged from a Poplar Creek nesting location in the past.	1.3.6.2
The Endangered Species Act prohibits activities that would jeopardize the continued existence of an endangered or threatened species or cause adverse modification to a critical habitat.	ORR is host to several plant and animal species categorized as endangered, threatened, or of special concern, and these species are protected in accordance with this act.	1.3.6.2
The Migratory Bird Treaty Act protects migratory birds by governing the taking, killing, possession, transportation, and importation of such birds, including their eggs, parts, and nests and any product, manufactured or not, from such items.	ORR hosts numerous migratory birds that are protected under this act.	1.3.6.2

Table 2.1. Applicable environmental laws and regulations and 2018 status (continued)

Regulatory program description	2018 status	Report sections
DOE Order 231.1B*, Environment, Safety, and Health Reporting,* ensures timely collection, reporting, analysis, and dissemination of information on environment, safety, and health issues.	The *2018 Oak Ridge Reservation Annual Site Environmental Report* summarizes ORR environmental activities during 2018 and characterizes environmental performance.	All chapters
DOE Order 435.1, Change 1, ***Radioactive Waste Management,*** is implemented to ensure that all DOE radioactive waste is managed in a manner that protects workers, public health and safety, and the environment.	Waste certification programs that are protective of workers, the public, and the environment have been implemented for all activities on ORR to ensure compliance with this DOE order.	3.8.1 4.2.3.4 5.8
DOE Order 436.1, *Department Sustainability,* provides requirements and responsibilities for managing sustainability within DOE to ensure the department carries out its missions in a sustainable manner that addresses national energy security and global environmental challenges and advances sustainable, efficient, and reliable energy for the future.	DOE contractors on ORR have developed site sustainability plans and have implemented environmental management systems that are incorporated with the contractors' integrated safety management systems to promote sound stewardship practices and ensure compliance with this DOE order.	3.2 4.2 5.2
DOE Order 458.1, ***Radiation Protection of the Public and the Environment,*** issued in June 2011, canceled DOE Order 5400.5 and was established to protect members of the public and the environment from undue risk from radiation. This order established standards and requirements for operations of DOE and DOE contractors.	In 2018, DOE Order 458.1 was the primary contractual obligation for radiation protection programs for UT-Battelle, LLC and Consolidated Nuclear Security LLC, and for all UCOR work scope areas where existing CERCLA decision documents do not specifically identify DOE Order 5400.5 requirements. A dose assessment, performed to ensure that the total dose to members of the public from all DOE ORR pathways did not exceed the 100 mrem annual limit established by this order, estimated the maximum 2018 dose to a hypothetically exposed member of the public from all ORR potential exposure pathways combined would be about 3 mrem. The 2018 maximum effective dose was about 3% of the limit given in DOE Order 458.1. Clearance of property from ORNL, ETTP, and the Y-12 Complex was conducted in accordance with approved procedures that comply with DOE Order 458.1. There were no unplanned radiological air emission releases from the three major ORR sites in 2018.	4.3.13 5.3.13 3.5.1.3 Chapter 7 5.4.3.2 4.3.11

Table 2.1. Applicable environmental laws and regulations and 2018 status (continued)

Regulatory program description	2018 status	Report sections
DOE Order 5400.5, *Radiation Protection,* was established to protect members of the public and the environment against undue risk from radiation. This order established standards and requirements for operations of DOE and DOE contractors.	DOE Order 5400.5 is the primary environmental surveillance radiological applicable, relevant, and appropriate requirement for most CERCLA activities across ORR. It will remain in force until the individual CERCLA decision documents are reissued or revised to incorporate DOE Order 458.1. A dose assessment, performed to ensure the total dose to members of the public from all ORR pathways did not exceed the 100 mrem annual limit established by this order, estimated the maximum 2018 dose to a hypothetical exposed member of the public from all ORR potential exposure pathways combined would be about 3 mrem.	Chapter 7
Executive Order (EO) 13186, *Responsibilities of Federal Agencies to Protect Migratory Birds,* identifies the responsibilities of federal agencies to promote the conservation of migratory bird populations.	A memorandum of understanding entered into by DOE and the US Fish and Wildlife Service meets the requirements under Section 3 of EO 13186. ORR hosts numerous migratory birds that are present either seasonally or year-round. This memorandum, which was updated in September 2013, strengthens migratory bird conservation on ORR through enhanced collaboration between DOE and the US Fish and Wildlife Service.	1.3.6.2
EO 13693, *Executive Order -- Planning for Federal Sustainability in the Next Decade,* instructs federal agencies to increase efficiency and improve their environmental performance, which will protect our planet for future generations and save taxpayer dollars through avoided energy costs.	EO 13693, *Planning for Federal Sustainability in the Next Decade*, superseded EO 13514 in fiscal year 2015 and established a new Scope 1 and Scope 2 total reduction target of 40% by 2025. Progress toward achieving DOE sustainability goals is summarized in this report. ORNL, Y-12, and ETTP activities complied with and exceeded the planning and reporting requirements of these executive orders in 2018. Comparing the ETTP fiscal year 2018 total of 19,731 metric tons to the 40% target level of 31,232 metric tons shows that the targeted 40% reduction in greenhouse gas emissions has already been achieved. The Y-12 Complex reduced Scope 1 and 2 greenhouse gas emissions by 55% in 2018. ORNL did not produce an annual site sustainability report, but submitted data in response to a data call from DOE Headquarters Sustainability Performance Office.	3.2.4 3.5.1.5 4.2.3.4 5.2.1.4

Acronyms:
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
CFR = Code of Federal Regulations
DOE = US Department of Energy
EISA = Energy Independence and Security Act
EMWMF = Environmental Management Waste Management Facility
EO = Executive Order
EPA = US Environmental Protection Agency
ETTP = East Tennessee Technology Park
NEPA = National Environmental Protection Act
NPDES = National Pollutant Discharge Elimination System
ORNL = Oak Ridge National Laboratory
ORR = Oak Ridge Reservation
PCB = polychlorinated biphenyl
RCRA = Resource Conservation and Recovery Act
TDEC = Tennessee Department of Environment and Conservation
Y-12 Complex = Y-12 National Security Complex

2.2 External Oversight and Assessments

Table 2.2 lists the inspections of ORR environmental activities conducted by regulatory agencies during 2018. This table does not include internal DOE or DOE contractor assessments, audits, or evaluations.

Table 2.2. Summary of regulatory environmental evaluations, audits, inspections, and assessments conducted at Oak Ridge Reservation in 2018

Date	Reviewer	Subject	Issues
		ORNL **(including UT-Battelle, LLC; UCOR; Isotek Systems LLC; and NorthWind Solutions, LLC activities)**	
January 8	TDEC	Notice of Termination for Construction Storm Water Permit Coverage	0
January 22	City of Oak Ridge	CFTF Wastewater Inspection	0
January	TDEC	HSWA Permit SWMUs and Areas of Concern	0
March 29	Knox County Air Quality Management	National Transportation Research Center CAA Inspection	0
April 10−11	TDEC	Annual RCRA Inspection for ORNL (including Transuranic Waste Processing Facility)	0
August 23	City of Oak Ridge	CFTF Wastewater Inspection	0
August 29	TDEC	RCRA Closure Inspection for 7823	0
October 3	TDEC	Annual CAA Inspection for ORNL and CFTF	0
October 24	TDEC	NPDES Inspection	0
		ETTP	
February 2	City of Oak Ridge	Sewage Pretreatment Plan	0
February 27 and October 30	TDEC	Annual RCRA Compliance Inspection	0
July 5	City of Oak Ridge	Windshield tour of ETTP	0
		Y-12 Complex	
January	TDEC	Inspection of Y-12 Post-closure Permitted Units	0
January 18 and 24	TDEC	Inspection of Landfills II, IV, and VII	0
March 1	TDEC	Landfill IV Leachate Tank Bypass Inspection	0
March 6	City of Oak Ridge	Semiannual Industrial Pretreatment Compliance Inspection	0
March 19	TDEC	Outfall 200 NPDES Inspection	0
April 3	TDEC	Landfill IV, V, and VII Inspection	0
April 10	TDEC	COLEX Inspection	0
April 24	TDEC	Sanitary Survey of Non-community Water System	0
June 20–21	TDEC	Underground Injection Control Program Compliance Inspection	0
July 17	TDEC	Landfill V and VII Inspection	0
August 1	TDEC	EMWMF Inspection	0
August 28−29	TDEC	Annual RCRA Hazardous Waste Compliance Inspection	1

Table 2.2. Summary of regulatory environmental evaluations, audits, inspections, and assessments conducted at Oak Ridge Reservation in 2018 (continued)

Date	Reviewer	Subject	Issues
September 25	TDEC	Landfill II and IV Clay Cap Inspection	0
September 26–27	TDEC	NPDES Compliance Evaluation Inspection	0
September 5	City of Oak Ridge	Semiannual Industrial Pretreatment Compliance Inspection	0
October 10	TDEC	Landfill IV Clay Cap Inspection	0
October 11	TDEC	Landfill II Inspection	0
October 20	TDEC	Y-12 Landfill Inspections	0
December 7	TDEC	Landfill IV and Area 1 Closure Inspection	0

Acronyms:
CAA = Clean Air Act
CFTF = Carbon Fiber Technology Facility
EMWMF = Environmental Management Waste Management Facility
ETTP = East Tennessee Technology Park
HSWA = Hazardous and Solid Waste Amendments of 1984
NPDES = National Pollutant Discharge Elimination System
ORNL = Oak Ridge National Laboratory
RCRA = Resource Conservation and Recovery Act
SWMU = storm water management unit
TDEC = Tennessee Department of Environment and Conservation
Y-12 Complex = Y-12 National Security Complex

2.3 Reporting of Oak Ridge Reservation Spills and Releases

CERCLA hazardous substances are substances considered to be harmful to human health and the environment. Many are commonly used substances that are harmless in normal uses but can be dangerous when released. CERCLA establishes reportable quantities for hazardous substance releases. Any hazardous substance release exceeding a reportable quantity triggers reports to the National Response Center, the State Emergency Response Center, and community coordinators. Discharges of oil must be reported if they “cause a film or sheen upon or discoloration of the surface of the water or adjoining shorelines or cause a sludge or emulsion to be deposited beneath the surface of the water or upon adjoining shorelines” (40 *Code of Federal Regulations* 110.3[b]).

ORNL, ETTP, and Y-12 had no reportable releases of extremely hazardous substances, as defined by the Emergency Planning and Community Right-to-know Act, in 2018. See Sections 3.6.4.7, 4.3.11, and 5.3.10 of this report for more information.

2.4 Notices of Violations and Penalties

ETTP: No issues, findings, or violations during fiscal year 2018

ORNL: No issues, findings, or violations during fiscal year 2018

Y-12: Three violations during fiscal year 2018

2.5 Community Involvement

DOE and its contractors provided or supported numerous community involvement activities in 2018 that addressed a range of subjects. These included ETTP historic interpretation efforts, Manhattan Project National Historical Park public meetings and public engagement efforts, Historic American Engineering Record activities, American Museum of Science and Energy community meetings hosted by the City of

Oak Ridge, ETTP airport public meetings, public comment periods for draft environmental assessments, and Community Relations Council meetings.

During 2018, organizations such as Great Smoky Mountains National Park, the East Tennessee Foundation, Girls, Inc., America Recycles Day and Earth Day activities, and local charities benefited from DOE and its contractors' efforts in the community.

2.5.1 Public Comments Solicited

To keep the public informed of comment periods and other matters related to cleanup activities on ORR, DOE publishes online notices at https://www.energy.gov/orem/services/community-engagement, conducts public meetings, and issues notices in local newspapers as appropriate. Information regarding environmental policy and DOE's commitment to providing sound environmental stewardship practices and keeping the public informed is available to the public via sponsored forums and public documents, such as this report.

2.5.2 Oak Ridge Site Specific Advisory Board

The Oak Ridge Site Specific Advisory Board (ORSSAB) is a federally appointed citizens' panel that provides independent advice and recommendations to the DOE Oak Ridge Environmental Management Program. The board was formed in 1995 and is composed of up to 22 members chosen to reflect the diversity of genders, races, occupations, views, and interests of persons living near ORR. Members are appointed by DOE and serve on a voluntary basis without compensation.

Information on recommendations the board has made since its establishment, minutes of board and committee meetings, and other information are available on the ORSSAB website at http://www.energy.gov/ORSSAB. Videos of the first hour of recent board meetings are posted at https://www.energy.gov/orem/listings/oak-ridge-site-specific-advisory-board-meetings. Additional information may be obtained by calling 865-241-4583 or 865-241-4584.

2.5.3 DOE Information Center

The DOE Information Center, located at 1 Science.Gov Way, Oak Ridge, Tennessee, is a one-stop information facility that maintains a collection of more than 40,000 documents describing environmental activities in Oak Ridge. The center is open Monday through Friday from 8 a.m. to 5 p.m. An online catalog that can be used to search for DOE documents by author, title, date, and other fields is available at https://www.energy.gov/orem/services/community-engagement/doe-information-center.

2.5.3.1 Telephone Contacts

- Agency for Toxic Substances and Disease Registry: 1-800-232-4636
- DOE Information Center: 865-241-4780; toll free 1-800-382-6938 (option 6)
- DOE Public Affairs Office: 865-576-0885
- EPA Region 4: 1-800-241-1754
- ORSSAB: 865-241-4583, 865-241-4584, 1-800-382-6938 (option 4)
- TDEC, DOE Oversight Division: 865-481-0995

2.5.3.2 Internet Sites

- Agency for Toxic Substances and Disease Registry: http://www.atsdr.cdc.gov

- American Recovery and Reinvestment Act: http://www.energy.gov/recovery-act
- DOE Main Website: http://www.energy.gov
- DOE Information Center: https://www.energy.gov/orem/services/community-engagement/doe-information-center
- EPA Region 4: http://www.epa.gov/region4
- ETTP: https://www.energy.gov/orem/cleanup-sites/east-tennessee-technology-park
- ORNL: https://www.ornl.gov/
- ORSSAB: http://www.energy.gov/ORSSAB
- TDEC: https://www.tn.gov/environment/program-areas/rem-remediation/rem-oak-ridge-reservation-clean-up.html
- Y-12 National Security Complex: http://www.y12.doe.gov/

2.6 References

DOE 2019. *2019 Remediation Effectiveness Report for the U.S. Department of Energy Oak Ridge Reservation, Oak Ridge, Tennessee, Data and Evaluations*. DOE/OR/01-2787&D1. US Department of Energy, Oak Ridge, Tennessee, March. (Note that the data reported in the 2019 report were collected prior to or in FY 2018.)

UCOR 2018, *2018 Annual Report to the Oak Ridge Regional Community, Oak Ridge, Tennessee,* OREM-18-2555. UCOR, Oak Ridge, Tennessee.

3. East Tennessee Technology Park

ETTP was originally built during World War II as part of the Manhattan Project. Formerly known as the K-25 Site, its primary mission was to enrich uranium for use in atomic weapons. After the war, the mission was changed to include the enrichment of uranium for nuclear reactor fuel elements and recycling of uranium recovered from spent fuel, and the name was changed to the "Oak Ridge Gaseous Diffusion Plant" (ORGDP). In the 1980s, a reduction in the demand for nuclear fuel resulted in the shutdown of the enrichment process and production ceased. The emphasis of the mission then changed to environmental management (EM) and remediation operations, and the name was changed to the "East Tennessee Technology Park."

EM and remediation operations consist of operations such as waste management, the cleanup of outdoor storage and disposal areas, the demolition and cleanup of facilities, land restoration, and environmental monitoring. Proper disposal of huge quantities of waste that were generated over the course of production operations is also a major task. Beginning in the 1990s, reindustrialization (the conversion of underused government facilities for use by the private sector) also became a major mission at ETTP. Reindustrialization allows private industry to lease and purchase underused land and facilities, thus providing both jobs and a new use for facilities that otherwise would have to be demolished. State and federally mandated effluent monitoring and environmental surveillance at ETTP involve the collection and analysis of samples of air, water, soil, sediment, and biota from ETTP and the surrounding area. Monitoring results are used to assess exposures to members of the public and the environment, to evaluate the performance of treatment systems, to help identify areas of concern, to plan remediation efforts, and to evaluate the efficacy of remediation efforts. In 2018, there was 100 percent compliance with permit standards for emissions/discharges from ETTP operations.

On November 10, 2015, DOE and the US Department of Interior (DOI) signed a memorandum of agreement (MOA) establishing the Manhattan Project National Historical Park (MPNHP). The MOA defines the respective roles and responsibilities of the departments in administering the park and includes provisions for enhanced public access, management, interpretation, and historic preservation. A portion of the ETTP, (the K-25 Gaseous Diffusion Building footprint) is included within the MPNHP. As part of the activities to establish the park, DOE released the K-25 Virtual Museum, which is a website that details the history of the K-25 Gaseous Diffusion Plant through narrative and photographs, and can be found **here**.

Due to different permit reporting requirements and instrument capabilities, this report uses various units of measurement. The lists of units of measure and conversion factors on pages xxvii and xxviii are included to help readers convert numeric values presented herein as needed for specific calculations and comparisons.

3.1 Description of Site and Operations

Construction of the K-25 Site (Figure 3.1) began in 1943 as part of the World War II Manhattan Project. The plant's original mission was the production of enriched uranium for nuclear weapons. Enrichment was initially carried out in the S-50 thermal diffusion process facility, which operated for 1 year, and the K-25 and K-27 gaseous diffusion process buildings. Later, the K-29, K-31, and K-33 buildings were built to increase the production capacity of the original facilities by raising the assay of the feed material entering K-27. Following the war years, the site became officially known as the Oak Ridge Gaseous Diffusion Plant (ORGDP).

After military production of highly enriched uranium was concluded in 1964, the two original process buildings were shut down. For the next 20 years, the plant's primary missions were the production of low enriched uranium fabricated into fuel elements for nuclear reactors throughout the world. Other missions during the latter part of this 20-year period included developing and testing the gas centrifuge method of uranium enrichment and laser isotope separation research and development.

Figure 3.1. East Tennessee Technology Park

By 1985, the demand for enriched uranium had declined, and the gaseous diffusion cascades at ORGDP were placed in standby mode. That same year, the gas centrifuge program was canceled. The decision to permanently shut down the diffusion cascades was announced in late 1987 and actions necessary to implement that decision were initiated soon thereafter. Because of the termination of the original and primary missions, ORGDP was renamed the "Oak Ridge K-25 Site" in 1989. Figure 3.2 shows the ETTP site areas before the start of decontamination and decommissioning (D&D) activities. In 1996, the K-25 Site was renamed the "East Tennessee Technology Park" to reflect its new mission.

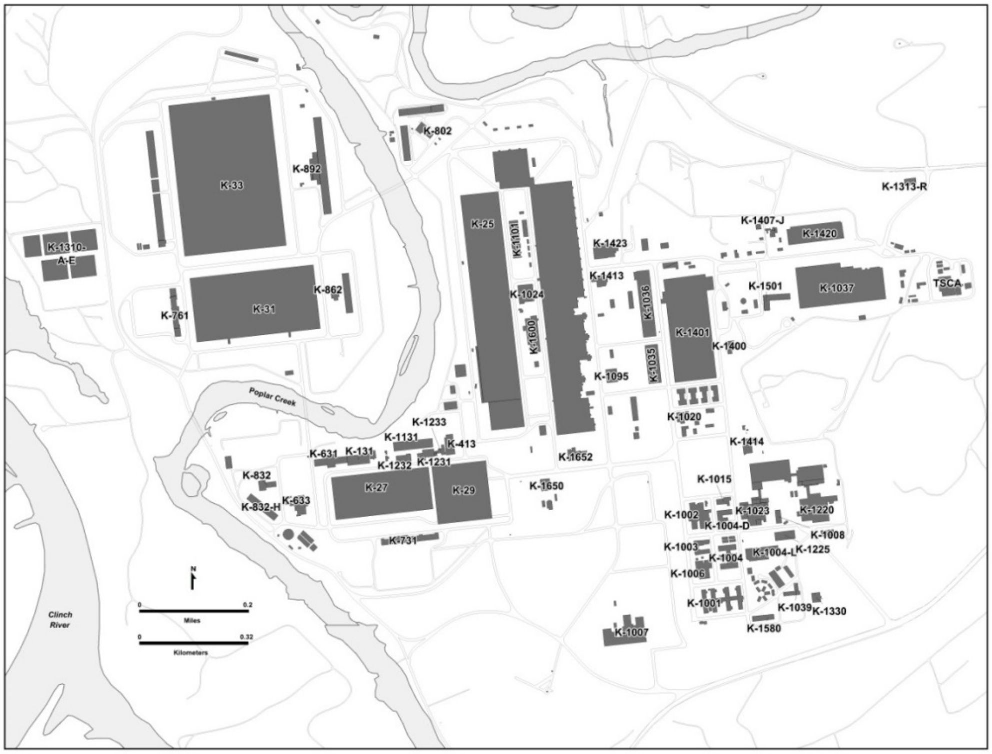


Figure 3.2. East Tennessee Technology Park before the start of decontamination and decommissioning activities in 1991

Figure 3.3 shows the ETTP areas designated for D&D activities through 2018. The ETTP mission is to reindustrialize and reuse site assets through leasing and/or transferring excess or underutilized land and facilities and through incorporating commercial industrial organizations as partners in the ongoing environmental restoration, D&D, and waste treatment and disposal.

The site is undergoing environmental cleanup of its land, as well as D&D of most of its buildings. The cleanup approach makes land and various types of buildings (e.g., office, manufacturing) suitable for private industrial use and for title transfer to the Community Reuse Organization of East Tennessee (CROET) or other entities such as the City of Oak Ridge (COR). The long-term DOE goal for ETTP is to transfer as much of the site property as practicable out of DOE ownership and into CROET's control for the development of a commercial business and industrial park. The facilities may then be subleased or sold, with the goal of stimulating private industry and recruiting business to the area. These transfers also reduce maintenance costs for DOE, which frees up additional money for environmental cleanup. The reuse of key facilities through title transfer is part of the site's closure plan.

UCOR, an AECOM-led partnership with Jacobs, the lead environmental management contractor for ETTP, supports DOE in the reindustrialization program as part of the continuing effort to transform ETTP into a private-sector industrial park. Unless otherwise noted, information on non-DOE entities located on the ETTP site is not provided in this document.

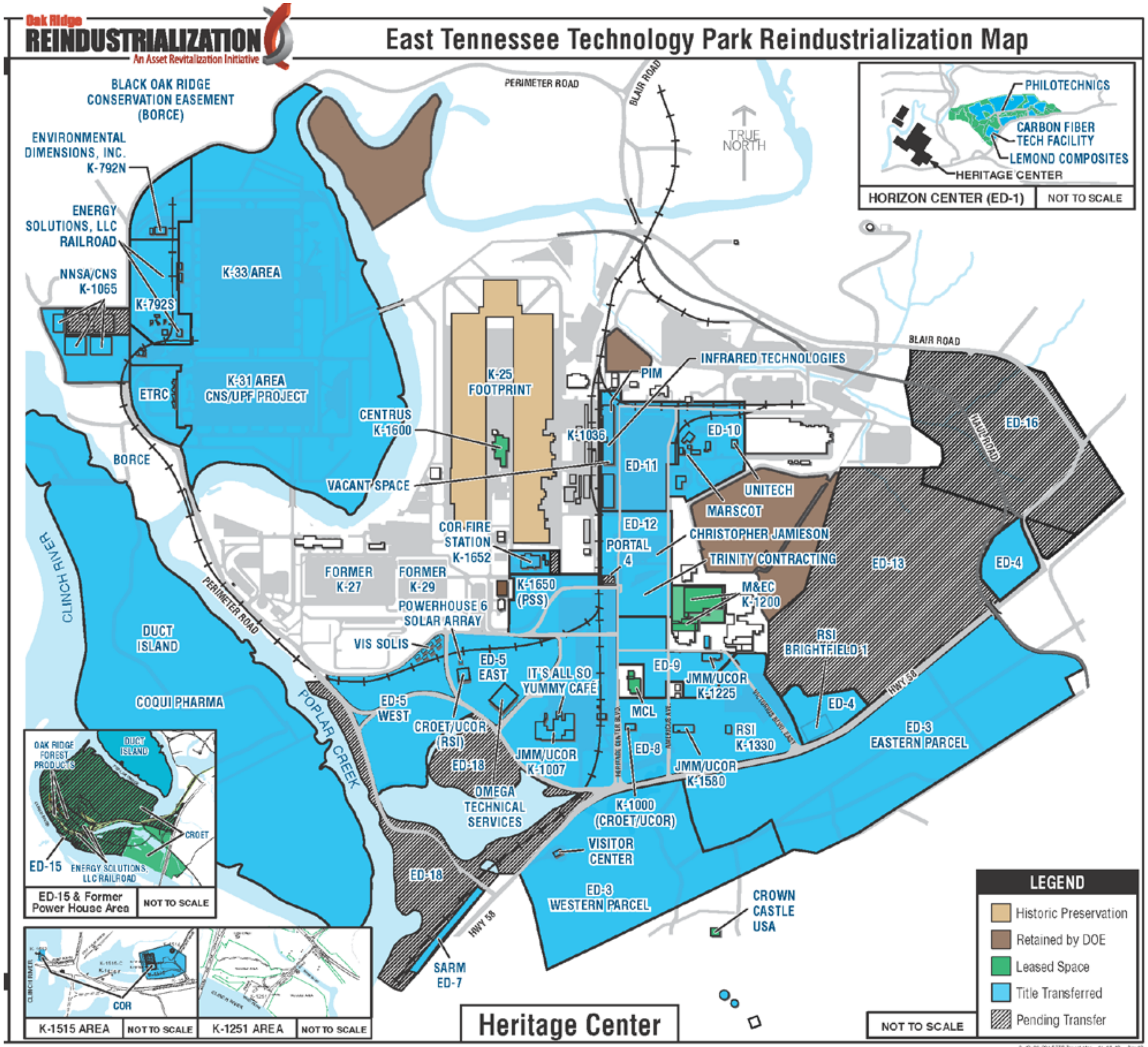


Figure 3.3. East Tennessee Technology Park in 2018, showing progress in reindustrialization

3.2 Environmental Management System

The UCOR Environmental Management System (EMS) is integrated with the UCOR Integrated Safety Management System (ISMS). UCOR's EMS is based on a graded approach for a closure and remediation contract and reflects the elements and framework contained in International Organization for Standardization (ISO) Standard 14001:2004 (ISO 2004), *Environmental management systems—Requirements with guidance for use*. UCOR is committed to incorporating sound environmental management, protection, and sustainability practices in all work processes and activities that are part of the DOE EM program in Oak Ridge, Tennessee. UCOR's environmental policy states in part, "Our commitment to protect and sustain human, natural, and cultural resources is inherent in our mission to complete environmental cleanup safely with reduced risks to the public, workers, and the environment." To achieve this, UCOR's environmental policy adheres to the following principles:

- **Leadership Commitment**—Integrate responsible environmental practices into project operations.
- **Environmental Compliance and Protection (EC&P)**—Comply with all environmental regulations and standards.
- **Sustainable Environmental Stewardship**—Minimize the effects of our operations on the environment through a combination of source reduction, recycling, and reuse; sound waste management practices; and pollution prevention (P2).
- **Partnership/Stakeholder Involvement**—Maintain partnerships through effective two-way communications with our customers and other stakeholders.

3.2.1 Environmental Stewardship Scorecard

The Environmental Stewardship Scorecard is used to track and measure site-level EMS performance. During 2018 UCOR received "green scores" for EMS performance. As an example, Figure 3.4 presents information on UCOR's 2018 P2 recycling activities related to solid waste reduction at ETTP. UCOR recycles office and mixed paper, cardboard, phone books, newspapers, magazines, aluminum cans, antifreeze, engine oils, batteries (lead [Pb] acid, universal waste, and alkaline), universal waste bulbs, plastic bottles, all types of #1 and #2 plastics, and surplus electronic assets, such as computers (CPUs and laptops) and monitors (cathode ray tubes [CRTs] and liquid crystal displays [LCDs]). Other recycling opportunities include unique structural steel, stainless-steel structural members, transformers, and electrical breakers.

UCOR's exceptional electronics stewardship earned it an award in 2018 from the Green Electronics Council for its use of Electronic Product Environmental Assessment Tool (EPEAT) methods. There are two categories at the two-star level—one for computers and displays, and one for imaging equipment. EPEAT purchasers earn a star for each product category for which they have a policy in place and purchase EPEAT-registered electronics. EPEAT is a free and trusted source of environmental product ratings that help purchasers select high-performance electronics that meet their organizations' information technology (IT) and sustainability goals. Manufacturers register products based on the devices' ability to meet various criteria developed and agreed upon by diverse stakeholders to address the full life cycle of an electronic product.

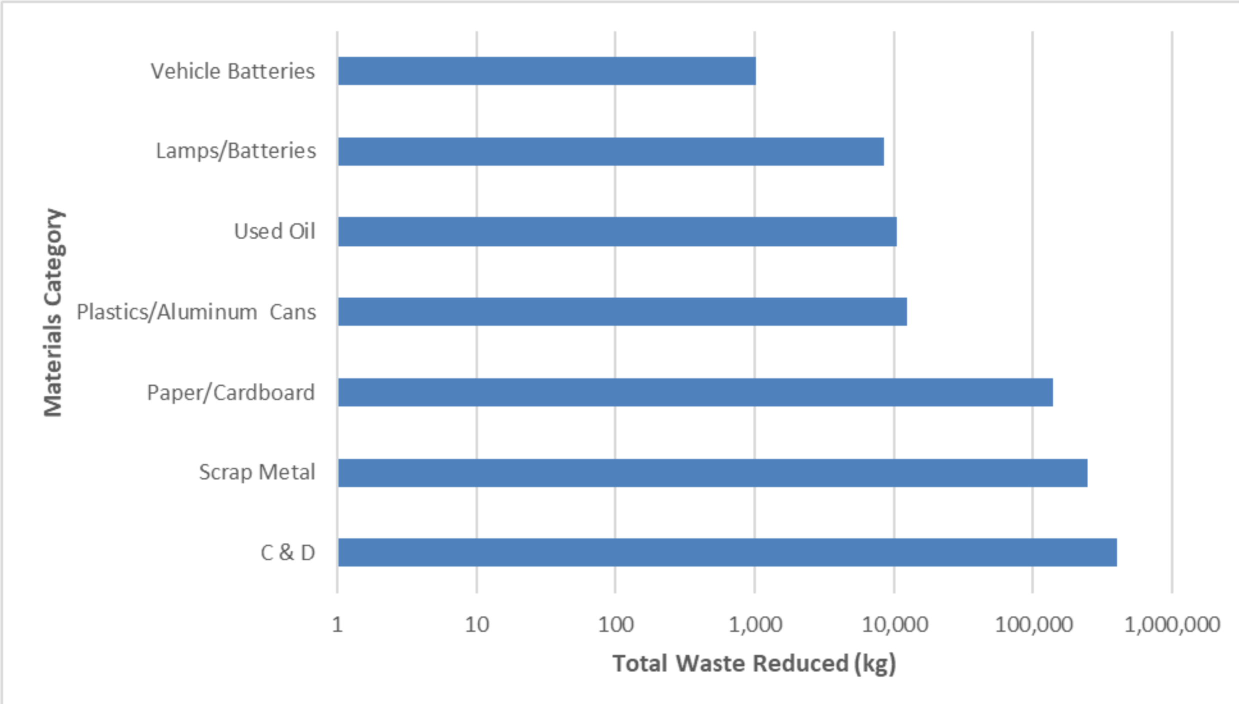


Figure 3.4. Pollution prevention recycling activities related to solid waste reduction at East Tennessee Technology Park in Calendar Year 2018

Additionally, UCOR internally recognized five projects for their P2/waste minimization (P2/WMin) accomplishments in 2018, which are summarized below.

- The Environmental Management Waste Management Facility (EMWMF) team was recognized for diverting approximately 156 tons of rubble through reuse, saving an estimated 1,100 yd^3 of landfill space.
- The K-1401 Treatability Study Team was recognized for its optimization of waste disposition efforts by applying the DOE preferred waste hierarchy model to the project. Through the diversion of offsite water treatment and waste disposal in favor of on-site options, carbon dioxide (CO_2) emissions and risk were greatly reduced, as well as approximately $9.4 million saved.
- The Oak Ridge National Laboratory Operations and Cleanup Enterprise project was recognized for identifying fill from the solid waste storage area (SWSA) 5 area for reuse at the SWSA 7 unit, saving approximately $3,000.
- The Operations and Cleanup Enterprise project diverted a contaminated manipulator from the 3028 building for reuse by UT-Battelle, LLC, saving approximately $75,000 and 10 yd^3 of landfill space.

The ETTP D&D/Exposure Unit (EU)-29/K-1407-C Retention Basin Soil Removal and Restoration Team was recognized for selecting a low maintenance, specialized seed mixture to restore the former K-1407-C Retention Basin at the EU-29 site in lieu of hydroseeding. The result was an enhanced cover of native plants, which provide a habitat conducive to pollinating insects and wildlife, as well as reduced life cycle surveillance and maintenance (S&M) costs through the avoidance of maintenance activities inherent with hydroseeding.

Together, the projects represented sustainability accomplishments in waste diversion, waste reduction and P2, and water management. These accomplishments were the result of team work, leveraging a number of work control and management tools to save landfill space, reduce the use of virgin material, mitigate hazards to the environment and workers, and increase work efficiencies. In addition to lessening the impact on the environment, P2 measures may also save money. In 2018, an estimated total in excess of $9 million was saved as a result of implementation of P2 measures by the projects.

ETTP also continually strives to find new avenues for waste diversion. In 2016, a significant improvement in the diversion of scrap metal was made. In the course of demolition and environmental cleanup, one challenge has been the ability to divert large volumes of construction and demolition debris from disposal in landfills due to radiological contamination. However, despite the radiological challenge, a substantial amount of scrap metal located inside of Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)-designated areas is still eligible for recycling because it is not radiologically contaminated. For the nonradiological areas, a second challenge was identified due to the CERCLA Off-Site Rule that requires all disposal and recycle facilities receiving CERCLA waste be reviewed and approved by the EPA for acceptability (CERCLA 1993). UCOR conducted a nationwide search for scrap metal recyclers that EPA had determined to be acceptable with the CERCLA Offsite Rule requirements all the way through the required smelter/foundry process step; however, none were located. Therefore, the only available option for disposal of the noncontaminated CERCLA scrap metal was land disposal.

In 2018 UCOR continued to work with EPA and the Tennessee Department of Environment and Conservation (TDEC) to apply the CERCLA screening process that allows noncontaminated scrap metal from CERCLA areas to be shipped to commercial scrap-metal dealers for recycle. Effectively, the screening process removes the noncontaminated scrap metal from regulation under CERCLA; therefore, any non-CERCLA commercial scrap-metal recyclers can receive the material for recycle. This unprecedented agreement allowed approximately an additional 27,440 lb (12.44 MT of scrap metal to be recycled in FY 2018 in lieu of land disposal and provides a path forward for additional waste diversion for the duration of the contract.

Some of the significant benefits of the scrap-metal recycling under this approval include:

- Provides funds from the recycling payments that are available to go back into the programs and support further actions in the Oak Ridge cleanup program.
- Conserves valuable landfill space. To date, the scrap metal recycled as a result of the screening process has saved approximately 218 yd^3 of valuable landfill space which translates into a considerable cost savings, which takes into consideration capital cost, landfill capacity, historical operating costs, packing, and transportation.
- Supports EPA, TDEC, and DOE programmatic environmental stewardship goals for waste diversion.

The CERCLA screening process will continue to be used as more demolition and cleanup are continued at ETTP, Oak Ridge National Laboratory (ORNL), and the Y-12 National Security Complex (Y-12).

In the area of alternative energy, Restoration Services, Inc. (RSI), in concert with UCOR, continued operations of ETTP's solar parks. Brightfield 1 is a 200-kW solar array located on a 0.405-ha (1-acre) tract purchased from CROET and built by RSI as part of UCOR's commitment to the revitalization of the former K-25 Site.

Figure 3.5. Oak Ridge Solar Park

RSI self-financed the project, using solar panels manufactured in Tennessee, and partnering with other local small businesses for the installation. Power generated from Brightfield 1 is being sold to the Tennessee Valley Authority (TVA) through the City of Oak Ridge Electric Department using a TVA Generation Partners contract. The completed project was commissioned in April 2012 and is part of RSI's Brownfields to Brightfields initiative that works to develop restricted use properties into solar farms. Brightfield 1 energy production in its first year was 110 percent more than projected, with no downtime due to maintenance issues. In calendar year (CY) 2018, Brightfield 1 produced approximately 249,250 kWh of energy.

In addition, through the cooperative efforts of DOE, UCOR, RSI, Vis Solis, Inc., CROET, and COR, a second solar farm—the Powerhouse 6 Solar Farm—was constructed on the west end of the park (Fig. 3.5). It is a 1-MW solar farm that became operational in April 2015 and provides renewable energy, long-term lease income to CROET and boosters development at ETTP. This project provides numerous benefits to the environment and the community at large, and includes the following:

- Generates enough clean energy to power more than 100 homes.
- Prevents pollution by removing the equivalent of 240 cars from the road annually (1,141 MT of CO_2).
- Provides brownfield reuse/redevelopment at ETTP.
- Supports the COR renewable energy goals.
- Supports the TVA renewable energy initiative.
- Offers community economic development jobs and property tax income to COR.
- Demonstrates benefits of ETTP reindustrialization.

- Supports DOE renewable energy goals.
- Demonstrates collaborative success between DOE and a public utility for renewable energy development.

UCOR also continued to use green products whenever possible and evaluated large quantity purchases for less toxic alternatives. In addition, UCOR maintained its extensive recycling program, which helps provide employment to beneficiaries of local charities who are employed by the local recycling facility for the county.

3.2.2 Environmental Compliance

UCOR maintains various layers of oversight to ensure compliance with legal and other requirements. The methods of evaluation include independent assessments by outside parties, management assessments conducted by functional or project organizations, and routine field walkdowns conducted by a variety of functional and project personnel. Management and independent assessments are performed in accordance with *Assessments*, PROC-PQ-1420, and *Independent Assessment*, PROC-PQ-1401. Assessments are scheduled on the UCOR Quality Assurance System (QAS) in accordance with PROC-PQ-1420. Records are maintained for all formal assessments and audits. Issues identified in assessments are handled, as required, by ISO 14001:2004, Section 4.5.3, "Nonconformity, Corrective Action, and Preventive Action" (ISO 2004).

3.2.3 Environmental Aspects/Impacts

Using a graded approach appropriate for EMS includes an environmental policy that provides a unified strategy for the management, conservation, and protection of natural resources; the control and attenuation of risks; and the establishment and attainment of all environment, safety, and health (ES&H) goals. UCOR works continuously to improve EMS to reduce impacts from activities and associated effects on the environment (i.e., environmental aspects) and to communicate and reinforce this policy to its internal and external stakeholders.

3.2.4 Environmental Performance Objectives and Targets

UCOR conserves and protects environmental resources by (1) incorporating environmental protection and the elements of an enabling EMS into the daily conduct of business; (2) fostering a spirit of cooperation with federal, state, and local regulatory agencies; and (3) using appropriate waste management, treatment, storage, and disposal methods.

UCOR has established a set of core, corporate-level EMS objectives that remain relatively unchanged from year to year. These objectives are generally applicable to all operations and activities throughout UCOR's work scope. The core environmental objectives are based on compliance with applicable legal requirements and sustainable environmental practices contained in DOE Order (O) 436.1, *Departmental Sustainability* (DOE 2011a), and include the following:

- Comply with all environmental regulations, permits, and regulatory agreements.

- Reduce or eliminate the acquisition, use, storage, generation, and/or release of toxic, hazardous, and radioactive materials; waste; and greenhouse gas emissions through acquisition of environmentally preferable products, conduct of operations, waste shipment, and P2/WMin and sustainable practices.
- Reduce degradation and depletion of environmental resources and potential impact on climate change through post-consumer material recycling, energy, fuel, and water conservation efforts, use or promotion of renewable energy, and transfer for reuse valuable real estate assets.
- Reduce the environmental impact on surface water and groundwater resources.
- Reduce the environmental impact associated with project and facility activities.

3.2.5 Implementation and Operations

UCOR protects the safety and health of workers and the public by identifying, analyzing, and mitigating aspects, hazards, and impacts from ETTP operations, and by implementing sound work practices. All UCOR employees and subcontractors are held responsible for complying with all ES&H requirements during all work activities and are expected to correct noncompliant conditions immediately. UCOR's internal assessments also provide a measure of how well EMS attributes are integrated into work activities through ISMS. UCOR has embodied its program for EC&P of natural resources in a companywide EM and protection policy. The policy is UCOR's fundamental commitment to incorporating sound EM practices in all work processes and activities.

3.2.6 Pollution Prevention/Waste Minimization

UCOR's work control process requires that all waste-generating activities be evaluated for source reduction and that product substitution be used to produce less toxic waste, when possible. The reuse or recycling of building debris or other wastes generated is evaluated in all cases.

The ETTP EMS program fosters P2 at every level of its operations, from routine office recycling of paper, cardboard and plastics, to unique reuse and recycling at the project-field level. UCOR's P2 program is successful because it is tightly bound to its work control process. Thus many original applications of material reuse and recycling have resulted, many of which have been captured through its internal P2 awards program.

Total cost savings and avoidance associated with these projects were in excess of $9.2 million and resulted in conserving valuable landfill space, and resources, as well as mitigating water contamination, and greenhouse gas emissions. The internal awards will be evaluated for nomination in national-level awards (e.g., DOE Headquarters annual award program).

3.2.7 Competence, Training, and Awareness

The UCOR training and qualification process ensures that needed skills for the workforce are identified and developed. The process also documents knowledge, experience, abilities, and competencies of the workforce for key positions requiring qualification. This process is described in PROC-TC-0702, *Training Program*. Completion and documentation of training, including required reading, are managed by the Local Education Administration Requirements Network, or LEARN.

3.2.8 Communication

UCOR communicates externally regarding environmental aspects through the UCOR public website, which includes a link to its environmental policy statement in *Environmental Management and Protection,* POL-UCOR-007, and a list of environmental aspects.

A number of other documents and reports that address environmental aspects and cleanup progress are also published and made available to the public (e.g., the Annual Site Environmental Report [ASER] [DOE 2018b, DOE/ORO-2511] and the annual cleanup progress report [UCOR 2019a, *2018 Cleanup Progress—Annual Report to the Oak Ridge Regional Community,* OREM-18-2555]).

UCOR participates in a number of public meetings related to environmental activities at the site (e.g., Oak Ridge Site Specific Advisory Board [ORSSAB] meetings, which include community stakeholders, public permit reviews, and public CERCLA decision document reviews). Written communications from external parties are tracked using the weekly Open Action Report.

3.2.9 Benefits and Successes of Environmental Management System Implementation

An EMS program provides many benefits to an organization's success. Based upon the simplified model of Do-Act-Check, it provides a framework by which work incorporates environmental hazards into its work control and planning. This translates into many returns to the organization. UCOR uses EMS objectives and targets, an internal P2 recognition program, environmentally preferable purchasing, work control processes, and a recycle program to meet sustainability and stewardship goals and requirements. The approach is outlined in UCOR's *Pollution Prevention and Waste Minimization Program Plan for the East Tennessee Technology Park, Oak Ridge, Tennessee* (UCOR 2019b, UCOR-4127/R7). The EMS program is audited by a third party triennially as for conformance to the ISO 14001:2004 standard (ISO 2004) as required by DOE Order 436.1, *Departmental Sustainability, Attachment1 Contractor Requirements Document* (DOE 2011a), with the most recent having been conducted in 2018. The results of the audit were zero Findings, three Observations, and four Proficiencies.

3.2.10 Management Review

Senior management review of the EMS is performed at several layers and frequencies. A formal review/presentation with UCOR senior management that addresses the ISO 14001:2004 (ISO 2004) required elements is conducted at least once per year. At least two of the senior managers are present for management reviews. The environmental policy is also reviewed during the management review annually and revised as necessary.

3.3 Compliance Programs and Status

During 2018, ETTP operations were conducted in compliance with contractual and regulatory environmental requirements. There were no National Pollutant Discharge Elimination System (NPDES) permit noncompliances and no Clean Air Act (CAA) noncompliances in 2018. Figure 3.6 shows the trend of NPDES compliance at ETTP since 2008. The following sections provide more detail on each compliance program and the environmental remediation-related activities in 2018.

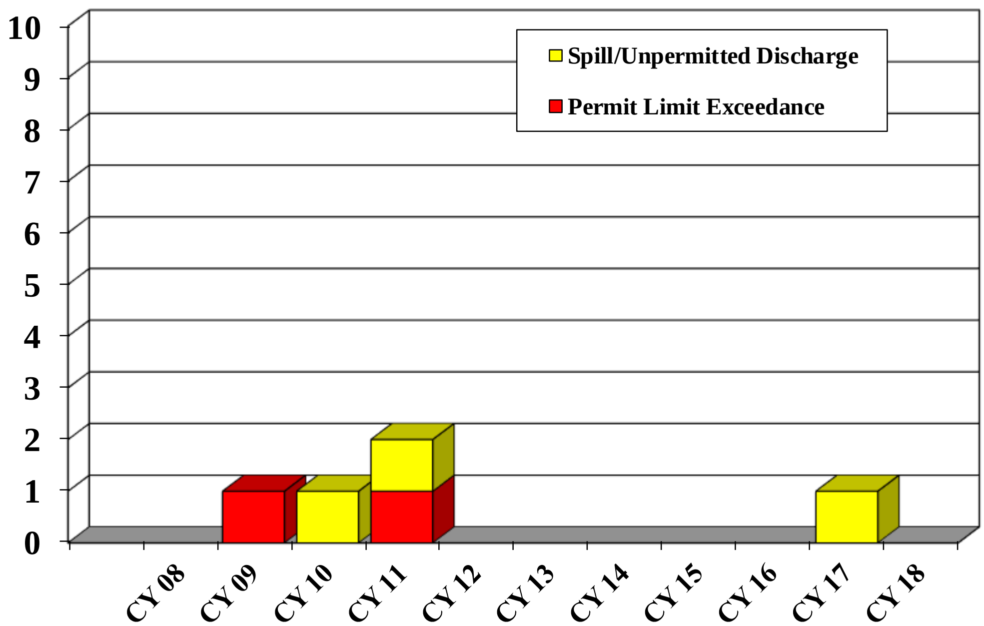


Figure 3.6. East Tennessee Technology Park National Pollutant Discharge Elimination System permit noncompliances since 2008

3.3.1 Environmental Permits

Table 3.1 contains a list of environmental permits that were in effect at ETTP in 2018.

3.3.2 Notices of Violation and Penalties

ETTP received no notices of environmental violations or penalties in 2018.

3.3.3 Audits and Oversight

Table 3.2 presents a summary of environmental audits and oversight visits conducted at ETTP in 2018.

Table 3.1. East Tennessee Technology Park environmental permits, 2018

Regulatory driver	Permit title/description	Permit number	Issue date	Expiration date	Owner	Operator	Responsible contractor
CAA	State permit to operate an air contaminant source—internal combustion engine–powered emergency generators and fire water pump replaced by Permit-by-Rule when NOA received from TDEC	069346P, NOA Number R74133	03-03-2015 Amended 11-22-2016 NOA issued 7-19-2018	10-01-2024, none for NOA	DOE[a]	UCOR	UCOR
CWA	NPDES permit for storm water discharges	TN0002950	02-01-2015	03-31-2020	DOE	UCOR	UCOR
CWA	SOP—waste transportation project; Blair Road and Portal 6 sewage pump and haul permit	SOP-05068	07-01-2014	02-28-2019	TFE	TFE	TFE
CWA	SOP—ETTP holding tank/haul system for domestic wastewater	SOP-99033	07-01-2015	06-30-2020	UCOR	UCOR	UCOR
UST	Authorized/certified USTs at K-1414 Garage	Customer ID 30166 Facility ID 073008	03-20-1989	Ongoing	DOE	UCOR	UCOR
RCRA	ETTP container storage and treatment units	TNHW-165	09-15-2015	09-15-2025	DOE	UCOR	UCOR
RCRA	Hazardous waste corrective action document (encompasses entire ORR)	TNHW-164	09-15-2015	09-15-2025	DOE	DOE/All[a]	DOE/All[a]

[a] DOE and ORR contractors that are co-operators of hazardous waste permits.

Acronyms
CAA = Clean Air Act
CWA = Clean Water Act
DOE = US Department of Energy
ETTP = East Tennessee Technology Park
ID = identification (number)
NOA-Notice of Authorization
NPDES = National Pollutant Discharge Elimination System
ORR = Oak Ridge Reservation
RCRA = Resource Conservation and Recovery Act
SOP = state operating permit
TFE = Technical and Field Engineering, Inc.
UCOR = UCOR, an AECOM-led partnership with Jacobs
UST = underground storage tank

Table 3.2. Regulatory oversight, assessments, inspections, and site visits at East Tennessee Technology Park, 2018

Date	Reviewer	Subject	Issues
February 2	COR	Sewage Pretreatment Plan	0
February 27 and October 30	TDEC	Annual RCRA Compliance Inspection	0
July 5	COR	Windshield Tour of ETTP	0

COR = City of Oak Ridge
RCRA = Resource Conservation and Recovery Act
TDEC = Tennessee Department of Environment and Conservation

3.3.4 National Environmental Policy Act/National Historic Preservation Act

The National Environmental Policy Act (NEPA) provides a means to evaluate the potential environmental impact of proposed federal activities and to examine alternatives to those actions. ETTP maintains compliance with NEPA through the use of site-level procedures and program descriptions that establish effective and responsive communications with program managers and project engineers to ensure NEPA is a key consideration in the formative stages of project planning. Many of the current operations at ETTP are conducted under CERCLA. NEPA reviews are part of the CERCLA planning process to ensure that NEPA values are incorporated into CERCLA projects and documentation.

During 2018, ETTP continued to operate under site-level, site-specific procedures that provide requirements for project reviews and NEPA compliance. These procedures call for a review of each proposed project, activity, or facility to determine the potential for impacts on the environment. To streamline the NEPA review and documentation process, DOE Oak Ridge Office (ORO) has approved generic categorical exclusion (CX) determinations that cover certain proposed activities (i.e., maintenance activities, facility upgrades, personnel safety enhancements). A CX is one of a category of actions defined in 40 Code of Federal Regulations (CFR) Part 1508.4 (EPA 1978) that does not individually or cumulatively have a significant effect on the human environment and for which neither an environmental assessment nor an environmental impact statement is normally required. UCOR activities on the ORR are in full compliance with NEPA requirements, and procedures for implementing NEPA requirements have been fully developed and implemented. At ETTP, a checklist incorporating NEPA and EMS requirements has been developed as an aid for project planners. For routine, recurring activities, DOE generic CX determinations are used. During 2018, a new CX determination was generated, CX-K25-564, for the demolition of non-CERCLA buildings at ETTP.

Compliance with the National Historic Preservation Act (NHPA) at ETTP is achieved and maintained in conjunction with NEPA compliance. The scope of proposed actions is reviewed in accordance with the ORR cultural resource management plan (Souza et al. 2001). At ETTP, there were 135 facilities eligible for inclusion on the National Register of Historic Places (NRHP), a US National Park Service (NPS) program to identify, evaluate, and protect historic and archeological resources in the United States, as well as numerous facilities that were not eligible for inclusion on NRHP. To date, more than 800 facilities have been demolished. Artifacts of historical and/or cultural significance are identified before demolition and are catalogued in a database to aid in the historic interpretation of ETTP.

Consultation for the development of a memorandum of agreement (MOA) for D&D of the K-25 and K-27 buildings started in 2001; the document, approved in 2003, required a third-party analysis of the preservation and interpretive strategies for those two buildings. In 2005, DOE, the Tennessee State Historic Preservation Office (SHPO), and the Advisory Council on Historic Preservation (ACHP) entered into an MOA that included the retention of the north end tower (also known as north wing and north end) of the K-25 building and Portal 4 (K-1028-45), among other features, as the “best and most cost-effective mitigation to permanently commemorate, interpret, and preserve the significance” of ETTP. Another series of consultation meetings ensued in 2009 and DOE advised that prohibitive costs and safety considerations precluded fulfillment of three stipulations in the 2005 MOA, including the preservation of the north end tower. The parties offered a wide array of potential mitigation measures and, in the absence of consensus on how best to commemorate Building K-25, DOE, SHPO, and ACHP entered into a bridge MOA until the parties could reach a final agreement. After completing an evaluation of the structural integrity of the K-25 building and interpretative approaches for the site, DOE distributed a preferred mitigation plan to the consulting parties in October 2011. The DOE final mitigation plan, which addressed comments submitted by consulting parties in November 2011, permitted demolition of the entire K-25 building and called for, among other mitigation measures, the designation of a commemorative area around the building’s perimeter from which future surface development would largely be restricted; the retention, if possible, of the entire concrete slab or the demarcation of the building’s footprint; the construction of a viewing tower and structure for equipment display; and the development of a history center within the ETTP Fire Station. A final MOA was signed in August 2012, finalizing the aspects set forth in the mitigation plan. A Professional Design Team and Museum Professional were selected in 2014. The museum design was completed in 2017 and a construction subcontract was awarded for the K-25 History Center in 2018.

On December 14, 2014, Congress authorized the establishment of the Manhattan Project National Historical Park to commemorate the history of the Manhattan Project (DOI 2015). It will comprise the three major sites: Los Alamos, New Mexico; Oak Ridge, Tennessee; and Hanford, Washington, which were dedicated to accomplishing the Manhattan Project mission.

The *Memorandum of Agreement Between the United States Department of the Interior and the United States Department of Energy for the Manhattan Project National Historical Park* was signed by DOI and DOE on November 10, 2015 (DOE 2015), creating the new Manhattan Project National Historical Park. The K-25 Virtual Museum website (K-25 Virtual Museum) was launched in conjunction with the signing of the MOA.

The Museum Preliminary Design Report was completed and provided to the Consulting Parties in July 2016. The Consulting Parties reviewed the report and plans and provided comments. The Final Design Plan was completed and sent to the consulting parties for review in January 2017. Comments from the consulting parties were received and incorporated into the Certified for Construction design package and a request for proposal was issued for construction, exhibit fabrication, and installation activities for the K-25 History Center. Construction of the K-25 History Center was begun in 2018 and is expected to open in the fall of 2019.

The Historic American Engineering Record (HAER) documentation is being prepared for the K-25 Building. The documentation will be transmitted to the NPS upon completion.

3.3.5 Clean Air Act Compliance Status

The CAA, passed in 1970 and amended in 1977 and 1990, forms the basis for the national air pollution control effort. This legislation establishes comprehensive federal and state regulations to limit air emissions and includes five major regulatory programs: the National Ambient Air Quality Standards (NAAQS), State Implementation Plans (SIPs), New Source Performance Standards (NSPSs), Prevention of Significant Deterioration permitting programs, and National Emission Standards for Hazardous Air Pollutants (NESHAPs). Airborne discharges from DOE Oak Ridge facilities, both radioactive and nonradioactive, are subject to regulation by EPA and the TDEC Division of Air Pollution Control.

Full compliance with CAA regulations and permit conditions was demonstrated in 2018. The ETTP ambient air-monitoring program, permitted source operations tracking, and record keeping provided documentation fully supporting a 100 percent compliance rate.

3.3.6 Clean Water Act Compliance Status

The objective of the Clean Water Act (CWA) is to restore, maintain, and protect the integrity of the nation's waters. This act serves as the basis for comprehensive federal and state programs to protect the waters from pollutants (see Appendix C for water reference standards). One of the strategies developed to achieve the goals of CWA was EPA establishment of limits on specific pollutants allowed to be discharged in US waters by municipal sewage treatment plants (STPs) and industrial facilities. EPA established the NPDES permitting program to regulate compliance with pollutant limitations. The program was designed to protect surface waters by limiting effluent discharges into streams, reservoirs, wetlands, and other surface waters. EPA has delegated authority for implementation and enforcement of the NPDES program to the state of Tennessee. In 2018, ETTP discharged storm water to the waters of the state of Tennessee under the individual NPDES permit TN0002950, which regulates storm water discharges.

In 2018, sewage discharges from routine breakrooms, restrooms, and change house showers were discharged to the COR Rarity Ridge Wastewater Treatment Plant collection network and sewage holding tanks under permits SOP-05068 and SOP-99033.

3.3.7 National Pollutant Discharge Elimination System Permit Noncompliances

In 2018, compliance with ETTP NPDES storm water permit TN0002950 was determined by more than 150 laboratory analyses, field measurements, and flow estimates. The NPDES permit compliance rate for all discharge points for 2018 was 100 percent. There were no permit noncompliances in 2018.

3.3.8 Safe Drinking Water Act Compliance Status

Since October 1, 2014, all water at the ETTP site is supplied by the COR drinking water plant, located north of the Y-12 Complex in Oak Ridge, Tennessee.

3.3.9 Resource Conservation and Recovery Act Compliance Status

ETTP is regulated as a large-quantity generator of hazardous waste because the facility generates more than 1,000 kg of hazardous waste per month. This amount includes hazardous waste generated under permitted activities (including repackaging or treatment residuals). At the end of 2018, ETTP had two generator accumulation areas for hazardous or mixed waste.

In addition, ETTP is permitted to store and treat hazardous and mixed waste under the Resource Conservation and Recovery Act (RCRA) Part B Permit TNHW-165. Hazardous waste may be treated and stored at permitted locations at the K-1065 complex. This hazardous waste permit was reissued on September 15, 2015, as a replacement for TNHW-117. The hazardous waste corrective action document, TNHW-164, which covers the ORR areas of concern and solid waste management units, was also reissued on September 15, 2015, as a replacement for TNHW-121.

In CY 2018, ETTP prepared and submitted to the TDEC Division of Solid Waste Management the CY 2017 annual report of hazardous waste activities. This report identifies the type and amount of hazardous waste that was generated, shipped off site, or is currently in storage.

3.3.10 Resource Conservation and Recovery Act Underground Storage Tanks

Underground storage tanks (USTs) containing petroleum and hazardous substances are regulated under RCRA Subtitle I (40 CFR 280, EPA 2015). EPA granted TDEC authority to regulate USTs containing petroleum under TDEC Rule 0400-18-01, *Underground Storage Tank Program* (TDEC 2018b); however, EPA still regulates hazardous substance USTs. During 2018, operations of the two USTs at ETTP were in complete regulatory compliance. In April 2018, TDEC was notified that both tanks had been emptied and were temporarily out of service, pending final closure.

3.3.11 Comprehensive Environmental Response, Compensation, and Liability Act Compliance Status

CERCLA, also known as "Superfund," was passed in 1980 and was amended in 1986 by the Superfund Amendments and Reauthorization Act (SARA). Under CERCLA, a site is investigated and remediated if it poses significant risk to health or the environment. The EPA National Priorities List (NPL) is a comprehensive list of sites and facilities that have been found to pose a sufficient threat to human health and/or the environment to warrant cleanup under CERCLA. ORR is on the NPL and numerous CERCLA decision documents are approved for ETTP site cleanup actions for both facility demolitions and soil remediation.

3.3.12 East Tennessee Technology Park RCRA-CERCLA Coordination

The *Federal Facility Agreement for the Oak Ridge Reservation* (FFA, DOE 2017, DOE/OR-1014) is intended to coordinate the corrective action processes of RCRA required under the *Hazardous and Solid Waste Amendments* permit with CERCLA response actions.

3.3.13 Toxic Substances Control Act Compliance Status—Polychlorinated Biphenyls

On April 3, 1990, DOE notified EPA headquarters (as required by 40 CFR 761.205, *Polychlorinated Biphenyls (PCBS) Manufacturing, Processing, Distribution In Commerce, And Use Prohibitions* [EPA 1979]) that ETTP is a generator with on-site storage, a transporter, and an approved disposer of polychlorinated biphenyl (PCB) wastes.

PCB waste generation, transportation, disposal, and storage at ETTP are regulated under EPA ID number TN0890090004. In 2018, ETTP operated five PCB waste storage areas in ETTP generator buildings, and when longer-term storage of PCB/radioactive wastes was necessary, RCRA-permitted storage buildings were used. These facilities were operated under 40 CFR 761.65(b)(2)(iii) (EPA 1979), which allows PCB storage permitted by the state authorized under Section 3006 of RCRA to manage hazardous waste in containers, and spills of PCBs are cleaned up in accordance with Subpart G of this part. ETTP operated one long-term PCB waste storage area on site where nonradioactive PCB waste was stored in a facility that was not a RCRA-permitted storage facility. The continued use of authorized PCBs in electrical systems and/or equipment (e.g., transformers, capacitors, rectifiers) is regulated at ETTP. At this time, no PCB-contaminated electrical equipment is in service at ETTP. Most TSCA-regulated equipment at ETTP has been disposed of. However, some ETTP facilities continue to use or store non-electrical PCB-contaminated equipment for future reuse.

Because of the age of many ETTP facilities and the varied uses for PCBs in gaskets, grease, building materials, and equipment, DOE self-disclosed unauthorized use of PCBs to EPA in the late 1980s. As a result, DOE ORO and EPA Region 4 consummated a major compliance agreement known as the *Oak Ridge Reservation Polychlorinated Biphenyl Federal Facilities Compliance Agreement* (DOE 2018c, ORR-PCB-FFCA), which became effective December 16, 1996, and was last revised on October 8, 2018, to Revision 6. The modification in 2018 allowed the continued use of the Chuck Vacuum System in Building 9215 and the Foundry Hydraulic System in Building 9998 located at Y-12. The prior modification that took place in 2012 incorporated PCB institutional controls at the TSCA Incinerator where limited areas of contamination remained in place at the facility after the facility closure actions were completed. The PCB institutional controls are also documented in the Oak Ridge Reservation (ORR) Corrective Actions Permit TNHW-165. The institutional controls remained in place until CERCLA demolition activities begun on June 7, 2018, and were completed September 13, 2018. All of the TSCA Incinerator PCB contaminated areas were disposed at the ORR EMWMF landfill.

ORR-PCB-FFCA (DOE 2018c) specifically addresses the unauthorized use of PCBs in ventilation ducts and gaskets, lubricants, hydraulic systems, heat transfer systems, and other unauthorized uses; storage for disposal; disposal; cleanup and/or decontamination of PCBs and PCB items, including PCBs mixed with radioactive materials; and ORR records and reporting requirements. A major focus of the agreement is the disposal of PCB waste. As a result of that agreement, DOE and UCOR continue to notify EPA when additional unauthorized uses of PCBs, such as in paint, adhesives, electrical wiring, or floor tile, are identified at ETTP. This notification process is routinely incorporated into the CERCLA documentation for demolition and remedial actions (RAs).

The ETTP site prepares a PCB Annual Document Log (PCBADL) each year per 40 CFR 761.180(a) (EPA 1979). The written PCBADL is prepared by July 1 of each year and covers the previous CY. The PCBADL documents such things as container inventory, shipments, and PCB spills at the facility. Authorized representatives of EPA may inspect the PCBADL at the facility where they are maintained during normal business hours. The PCBADL must be maintained on site for a minimum of 3 years.

3.3.14 Emergency Planning and Community Right-to-Know Act Compliance Status

The Emergency Planning and Community Right-to-Know Act (EPCRA) that is also identified as Title III of SARA requires that facilities report inventories that exceed threshold planning quantities and releases of hazardous and toxic chemicals. The reports are submitted electronically and are available online for the local emergency planning committee, the state emergency response commission, and the local fire department. ETTP complied with these requirements in 2018 through the submittal of required reports as applicable under EPCRA Sections 302, 311, 312, and 313. ETTP had no reportable releases of hazardous substances or extremely hazardous substances, as defined by EPCRA, in 2018.

3.3.14.1 Chemical Inventories (EPCRA Section 312)

Inventories, locations, and associated hazards of hazardous and extremely hazardous chemicals were submitted in an annual report to state and local emergency responders, as required by EPCRA Section 312. Of the ORR chemicals identified for 2018, 13 were located at ETTP. These chemicals were nickel metal, lead metal (including large, lead-acid batteries), sodium metal, diesel fuel, sulfuric acid (including large, lead-acid batteries), Chemical Specialties Ultrapoles, creosote-treated wood, unleaded gasoline, Sakrete Type S or N mortar mix, Portland cement, CCA Type C pressure-treated wood, Flexterra FGM erosion control agent, and sodium chloride.

3.3.14.2 Toxic Chemical Release Reporting (EPCRA Section 313)

EPCRA Section 313 requires facilities to complete and submit a toxic chemical release inventory (TRI) form (Form R) annually. Form R must be submitted for each TRI chemical that is manufactured, processed, or otherwise used in quantities above the applicable threshold quantity. The reports address releases of certain toxic chemicals to air, water, land, and waste management, recycling, and P2 activities.

Threshold determinations and reports for each of the ORR facilities are made separately. Operations involving TRI chemicals were compared with regulatory thresholds to determine which chemicals exceeded the reporting thresholds based on amounts manufactured, processed, or otherwise used at each facility. After threshold determinations were made, releases and off-site transfers were calculated for each chemical that exceeded the threshold quantity. In 2018, there were no chemicals that met the reporting requirements..

3.4 Quality Assurance Program

3.4.1 Integrated Assessment and Oversight Program

Quality assurance (QA) program implementation and procedural and subcontract compliance are verified through the UCOR integrated assessment and oversight program. The program identifies the processes for planning, conducting, and coordinating assessment and oversight of UCOR activities, including both self-performed and subcontracted activities, resulting in an integrated assessment and oversight process. The program is composed of three key elements (1) external assessments conducted by organizations external to UCOR, (2) independent assessments conducted by teams composed of UCOR personnel who are not directly involved with the project/function being assessed, and (3) management assessments and surveillances conducted as self-assessments and surveillances by the organization or on behalf of the organization manager.

Self-assessments are performed by the organization/function with primary responsibility for the work, process, or system being assessed. Organizations and functions within the company plan and schedule self-assessments. Self-assessments encompass both formal and informal assessments. The formal self-assessments include management assessments and surveillances, and subcontractor oversight. Informal self-assessments include weekly inspections and routine walkthroughs conducted by subcontractor coordinators, ES&H and QA representatives, quality engineers, and line managers.

Conditions adverse to quality identified from internal and external assessments are documented, causal analyses are performed, and corrective actions are developed and tracked to closure. Analyses are conducted periodically to identify trends for management action. Senior management evaluates data from those processes to identify opportunities for improvement.

3.5 Air Quality Program

The state of Tennessee has been delegated authority by EPA to convey the clean air requirements that are applicable to ETTP operations. New projects are governed by construction and operating permit regulatory requirements. The owner or operator of air pollutant emitting sources is responsible for ensuring full compliance with any issued permit or other generally applicable CAA requirement. During 2018, ETTP DOE EM operations were under UCOR responsibility for regulatory compliance.

3.5.1 Construction and Operating Permits

UCOR ETTP operations are subject to CAA regulations and permitting under TDEC Air Pollution Control rules that are specific to stationary fossil-fueled reciprocating internal combustion engines (RICE) for emergency use. TDEC originally issued an operating permit (069346P) covering six stationary emergency RICE units on March 3, 2015. An amended permit was issued on November 22, 2016, that removed one permanently shut down unit. The last operating permit was amended on November 22, 2016, and covered four stationary emergency RICE generators and one stationary emergency RICE firewater booster pump. Three generators have diesel-fueled engines, one generator has a natural gas-fueled engine, and the firewater booster pump engine is diesel fueled. On July 19, 2018, TDEC provided a Notice of Authorization (NOA) to UCOR for coverage under Permit-by-Rule for all of the ETTP stationary emergency RICE.

Although the Permit-by-Rule subsumed the previous operating permit for the ETTP stationary emergency RICE generators and firewater booster pump, the compliance requirements remained the same. Compliance for all units is demonstrated by following specified maintenance schedules, limiting hours of operations for nonemergencies to 100 h per year, and record keeping. Regulations exempt any operating hours of these units during nonscheduled (emergency) power outages.

All other ETTP operations that emit low levels of air pollutants have been classified as insignificant under TDEC rules. Any planned stationary sources that may emit air pollutants are evaluated and compared against applicable pollutant emission limits to document this classification and pursue permitting if required under TDEC regulations.

3.5.1.1 Generally Applicable Permit Requirements

ETTP is subject to a number of generally applicable requirements that involve management and control. Asbestos, ozone-depleting substances (ODSs), and fugitive particulate emissions are specific examples.

Control of Asbestos

ETTP's asbestos management program ensures all activities involving demolitions and all other actions impacting asbestos-containing materials (ACM) are fully compliant with 40 CFR 61, Subpart M, *National Emission Standards for Hazardous Air Pollutants*, "National Emission Standard for Asbestos." This includes using approved engineering controls and work practices, inspections, and monitoring for proper removal and waste disposal of ACM. ETTP has numerous buildings and equipment that contain ACMs. Major demolition activities during 2018 involved the abatement of ACM that were subject to the requirements of 40 CFR Part 61, Subpart M. Most demolition and ACM abatement activities are governed under CERCLA. Under this act, notifications of asbestos demolition or renovations, as specified in 40 CFR Part 61.145(b), are incorporated into CERCLA document regulatory notifications. All other non-CERCLA planned demolition or renovation activities were individually reviewed for applicability of the TDEC notification requirements of the rule. During 2018, seven Notifications of Demolition and/or Asbestos Renovation were submitted to TDEC for non-CERCLA ETTP activities. All of these notifications were for non-asbestos demolition. The rule also requires an annual notification for all nonscheduled, minor asbestos renovations if the accumulated total amount of regulated or potentially regulated asbestos exceeds stipulated thresholds. For 2018, the total ETTP projected nonscheduled amounts were below thresholds that would require the submittal of an annual notification to TDEC. No releases of reportable quantities of ACM occurred at ETTP during 2018.

Stratospheric Ozone Protection

The management of ODSs at ETTP is subject to regulations in 40 CFR Part 82, Subpart F, Recycling and Emissions Reduction; these regulations require preparation of documentation to establish that actions necessary to reduce emissions of Class I and Class II refrigerants to the lowest achievable level have been observed during maintenance activities at ETTP. The applicable actions include, but may not be limited to, the service, maintenance, repair, and disposal of appliances containing Class I and Class II refrigerants, such as motor vehicle air conditioners. In addition, the regulations apply to refrigerant reclamation activities, appliance owners, manufacturers of appliances, and recycling and recovery equipment. Figure 3.7 illustrates the historical onsite ODS inventory at ETTP.

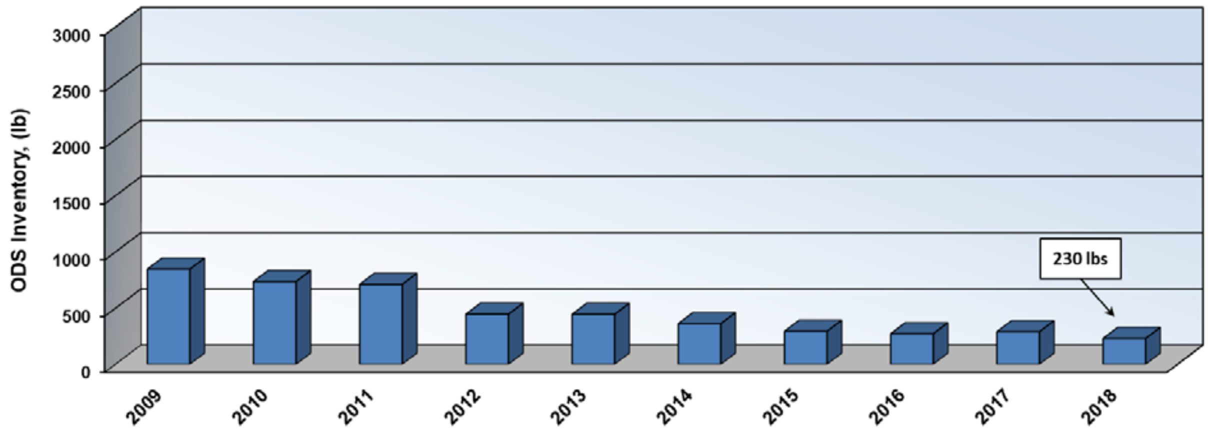


Figure 3.7. East Tennessee Technology Park total onsite ozone-depleting substances inventory, 10-year history

3.5.1.2 Fugitive Particulate Emissions

ETTP has been the location of major building demolition activities, soil remediation activities, and waste debris transportation with the potential for the release of fugitive dust. All planned and ongoing activities include the use of dust control measures to minimize the release of visible fugitive dust beyond the project perimeter. This includes the use of specialized demolition equipment and water misters. Gravel roads in and around ETTP that are under DOE control are wetted with water, as needed, to minimize airborne dusts caused by vehicle traffic.

3.5.1.3 Radionuclide National Emission Standards for Hazardous Air Pollutants

Radionuclide airborne emissions from ETTP are regulated under 40 CFR Part 61, *National Emission Standards for Hazardous Air Pollutants (Rad-NESHAP)*. Characterization of the impact on public health of radionuclides released to the atmosphere from ETTP operations was accomplished by conservatively estimating the dose to the maximally exposed member of the public. The dose calculations were performed using the Clean Air Assessment Package (CAP-88) computer codes, which were developed under EPA sponsorship for use in demonstrating compliance with the 10 mrem/year effective dose Rad-NESHAP emission standard for the entire DOE ORR. Source emissions used to calculate the dose are determined using EPA-approved methods that can range from continuous sampling systems to conservative estimations based on process and waste characteristics. Continuous sampling systems are required for radionuclide-emitting sources that have a potential dose impact of not less than 0.1 mrem per year to any member of the public. ETTP Rad-NESHAP sources that operated during 2018—the K-1407 Chromium Water Treatment System (CWTS) Volatile Organic Compound (VOC) Air Stripper and K-2500-H Segmentation Shop C—are considered minor based on emissions evaluations using EPA-approved calculation methods. A minor Rad-NESHAP source is defined as having a potential dose impact on the public that is less than 0.1 mrem/year. Compliance is demonstrated using data collected by the ETTP ambient air monitoring program described in Section 3.5.2.

Quarterly radiochemical analyses are performed on composited samples collected at all ETTP ambient air sampling stations. The selected isotopes of interest were ^{234}U, ^{235}U, and ^{238}U with the ^{99}Tc inorganic analysis results included as a dose contributor. The concentration and dose results for each of the nuclides are presented in Table 3.3 for the 2018 reporting period.

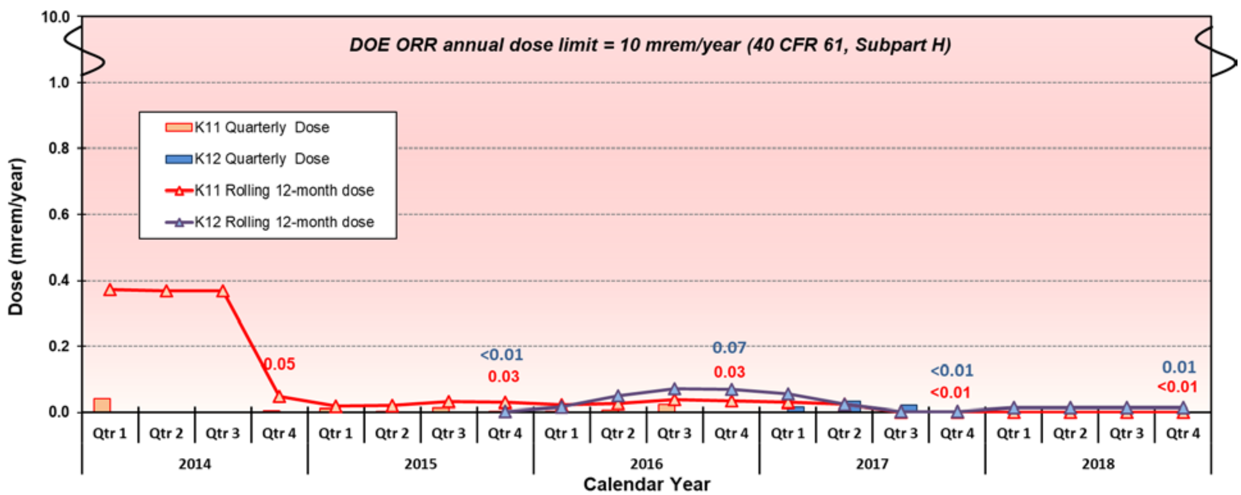
Table 3.3. Radionuclides in ambient air at East Tennessee Technology Park, January 2018 through December 2018

Station	Concentration (μCi/mL)				
	^{99}Tc	^{234}U	^{235}U	^{238}U	
K2[a]	ND[b]	4.38E-18	5.16E-19	ND	
K11[c]	ND	1.41E-17	2.03E-18	1.42E-17	
K12[c]	ND	3.59E-16	1.56E-17	8.98E-17	
	40 CFR 61, Effective Dose (mrem/year)				Total Dose
K2	ND	< 0.001	< 0.001	ND	< 0.001
K11	ND	< 0.01	< 0.01	< 0.01	0.01
K12	ND	0.010	0.001	0.002	0.013

[a] K2 result represents a residential exposure.
[b] ND = not detectable.
[c] K11 and K12 represent an onsite business exposure equivalent to half of a yearly exposure at this location.

Figure 3.8 provides a historical dose trend for the most impacted onsite member of the public if they were located at any of the three sampling locations. Each data point represents the accumulated dose over the previous four quarterly sampling periods. Stations K11 and K12 are near onsite businesses, therefore the estimated doses based upon residential exposures were divided by 2 to account for occupational exposures following approved procedures. This conservatively assumes that the onsite member of the public is at his or her workstation for half of the year.

During 2018, the onsite annual dose remained very low at <0.01 mrem at ambient air station K11. The highest annual dose impact as measured at the ambient air station K12 was 0.013 mrem; this was an increase from 2017 but still very low as compared to the annual dose limit of 10 mrem. The onsite location of K12 was in close proximity to K-29 concrete slab removal that impacted radiologically contaminated materials. The results are based on actual ambient air sampling in a location conservatively representative of onsite business locations. All data continue to show potential exposures are all well below the 10 mrem annual dose limit.



DOE = US Department of Energy ORR = Oak Ridge Reservation

Figure 3.8. East Tennessee Technology Park ambient air stations K11 and K12 radionuclide monitoring results: 5-year rolling 12-month dose history up through 2018

3.5.1.4 Quality Assurance

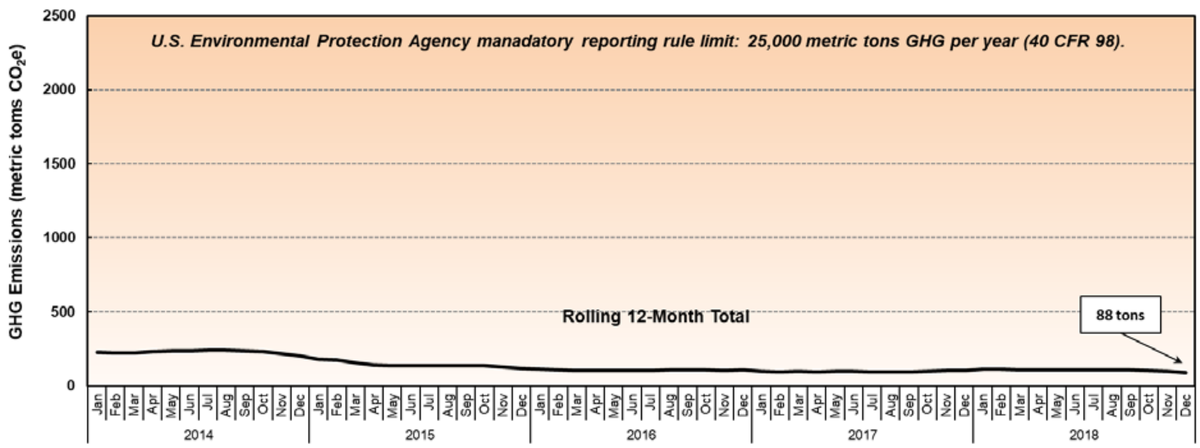
QA activities for the Rad-NESHAP program are documented in the *Quality Assurance Program Plan for Compliance with Radionuclide National Emission Standards for Hazardous Air Pollutants, East Tennessee Technology Park, Oak Ridge Tennessee* (UCOR 2018b, UCOR-4257/R2). The plan satisfies the QA requirements in 40 CFR Part 61, Method 114, for ensuring that the radionuclide air emission measurements from ETTP are representative of known levels of precision and accuracy and that administrative controls (ACs) are in place to ensure prompt response when emission measurements indicate an increase over normal radionuclide emissions. The requirements are also referenced in TDEC regulation 1200-3-11-08, *Emission Standards for Emissions of Radionuclides Other Than Radon From Department of Energy Facilities*. The plan ensures the quality of ETTP radionuclide emission measurement data from continuous samplers and minor radionuclide release points. Only EPA preapproved methods are referenced through the *Compliance Plan National Emission Standards for Hazardous Air Pollutants for Airborne Radionuclides on the Oak Ridge Reservation, Oak Ridge, Tennessee* (DOE/ORO/2196).

3.5.1.5 Greenhouse Gas Emissions

The EPA rule for mandatory reporting of Greenhouse Gases (GHGs) (also referred to as the "Greenhouse Gas Reporting Program") was enacted October 30, 2009, under 40 CFR Part 98. According to the rule in general, the stationary source emissions threshold for reporting is 25,000 MT of CO_2 equivalent (CO_2e) or more of GHGs per year. The rule defines GHGs as:

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)
- Hydrofluorocarbons
- Perfluorocarbons
- Sulfur hexafluoride (SF_6)

A 2018 review was performed of ETTP processes and equipment categorically identified under 40 CFR 98.2 whose emissions must be included as part of a facility annual GHG report starting with the CY 2010 reporting period. Based on total GHG emissions from all ETTP stationary sources during 2018, ETTP did not exceed the annual threshold limit and therefore was not subject to mandatory annual reporting under the GHG rule during this performance period. The total GHG emissions for any continuous 12-month period beginning with CY 2008 have not exceeded 12,390 MT of GHGs. The most significant decrease in stationary source emissions was due to the permanent shutdown of the TSCA Incinerator in 2009. The remaining sources are predominantly small comfort heating systems, hot water systems, and power generators. Figure 3.9 shows the 5-year trend up through 2018 of ETTP total GHG stationary emissions. For the 2018 CY, GHG emissions totaled only 88 MT, which is less than 1 percent of the 25,000 MT per year threshold for reporting.



in carbon dioxide equivalent [CO^2e]; CFR = Code of Federal Regulations; GHG = greenhouse gas

Figure 3.9. East Tennessee Technology Park stationary source greenhouse gas emissions tracking history

Executive Order (EO) 13514, *Federal Leadership in Environmental, Energy, and Economic Performance*, was signed by President Barak Obama on October 5, 2009. The purpose of this order was to establish policies for federal facilities that will increase energy efficiency; measure, report, and reduce GHG emissions from direct and indirect activities; conserve and protect water resources through efficiency, reuse, and storm water management; eliminate waste; recycle; and prevent pollution at all such facilities. While the order deals with a number of environmental media, only its applicability to GHG is considered here. The EO defines three distinct scopes for purposes of reporting:

1. Scope 1 is essentially direct GHG emissions from sources that are owned or controlled by a federal agency.
2. Scope 2 encompasses GHG emissions resulting from the generation of electricity, heat, or steam purchased by a federal agency.
3. Scope 3 involves GHG emissions from sources not owned or directly controlled by a federal agency, but related to agency activities, such as vendor supply chains, delivery services, and employee business travel and commuting.

One goal of this order was to establish a FY 2020 Scope 1 and Scope 2 reduction target of 28 percent, as compared to the 2008 baseline year.

EO 13693, *Planning for Federal Sustainability in the Next Decade*, was signed and issued on March 25, 2015. This order supersedes EO 13514 and established a new Scope 1 and Scope 2 total reduction target of 40 percent by 2025, as compared to the 2008 baseline year. For reporting purposes, GHG emission data are compared to both goals.

The information reported here includes GHG emissions from the industrial landfills at Y-12 that are managed and operated by UCOR. The landfills are not part of the contiguous ETTP site; however, DOE requested that UCOR, as the operator, include landfill GHG emissions with ETTP reporting in the Consolidated Energy Data Report. To be consistent with reporting this information, the landfill emissions are also included with ETTP ASER data. Figure 3.10 shows the trend toward meeting both the original EO 13514 28 percent total Scope 1 and 2 GHG emissions reduction target by FY 2020 and the current EO 13693 40 percent goal by FY 2025.

With respect to EO 13514, emissions for FY 2018 Scope 1 and 2 including the landfills totaled 19,731 MT CO_2e, roughly 47 percent below the FY 2020 target level of 37,478 MT CO_2e and a 62 percent reduction to date compared to the FY 2008 baseline year level of 52,053 MT. When compared to the EO 13693 target, FY 2018 data show that the targeted 40 percent reduction has already been achieved by comparing the FY 2018 total of 19,731 MT to the 40 percent target level of 31,232 MT.

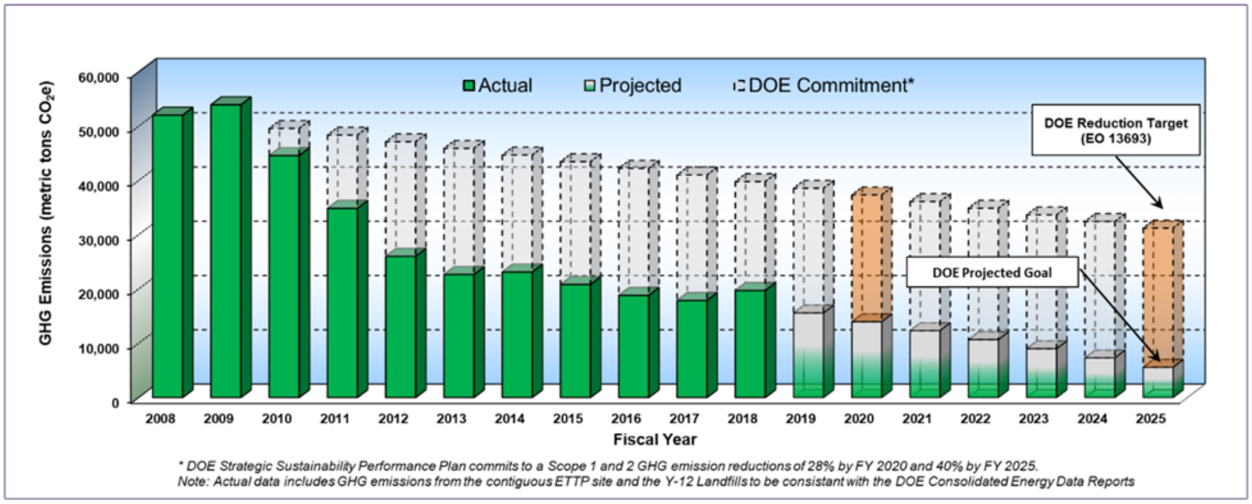
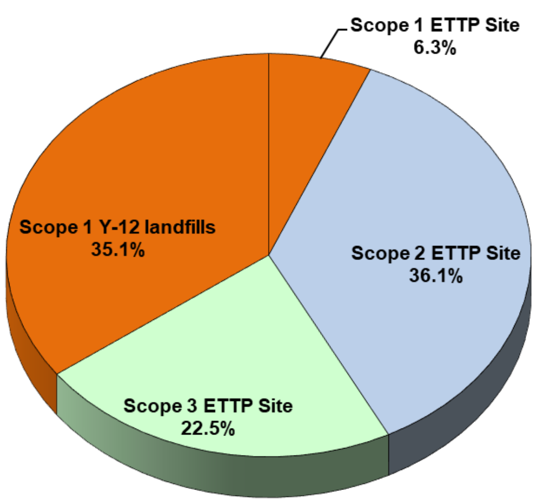


Figure 3.10. East Tennessee Technology Park greenhouse gas emissions trend and targeted reduction commitment

Figure 3.11 shows the relative distribution and amounts of all ETTP FY 2018 GHG emissions for Scopes 1, 2, and 3 including the landfills. Total GHG emissions remain well below the levels first reported in the 2008 baseline year as demolition and remediation efforts continue at ETTP. Many of the early reductions were due to lower onsite combustion of fuels (stationary and mobile sources), lower consumption of electricity, and a smaller workforce. The total amount of GHG emissions for FY 2018 was 25,454 tons, as compared to the 23,709 tons for FY 2017. Total reduction to date starting with the 2008 baseline year of 61,453 tons of GHG emissions is 58.6 percent.



ETTP FY 2018 Greenhouse Gas Emissions: 25,454 tons

Scope 1: ETTP Site Releases
Onsite stationary fossil fuel combustion, 108 tons
Onsite releases of freons and SF_6, 351 tons
Onsite mobile source fuel combustion, 1,156 tons

Scope 1: Y-12 Industrial Landfills
Y-12 Industrial Landfills, 8,924 tons

Scope 2: Indirect GHG Releases
Electricity purchase, 9,192 tons

Scope 3: Indirect GHG Releases
Business alr travel, 51 tons
Business ground travel, 24 tons
Employee commuting, 5,639 tons
Contracted wastewater treatment, 9 tons

ETTP = East Tennessee Technology Park
GHG = greenhouse gas
SF_6 = sulfur hexafluoride)
Y-12 = Y-12 National Security Complex

Figure 3.11. FY 2018 East Tennessee Technology Park greenhouse gas emissions by scope, as defined in Executive Order 13514

3.5.1.6 Source-Specific Criteria Pollutants

ETTP operations included one functioning minor stationary source, the CWTS, with a potential to emit any form of criteria air pollutant. This unit is equipped with an air stripper to remove VOCs from the effluent stream. All process data records and the calculated potential maximum VOC emission rates for the CWTS air stripper were below levels that would require permitting. The calculated VOC annual emissions during 2018 for CWTS were only 0.013 ton/year as compared to an emission limit of 5 tons/year. The annual potential emissions for this facility would be well below the 5 ton/year limit assuming it operated at the maximum hourly emission rate continuously for the entire year.

Federal regulations amended in January of 2013 require TDEC permitting for existing and new stationary RICE-powered emergency generators and firewater booster pumps (i.e., emergency or e-RICE). Permitting actions do not apply to e-RICE covered under CERCLA projects. However, specific maintenance and recordkeeping requirements specified in the federal regulations are applicable to CERCLA projects operating e-RICE. The 2018 operations included four e-RICE powered emergency generators (K-1007, K-1039, K-1095, and K-1652), and one e-RICE powered firewater booster pump (K-1310-RW). During 2016 the K-802 e-RICE powered firewater booster pump was permanently removed from service. TDEC issued an amended permit with an effective date of November 22, 2016. The expiration date of the amended permit is October 1, 2024. TDEC issued a Notice of Authorization (NOA) to UCOR on July 19, 2018, for e-RICE at ETTP to operate under the Permit-by-Rule provisions of Rule 1200-03-09-.07 for stationary emergency internal combustion engines. This authorization (number R74133) subsumed the previous operating permit.

Regulations limit e-RICE nonemergency and maintenance operations to 100 h of operations per 12-month rolling total (i.e., 100 h of running the engines for testing and maintenance purposes per year). Additionally, nonemergency operations are limited to 50 h of the 100-h annual limit. The current permit specifies conditions that must be met to demonstrate compliance. These requirements include performing scheduled maintenance, record keeping, and tracking the run times of each of the five permitted units. Copies of all maintenance activities are provided for permit compliance review, and the runtimes are entered into spreadsheets to track against annual limits. Table 3.4 provides the number of hours of operations for each unit, up through December 31, 2018.

Table 3.4. East Tennessee Technology Park UCOR emergency reciprocating internal combustion engine air permit compliance demonstration, 2018

e-RICE Unit	Permit limits: Total hours/year = 100		Nonemergency hours/year = 50	
	PM Testing (hours/year)	Nonemergency (hours/year)	Total (hours/year)	Emergency (hours/year)
K-1007	6.0	1.2	7.2	3.9
K-1039	6.0	0.1	6.1	1.5
K-1095	6.0	10.9	16.9	0.0
K-1310-RW	5.5	23.8	29.3	0.0
K-1407[a]	3.7	0.5	4.2	2.6
K-1652	6.0	26.8	32.8	6.5

[a] K-1407 e-RICE operating under CERCLA and exempt from TDEC air emission permitting.

e-RICE = emergency reciprocating internal combustion engine
PM = particulate matter
TDEC = Tennessee Department of Environment and Conservation
UCOR = UCOR, an AECOM-led partnership with Jacobs

ETTP operations released airborne pollutants from a variety of minor pollutant-emitting sources, such as stacks, vents, and fugitive and diffuse activities. The emissions from all stacks and vents are evaluated following approved methods to establish their low emissions potential. This is done to verify and document their minor source permit exempt status under all applicable state and federal regulations.

3.5.1.7 Hazardous Air Pollutants (Nonradionuclide)

Unplanned releases of hazardous air pollutants (HAPs) are regulated through the risk management planning regulations under 40 CFR Part 68. To ensure compliance, periodic inventory reviews of ETTP operations were performed that used monthly data obtained through the EPCRA Section 311 reporting program. This program applies to any facility at which a hazardous chemical is present in an amount exceeding a specified threshold. A comparison of the EPCRA 311 monthly Hazardous Materials Inventory System (HMIS) chemical inventories at ETTP with the risk management plan (RMP) threshold quantities listed in 40 CFR 68.130 was conducted. This is an ongoing action that documents the potential applicability for maintaining and distributing an RMP and to ensure threshold quantities are not exceeded.

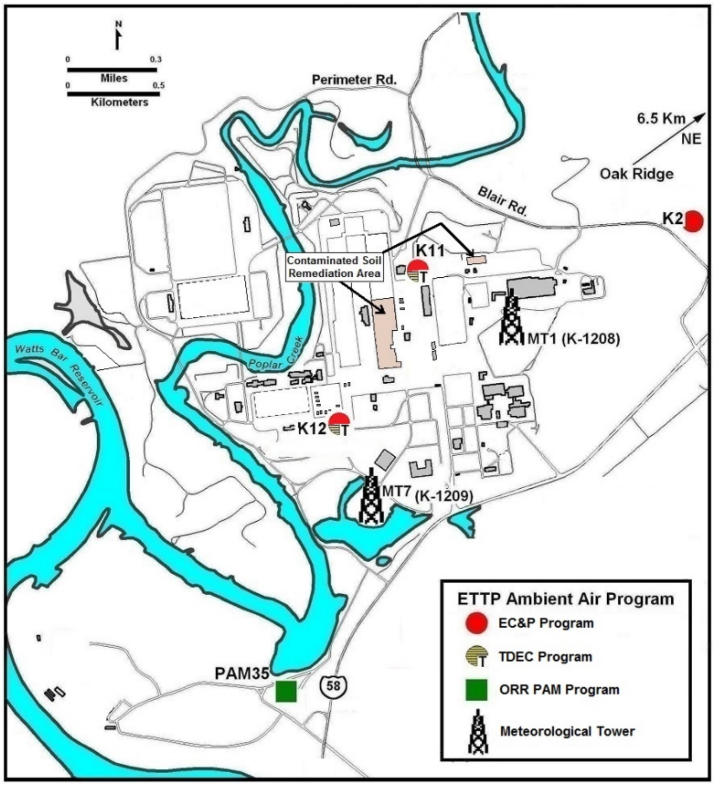
ETTP personnel have determined that there are no processes or facilities containing inventories of chemicals in quantities exceeding thresholds specified in rules pursuant to CAA, Title III, Section 112(r), “Prevention of Accidental Releases.” Therefore, activities at ETTP are not subject to the rule. Procedures are in place to continually review new processes, process changes, or activities with the rule thresholds.

3.5.2 Ambient Air

Compliance of fugitive and diffuse sources is demonstrated based on environmental measurements. The ETTP Ambient Air Quality Monitoring Program is designed to provide environmental measurements to accomplish the following:

- Tracking of long-term trends of airborne concentration levels of selected air contaminant species.
- Measurement of the highest concentrations of the selected air contaminant species that occur in the vicinity of ETTP operations.
- Evaluation of the potential impact on air contaminant emissions from ETTP operations on ambient air quality.

The three sampling programs in the ETTP area are designated as the EC&P program, TDEC program, and the ORR perimeter air monitoring (PAM) program. Figure 3.12 shows the locations of all ambient air sampling stations in and around ETTP that were active during the 2018 reporting period. Figure 3.13 shows an example of a typical EC&P program air monitoring station.



ETTP = East Tennessee Technology Park
MT = meteorological tower
ORR = Oak Ridge Reservation
PAM = perimeter air monitoring
TDEC = Tennessee Department of Environment and Conservation

Figure 3.12. East Tennessee Technology Park ambient air monitoring station locations

The EC&P program consisted of three sampling locations throughout 2018. All projects are operating similar high-volume sampling systems. The EC&P, TDEC, and PAM samplers operate continuously with exposed filters collected weekly. The radiological monitoring results for samples collected at the one ETTP area PAM station are the responsibility of UT-Battelle, LLC. TDEC is responsible for the data collected from their two samplers. UT-Battelle, LLC and TDEC results are not included with the EC&P data presented in this section. However, periodic requests for results from the other programs are made for comparison purposes.

The analytical parameters were chosen with regard to existing and proposed regulations and with respect to activities at ETTP. The principle reason for EC&P program stations is to demonstrate that radiological emissions from the demolition of ETTP gaseous diffusion buildings, supporting structures, and associated remediation activities are in compliance with the annual dose limit to the most exposed members of the public that is either onsite (on the ORR) or offsite. K12 remained a key sampling location regarding the potential dose impact on the most exposed member of the public at an onsite business location during the demolition and debris removal of the last gaseous diffusion building on the ETTP site.

Changes of emissions from ETTP will warrant periodic reevaluation of the parameters being sampled. Ongoing ETTP reindustrialization efforts will also introduce new locations for members of the public that may require adding or relocating monitoring site locations. To ensure understanding of the potential impacts on the public and to establish any required emissions monitoring and emissions controls, a survey of all onsite tenants is reviewed every 6 months through a request for the most recent ETTP reindustrialization map.

Figure 3.13. East Tennessee Technology Park ambient air monitoring station

All EC&P program stations collected continuous samples for radiological analyses during 2018. Radiological analyses of samples from the EC&P stations test for the isotopes ^{234}uranium (^{234}U), ^{235}uranium (^{235}U), and ^{238}uranium (^{238}U).

Station K2 is in the prevailing topography of influenced downwind directions that are for identifying the impact to offsite members of the public. Stations K11 and K12 are located to provide a conservative measurement of the impact to onsite members of the public.

3.6 Water Quality Program

3.6.1 NPDES Permit Description

The latest ETTP NPDES permit became effective on April 1, 2015. It is scheduled to expire on March 31, 2020. A total of 27 representative outfalls are monitored on an annual basis for oil and grease, TSS, pH, and flow. Outfall 170 is monitored quarterly for total chromium and hexavalent chromium. ETTP NPDES permit monitoring requirements for storm water outfalls are shown in Tables 3.5 and 3.6.

Table 3.5. Representative outfalls

(Outfalls 05A, 100, 142, 150, 170, 180, 190, 195, 198, 230, 280, 294, 334, 350, 430, 490, 510, 560, 660, 690, 694, 700, 710, 724, 890, 930, and 992)

Parameter	Qualifier	Value	Unit	Sample Type	Frequency	Statistical Base
Flow	Report	-	million gallons per day (MGD)	Estimate	Annual	Daily Maximum
Oil & Grease	Report	-	mg/L	Grab	Annual	Daily Maximum
Total Suspended Solids (TSS)	Report	-	mg/L	Grab	Annual	Daily Maximum
pH	≥ 6.0 and ≤ 9.0	-	SU	Grab	Annual	Daily Minimum and Daily Maximum

Table 3.6. Storm Water Outfall 170 for chromium monitoring

Parameter	Qualifier	Unit	Sample Type	Frequency	Report
Chromium, hexavalent (as Cr)	Report	mg/L	Grab	Quarterly	Daily Maximum
Chromium, total (as Cr)	Report	mg/L	Grab	Quarterly	Daily Maximum

In addition to periodic monitoring requirements specified in the ETTP NPDES permit, several additional monitoring efforts were included to support the CERCLA actions that are ongoing at ETTP. This monitoring was conducted as part of the Storm Water Pollution Prevention (SWPP) Program and/or the ETTP Biological Monitoring and Abatement Program (BMAP).

3.6.1.1 Flux Monitoring

For bioaccumulative pollutants such as mercury, a long-term monitoring of pollutant loadings (known as flux) was conducted. This flux monitoring included the following:

- Flow Monitoring

  For Outfalls 100, 170, 180, and 190, field-installed flow meters were used to gauge flows for various ranges of rain events during the permit term at each outfall.

- These flows were used to compare against flows generated using the Natural Resources Conservation Service (NRCS) Technical Report-55 (TR-55, NRCS 1986), the current flow modeling technique used at ETTP, to increase the accuracy of the TR-55 flow modeling process.

- Mercury Monitoring

  Mercury was sampled at Outfalls 180 and 190 using the flow-weighted sampling technique. Specific sample collection guidelines were included as part of SWPP Program sampling and analysis plans (SAPs).

- Flux Calculation

  Flow monitoring results were used to calibrate the variable inputs to the TR-55 flow model. Flow-paced mercury samples were also collected at Outfalls 180 and 190. Results from the analyses of these samples are being used with the revised flow models in order to determine mercury flux at Outfalls 180 and 190.

3.6.1.2 RA Activities, CERCLA, and Legacy Pollutant Monitoring

- Storm water samples have been collected at locations that are affected by RA activities prior to the initiation of these activities in order to determine the conditions present before remediation begins. In addition, storm water samples were collected at potentially affected outfalls and storm water catch basins after remedial activities had been undertaken, and after they had been completed, to help gauge the effectiveness of the remediation efforts.
- The results of the monitoring effort at the D&D sites, which are a subset of remedial activities, are utilized in determining the effectiveness of best management practices (BMPs) in controlling off-site releases of legacy pollutants.
- Periodic monitoring was performed as part of the ETTP SWPP Program to monitor the continued effectiveness of the chromium collection system.

3.6.1.3 Permit Renewal Sampling

- Sampling required for the completion of the NPDES permit application was initiated in FY 2015 as part of the ETTP SWPP Program. The application for this permit renewal is required to be submitted to TDEC by October 1, 2019, for a 180-day review prior to permit expiration on March 31, 2020. Additionally, DOE will require time to review the permit application before it is submitted to TDEC. Based on previous TDEC guidance, composite samples were collected as time-weighted composites due to the short travel time for storm water runoff in the storm drain piping system and to site conditions within the watersheds. Monitoring was conducted to ensure all required samples were collected to complete EPA Form 2F, *Application for Permit to Discharge Storm Water Discharges Associated with Industrial Activity* for each representative outfall
- The following sampling was conducted:

  Representative outfalls were sampled to ensure completion of EPA Form 2F, Section VII, Discharge Information, Parts A, B, and C, as required:

- Part A—Parameters were collected in compliance with Form 2F. Oil and grease, total nitrogen, total phosphorus, and pH were collected as grab samples per EPA guidance. Biochemical oxygen demand, chemical oxygen demand, and total suspended solids (TSS) were collected as either grab samples or as time-weighted composites.
- Part B—All facilities generating process wastewater at ETTP have been closed, and the respective NPDES permits have expired. Therefore, ETTP is no longer subject to any effluent guidelines, and there are no sampling requirements under Part B at any storm water outfall at ETTP.
- Part C—Each representative storm water outfall was sampled only for pollutants that could potentially be present based on the characteristics and uses of the drainage area for that outfall. The potential pollutants to be considered for monitoring are shown in Tables 2F-2, 2F-3, and 2F-4 of EPA Form 2F. Based upon historical site knowledge and analytical monitoring results, metals, mercury, and PCBs were collected from all representative outfalls. In addition, each representative outfall was evaluated, and VOCs, radionuclides, and other selected parameters

were collected as required. Part C parameters that must be collected by grab sample, per analytical method or regulatory guidance, were collected as grab samples only. All other Part C parameters were collected as time-weighted composites only.

3.6.1.4 Investigative Sampling

- Investigative sampling was performed as part of the ETTP SWPP Program. This included sampling of storm drain networks for bioaccumulative parameters and investigations triggered by analytical results, CERCLA requirements, changes in site conditions, etc. (UCOR 2018b, UCOR-4028, *East Tennessee Technology Park Storm Water Pollution Prevention Program Sampling and Analysis Plan, Oak Ridge, Tennessee).*
- Storm water sampling results were reviewed and evaluated to provide feedback for the next round of investigative sampling, generate suggested modifications and improvements to storm water runoff controls, and provide input for CERCLA project cleanup decisions.

3.6.2 Storm Water Pollution Prevention Program

3.6.2.1 Radiologic Monitoring of Storm Water

ETTP conducts radiological monitoring of storm water discharges to determine compliance with applicable dose standards. ETTP also applies the as low as reasonably achievable (ALARA) process to minimize potential exposures to the public. Sampling for gross alpha and gross beta radioactivity, as well as specific radionuclides, is conducted as part of the ongoing SWPP Program sampling efforts. Analytical results are used to estimate the total discharge of each radionuclide from ETTP via the storm water discharge system.

As part of the ETTP SWPP SAP, storm water samples were collected from discharges that occurred after a storm event that (1) was greater than 0.1 in. in 24 h, and (2) occurred at least 72 h after a rain event greater than 0.1 in. in 24 h. No specified dry period was required before the samples were taken. A series of at least three manual grab samples of equal volume were collected during the first 60 min of a storm event discharge, and combined into a composite sample.

Table 3.7 contains the results of this sampling effort. Screening levels for individual radionuclides are established at 4 percent of the derived concentration standards (DCS) values listed in DOE Standard 1196 (DOE 2011b, DOE-STD-1196). Table 3.8 lists the cumulative activity levels of each of the major isotopes that were discharged from the overall ETTP storm water system in 2018.

Table 3.7. Analytical results for radiological monitoring at ETTP storm water outfalls

Parameter	Screening level	Outfall 198	Outfall 382	Outfall 660	Outfall 750	Outfall 760
Alpha activity (pCi/L)	15	1.95 U	**22.5**	2.82 U	4.17 U	3.11 U
Beta activity (pCi/L)	50	5.38	8.8	2.1 U	5.07	1.44 U
^{99}Tc (pCi/L)	1760	1.32 U	5.59 U	-2.28 U	4.08 U	3.34 U
$^{233/234}$U (pCi/L)	28	0.46 U	10.3	1.1	3.46	2.16
$^{235/236}$U (pCi/L)	29	0.164 U	0.9	0.0477 U	0.704	0.295 U
^{238}U (pCi/L)	30	0.154 U	10	0.787	2.35	1.02

Bold indicates screening level exceeded.

Table 3.8. Radionuclides released to off-site waters from the ETTP storm water system in 2018 (Ci)

Isotope	^{234}U	^{235}U	^{238}U	^{99}Tc
Activity level	8.4 E-3	7.2 E-4	4.5 E-3	1.2 E+1

The only screening criterion exceeded as part of this sampling effort was gross alpha radiation at Outfall 382. Outfall 382 receives storm water runoff from a portion of Bldg. K-131. Operations in this facility included uranium hexafluoride (UF_6) feed enrichment, as well as uranium recovery from decontamination solutions. Discharges from this outfall have historically contained radiological contaminants at levels above screening criteria due to past operations at the K-131 building.

No screening criteria were exceeded at Outfalls 198, 660, 750, or 760.

On January 4, 2018, a sanitary water line break occurred near the K-2500-H segmentation shop (the “seg shop”), which is located in the K-25 Building Footprint. Based on the type of operations that have been and continue to be conducted at the facility, the seg shop is known to contain radiological contamination. Water from the sanitary water line break entered the Outfall 240 drainage system. No samples of the water from the water line break could be collected at the time of the incident. To determine if there was any impact to the Outfall 240 network from this water line break, samples were collected from Outfall 240 for isotopic uranium and ^{99}technetium (^{99}Tc) at the outfall during the next rainfall event after the water line break, which occurred on February 7, 2018.

As shown in Table 3.9, no radiological parameters were detected at levels exceeding screening levels as part of this sampling effort. The sanitary water line break was determined not to have negatively impacted the discharge from the Outfall 240 drainage system.

Table 3.9. Analytical results for radiological monitoring at Outfall 240

Parameter	Screening level	Outfall 240
^{99}Tc (pCi/L)	1760	0.763 U
$^{233/234}$U (pCi/L)	28	20.7
$^{235/236}$U (pCi/L)	29	2.11
^{238}U (pCi/L)	30	3.4

3.6.3 D&D of the K-633 Test Loop Facility

K-633 was built in 1954 and operated until 1985 to test and evaluate performance of gaseous diffusion process equipment under production conditions. Isotopically depleted UF_6 inventory for various process loops was provided in via the distribution header from the K-31 building. Recirculating cooling water (RCW), R 114 process coolant, a recirculating compressor, motor lubrication systems, a compressor seal feed, and exhaust system were provided as auxiliary process support.

Demolition activities began at the K-633 facility in February 2018. Initial sampling was performed at Outfall 420 before demolition begins to provide baseline data. Sampling was also conducted following each qualifying rain event while D&D activities were being conducted. Storm water runoff monitoring was performed for the duration of demolition and waste handling activities, as well as for any potential post-demolition mitigation actions. A final monitoring event was conducted at the conclusion of demolition, waste handling, and potential post-demolition mitigation actions.

For collection of storm water samples at the K-633 D&D project, a qualifying rain event is defined as a rain event that: 1) produces 1 in. or greater measured rainfall within a 24-h period; 2) causes runoff to be present at the outfall; and 3) occurs after a dry period of at least 72 h. A dry period means no measurable rainfall (0.1 in. or greater) occurs within a 72-h period. Parameters that were sampled as part of the K-633 D&D storm water runoff monitoring activities include isotopic uranium, ^{99}Tc, PCBs, metals, mercury, hexavalent chromium, and TSS.

Initial sampling to provide baseline data for storm water Outfall 420 was performed on February 12, 2018, after a rainfall event of 5.3 in. (over a 2-day period). No screening criteria exceedances were noted in the analytical results from this sampling event. A sampling event was conducted on April 23, 2018, during D&D activities. These samples were collected after a rainfall event of 1.01 in., which occurred over a 2-day period. No screening criteria exceedances were noted in the analytical results from this sampling event.

Final D&D of the K-633 building was completed in June 2018. No qualifying rainfall events that created flow at Outfall 420 have occurred from the time of the completion of D&D activities at K-633 until September 2018. Post D&D monitoring was conducted at Outfall 420 on September 26, 2018, during a rainfall event of 5.1 in. over a 3-day period. PCB-1254 was detected at a level of 0.0714 ug/L. A follow-up sample was collected on November 6, 2018, to determine if PCB levels could still be detected in runoff from the K-633 area. Samples were collected during a rainfall event of 0.39 in. over 3 days. PCB-1254 was detected in this sample at a level of 0.087 ug/L. Additional PCB data will be collected at Outfall 420 as part of ongoing monitoring activities.

3.6.4 D&D of the K-1314-G, H, and J Facilities

In the 1990s, buildings K-1314-G, H, and J were constructed adjacent to the K-1066-E UF_6 cylinder yard. The buildings functioned as a location where UF_6 cylinders could be sandblasted and repainted. The paint that had originally been applied to the UF_6 cylinders contained PCBs; therefore, the K-1314 buildings and the concrete pad they were built on became contaminated with PCBs.

D&D of these buildings was initiated in the first quarter of CY 2018. These buildings are located in the storm water Outfall 387 drainage area. Outfall 387 is listed on the ETTP NPDES permit, but it is not a representative outfall. No samples had been collected from the outfall in almost 20 years. Because very limited analytical data was available on discharges from Outfall 387, a relatively wide range of background data was collected from the outfall before D&D actions began at the K-1314 buildings. Parameters that were sampled as part of the K-1314 facilities D&D storm water runoff monitoring activities include isotopic uranium, ^{99}Tc, PCBs, metals, mercury, hexavalent chromium, and TSS. Samples for PCBs and TSS were to be collected any time the outfall was observed to be discharging during demolition of these facilities. Also, samples were to be collected after all D&D activities had been completed at these buildings.

On February 26, 2018, samples of the discharge from Outfall 387 were collected before demolition of the K-1314 buildings was initiated. No qualifying rainfall events occurred during the time D&D activities were being conducted at these buildings. D&D activities at the K-1314 buildings were completed in early April 2018. Samples were collected on June 25, 2018, after demolition of the K-1314 buildings had been completed. Results over screening levels are presented in Table 3.10.

Table 3.10. Analytical results over screening levels from sampling at Outfall 387

	Date sampled	PCB-1260 Screening level detectable
Outfall 387	2/26/18 (prior to D&D activities)	0.0555 µg/L
	6/25/18 (after completion of D&D activities)	0.0489 µg/L

Additional PCB data may be collected at Outfall 387 as part of ongoing storm water monitoring activities.

3.6.5 D&D of the TSCA Incinerator

As part of the Closure Certification Report (CCR) for the Toxic Substances Control Act of 1976 (TSCA) Incinerator (TSCAI) submitted to EPA by DOE, institutional controls were established for the closed TSCAI. One of these institutional controls mandated the monitoring of storm water runoff from the facility until it could be demolished under CERCLA. In order to meet the storm water monitoring requirement of the CCR, sampling of storm water runoff from the TSCAI area was conducted during the first quarter of CY 2018. Samples were collected from Outfall 142, which receives storm water drainage from the combustion portion of TSCAI, and from Outfall 144, which receives storm water drainage from the storage tank area of TSCAI.

To meet the requirements for this storm water sampling effort at the TSCAI area, grab samples were to be collected at Outfalls 142 and 144 for PCBs, isotopic uranium, and TSS during a storm event. These samples could be collected any time these outfalls were found to be flowing during a storm event and did not have to be first flush runoff samples.

Sampling at Outfall 142 was conducted during a storm event of 0.29 in. that occurred on January 8, 2018. No parameters exceeded screening levels as part of this sampling event. Sampling at Outfall 144 was conducted on January 29, 2018, after a storm event of 0.89 in. No parameters exceeded screening levels at Outfall 142 or Outfall 144 as part of this sampling effort. Storm water runoff from TSCAI will continue to be sampled on an annual basis as part of the CCR requirements.

Demolition activities began at the TSCAI facilities in June 2018 and were completed in September 2018. Environmental monitoring of storm water effluent for TSCAI facilities demolition was performed in accordance with UCOR-4028 (UCOR 2018b). A baseline sample from Outfall 140 was not able to be obtained prior to demolition activities due to insufficient flow at the outfall. Since a qualifying rainfall event did not occur prior to demolition, historical sampling data from Outfall 142 was used as baseline data.

Since demolition was initiated, monitoring was performed at Outfall 140 during each qualifying rain event for the duration of demolition activities if sufficient flow was present at the outfall. Samples were analyzed for PCBs, metals, mercury, TSS, hexavalent chromium, gross alpha/gross beta radiation, isotopic uranium, and transuranics. A qualifying rain event is defined as a rain event that (1) produces 1 in. or greater measured rainfall within a 24-h period, (2) causes runoff to be present at the outfall, and (3) occurs after a dry period of at least 72 h. A dry period means no measurable rainfall (0.1 in. or greater) occurs within a 72-h period.

As stated previously, no qualifying rainfall events occurred prior to initiation of D&D activities at TSCAI, so no pre-D&D baseline samples were collected at Outfall 140. The first monitoring event at Outfall 140 was conducted on August 20, 2018, while D&D activities were underway. Samples were collected during a rainfall of approximately 1 in. over a 5-day period. There were no screening level exceedances in any of the data received from the laboratory. Additional samples were collected at Outfall 140 on September 25, 2018, after a rainfall event of 1.64 in. There were no screening level exceedances in any of the data received from the laboratory. Final sampling after the D&D of the TSCAI was conducted on December 31, 2018, after a rainfall event of 0.62 in. Again, no screening level exceedances were observed in any of the data received from the laboratory.

3.6.6 D&D of K-1232 Facility

K-1232 was built in 1974. The facility was operated in conjunction with K-1231 to process uranium process material until 1980. Beginning in 1984, K-1232 was used to treat corrosive wastewaters from Y-12 by neutralization, metal removal, and carbon filtration. Two types of Y-12 wastes were treated, nitrate wastes and non-nitrate wastes. The nitrate wastes were basic solutions contaminated with nitrates, heavy metals, organics, and small amounts of uranium. The non-nitrate waste included plating wastewaters and cleaning solutions from production facilities.

For collection of storm water samples at the K-1232 D&D project, a qualifying rain event was defined as a rain event that (1) produced 1 in. or greater measured rainfall within a 24-h period, (2) caused runoff to be present at the outfall, and (3) occurred after a dry period of at least 72 h. A dry period means no measurable rainfall (0.1 in. or greater) occurs within a 72-h period. Parameters to be monitored include PCBs, metals, mercury, TSS, VOCs, SVOCs, isotopic uranium, and hexavalent chromium.

Demolition activities began at the K-1232 facility in September 2018. Initial sampling was performed at Outfall 380 on August 20, 2018, before demolition began in order to provide baseline data. Analytical results that exceeded screening levels are shown in Table 3.11.

Table 3.11. Results over screening levels for the K-1232 pre-D&D monitoring

Sampling location	Copper (pCi/L)	Lead (µg/L)	Mercury (ng/L)	Cadmium (µg/L)
Screening Level	7	1.8	51	Detectable
Outfall 380	7.72	28.2	119	0.626

Storm water monitoring was conducted on January 24, 2019, after the conclusion of demolition, waste handling, and post-demolition mitigation actions. No parameters were detected above screening levels as part of this monitoring effort.

3.6.7 D&D of the K-25 Building

Final D&D activities were completed for the K-25 building in July 2014. In order to assess any ongoing impacts, the remaining K-25 building slab has on the quality of the storm water runoff, monitoring of runoff from the slab is performed on an annual basis. Runoff samples are collected at Outfall 490 to monitor east wing slab runoff; runoff from Outfall 334 is sampled to monitor west wing slab runoff; and Outfall 230 was sampled to monitor north end slab runoff. Samples from each of these locations are analyzed for gross alpha/gross beta radiation, isotopic uranium, PCBs, metals, mercury, and total suspended solids. Because sampling of the K-25 building slab runoff requires a fairly heavy and intense rain event, samples were collected when runoff was sufficient to allow all of the samples for the given analytical parameters to be collected, regardless of the amount or intensity of the rainfall event. All samples collected as part of this effort were taken using the manual grab sampling method. Manual grab samples were collected according to the guidelines specified in Sects. 3.1.2 and 3.3.1 of the EPA's *NPDES Storm Water Sampling Guidance Document* (EPA 1992, EPA 833-B-92-001) and applicable procedures developed by the sampling subcontractor. Analytical results from this sampling effort that exceeded screening levels are shown in Table 3.12. None of the data from Outfall 230 exceeded the screening limit.

Table 3.12. Analytical results exceeding screening levels in samples of K-25 building slab runoff

Sampling location	Lead	Gross beta radiation
	Screening level 1.8 µg/L	Screening level 50 pCi/L
West wing (Outfall 334)	5.69 J	
East wing (Outfall 490)		60.8

In order to collect data that is to be reported in the remediation effectiveness report (RER) and the ASER, and to collect data that can be compared to information that is being gathered by TDEC on an ongoing basis, a sample for ^{99}Tc is collected at Outfall 190 each time a quarterly mercury sample is collected at this outfall. The analytical data from this sample will assist in determining if groundwater contaminated with ^{99}Tc from the K-25 D&D project could be migrating toward the Outfall 190 drainage area and discharging into Mitchell Branch via Outfall 190. Table 3.13 contains analytical data from CY 2016 through part of CY 2018 for this monitoring effort.

As shown in Table 3.13, the storm water results for the Mitchell Branch watershed area indicate that ^{99}Tc was not detected in samples collected at Outfall 190 during CY 2017 except during the third quarter of the FY. Technetium-99 was not detected at all during sampling conducted in CY 2018. Based on this data, it does not appear that ^{99}Tc-contaminated groundwater from the K-25 building D&D project is discharging to Mitchell Branch via storm water Outfall 190.

As shown in Figure 3-14, the cumulative radionuclide measurements at the Mitchell Branch exit weir K-1700 location are calculated to be less than 1 percent of the DCS sum of fractions (SOF) values. The maximum ^{99}Tc measurement at K-1700 was 19.8 pCi/L, which is orders of magnitude below the ^{99}Tc

DCS value of 44,000 pCi/L and the drinking water maximum contaminant level (MCL)-derived concentration (DC) of 900 pCi/L.

Table 3.13. Results from quarterly ^{99}Tc sampling at Outfall 190

Sampling location	^{99}Tc* (pCi/L) 1/12/16	^{99}Tc* (pCi/L) 4/19/16	^{99}Tc* (pCi/L) 10/17/16	^{99}Tc* (pCi/L) 1/9/17	^{99}Tc* (pCi/L) 4/18/17	^{99}Tc* (pCi/L) 7/13/17	^{99}Tc* (pCi/L) 10/12/17	^{99}Tc* (pCi/L) 1/9/18	^{99}Tc* (pCi/L) 4/26/18	^{99}Tc* (pCi/L) 7/10/18	^{99}Tc* (pCi/L) 10/15/18
Screening level	1760	1760	1760	1760	1760	1760	1760	1760	1760	1760	1760
Outfall 190	13.4	6.37 U	3.26 U	4.38 U	-3.27 U	6.71	2.96 U	8.12 U	7.44 U	1.07 U	6.38 U

*Technetium-99 results are provided as a reference. They do not exceed screening criteria.

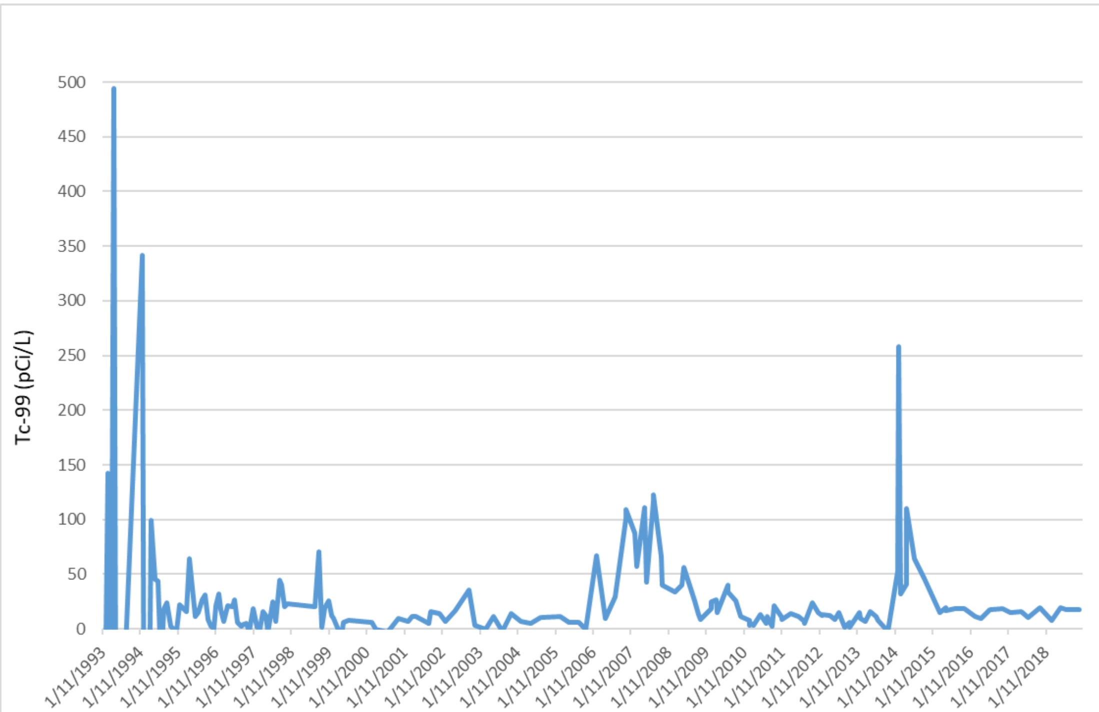


Figure 3.14. ^{99}Tc levels at K-1700 Weir

3.6.8 Mercury Investigation Monitoring

Activities involving mercury that were conducted at ETTP included usage, handling, and recovery operations. Mercury usage and handling were common in such equipment as manometers, switches, mass spectrometers, mercury diffusion pumps, mercury traps, and laboratory operations. Large quantities of mercury-bearing wastes from the on-site gaseous diffusion plant operations and support buildings, ORNL, and Y-12 were processed and stored at ETTP. Mercury from soils and spill cleanups was processed on site as well. Mercury recovery operations were conducted in a number of buildings. Many buildings were located in watersheds that discharged primarily to Mitchell Branch.

Mercury levels that exceed the ambient water quality criterion (AWQC) of 51 ng/L at ETTP have been identified in the Mitchell Branch watershed, as well as in a number of storm water outfalls, surface water locations, and groundwater monitoring wells at ETTP. In addition, knowledge of known historical mercury processes at the facility has increased substantially. These factors have led to an ongoing facility investigation to more precisely detect and quantify the extent of any mercury contamination that may exist.

Factors considered as part of the mercury investigation include weather conditions (wet versus dry), remedial activities (before, during, and after demolition of ETTP facilities), and types of monitoring locations chosen for sampling (in-stream, outfall, ambient, catch basin). For the investigation activities, a dry-weather period was defined as being at least 72 h after a storm event of 0.1 in. or more. Wet weather conditions were defined as a storm event greater than 0.1 in. that occurs within a period of 24 h or less and which occurs at least 72 h after any previous rainfall greater than 0.1 in. in 24 h. In addition, manual grab samples were defined as samples collected according to the guidelines specified in Sects. 3.1.2 and 3.3.1 of EPA 833-B-92-001 (EPA 1992) and applicable procedures that have been developed by the sampling subcontractor. All mercury samples collected as part of the ETTP SWPPP sampling effort were analyzed using the low-level mercury method, *Method 1631, Revision E: Mercury in Water by Oxidation, Purge and Trap, and Cold Vapor Atomic Absorption Fluorescence Spectrometry* (EPA 2002, EPA-821-R-02-019).

3.6.8.1 Mercury Sampling Conducted as Part of the Previous NPDES Permit

As part of the previous NPDES permit compliance program, mercury was sampled on a quarterly basis at Outfalls 05A, 180, and 190. These locations were selected because information gathered as part of the permit application process indicated that mercury levels at these outfalls occasionally exceeded the AWQC level of 51 ng/L. Outfalls 180 and 190 collect storm water from large areas on the north side of ETTP and discharge to Mitchell Branch. Outfall 05A is the discharge point for the former K-1203-10 overflow sump. This sump, which is part of the former K-1203 STP, collects storm water runoff from a large portion of the K-1203 area and discharges it into Poplar Creek.

The current NPDES permit no longer requires quarterly mercury monitoring. However, to continue collecting data for the analysis of trends in mercury discharges from these outfalls, quarterly mercury sampling is conducted as part of the ETTP SWPP Program. Data from this sampling effort is used as part of the RER and may provide information that will be used in upcoming CERCLA cleanup decisions.

Table 3.14 contains analytical data from mercury sampling performed at Outfalls 180, 190, and 05A from CY 2017 through the fourth quarter of CY 2018.

Table 3.14. Quarterly NPDES/SWPP Program mercury monitoring results— CY 2017 through CY 2018

Sampling location	1st Quarter CY 2017 (ng/L)	2nd Quarter CY 2017 (ng/L)	3rd Quarter CY 2017 (ng/L)	4th Quarter CY 2017 (ng/L)	1st Quarter CY 2018 (ng/L)	2nd Quarter CY 2018 (ng/L)	3rd Quarter CY 2018 (ng/L)	4th Quarter CY 2018 (ng/L)
Outfall 180	44.3	**117**	**93.5**	**63.7**	28.4	**235**	33.5	**61**
Outfall 190	16.1	**74.5**	15.2	16.6	39.1	29.1	23.2	15.5
Outfall 05A	**75.2**	**186**	**127**	**427**	**68.4**	**87.3**	**232**	**333**

*Results in **bold** exceed the screening criteria for mercury (51 ng/L).

3.6.8.2 Mercury Graphs for Outfall 180, Outfall 190, and the K-1700 Weir

There are numerous legacy mercury historical operations within the Outfall 180 and 190 network areas and overall Mitchell Branch watershed. Collectively, these are potential contributors to the continuing legacy mercury discharges to Mitchell Branch due to contaminated sediment within storm water networks and potential infiltration sources into the piping. These include mercury recovery operations at the K-1401 and K-1420 buildings that led to downstream waste disposal areas such as the K-1407 Ponds and K-1070-B Burial Ground. Additionally, the K-1035 building instrument shop with associated mercury activities discharged liquids through building acid pits to the storm drain network. In addition to the continuing contributions from the storm drain outfalls, the instream sediments within Mitchell Branch are a potential contributor to water column measurements and fish bioaccumulation. Figures 3-15 and 3-16 indicate mercury discharges to Mitchell Branch from storm water Outfalls 180 and 190 from CY 2010 through CY 2018, respectively.

Outfalls 180 and 190 are two of the major outfalls that contribute flow to Mitchell Branch. Because the discharges from Outfalls 180 and 190 routinely contain mercury at levels above screening criteria, these outfalls are thought to be the major contributors of mercury to Mitchell Branch as well. Mitchell Branch mercury levels are monitored routinely at the K-1700 weir as part of the ETTP Environmental Monitoring Program. Please note that Figs. 3-15 and 3-16 indicate results from the quarterly monitoring performed at Outfalls 180 and 190, respectively, as well as other SWPP Program sampling that was conducted at the outfall during the period covered by these graphs. Figure 3.17 shows mercury levels at the K-1700 Weir from CY 2010 through CY 2018.

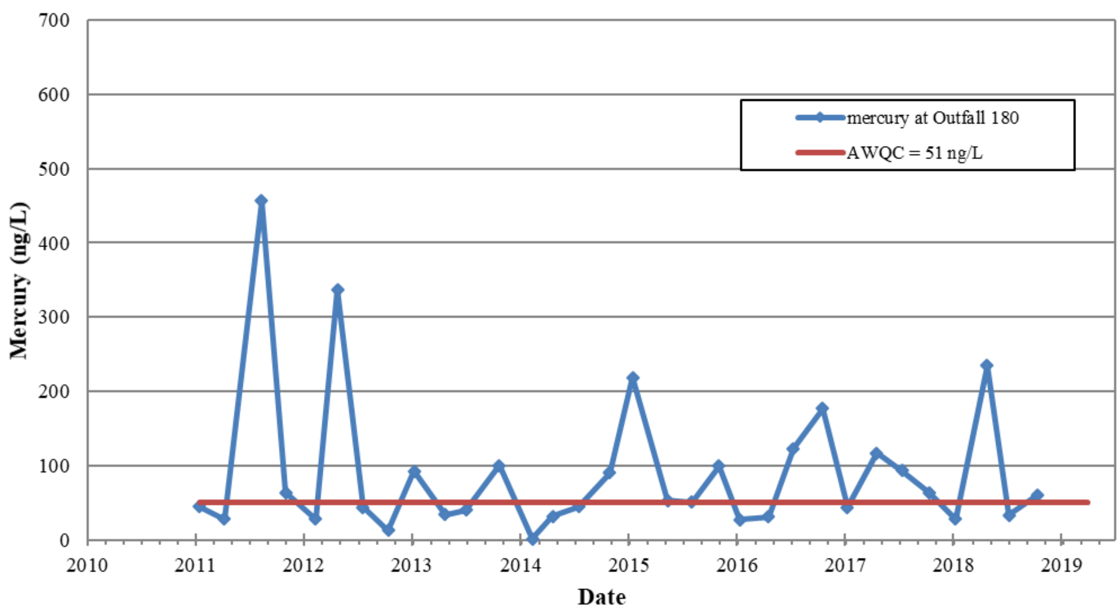


Figure 3.15. Mercury concentrations at Outfall 180

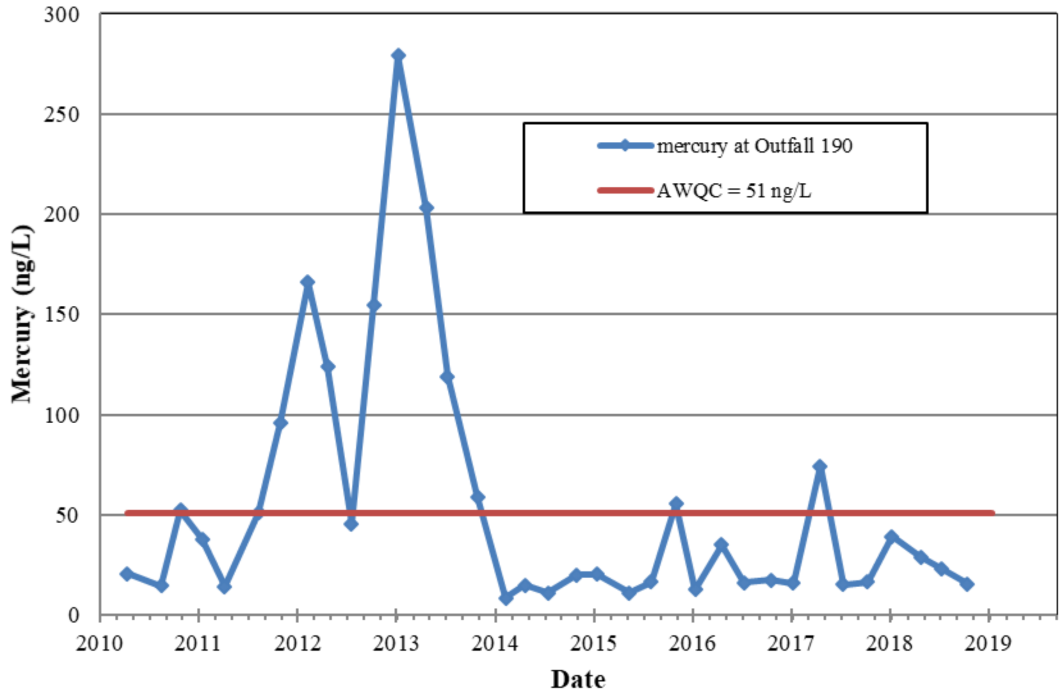


Figure 3.16. Mercury concentrations at Outfall 190

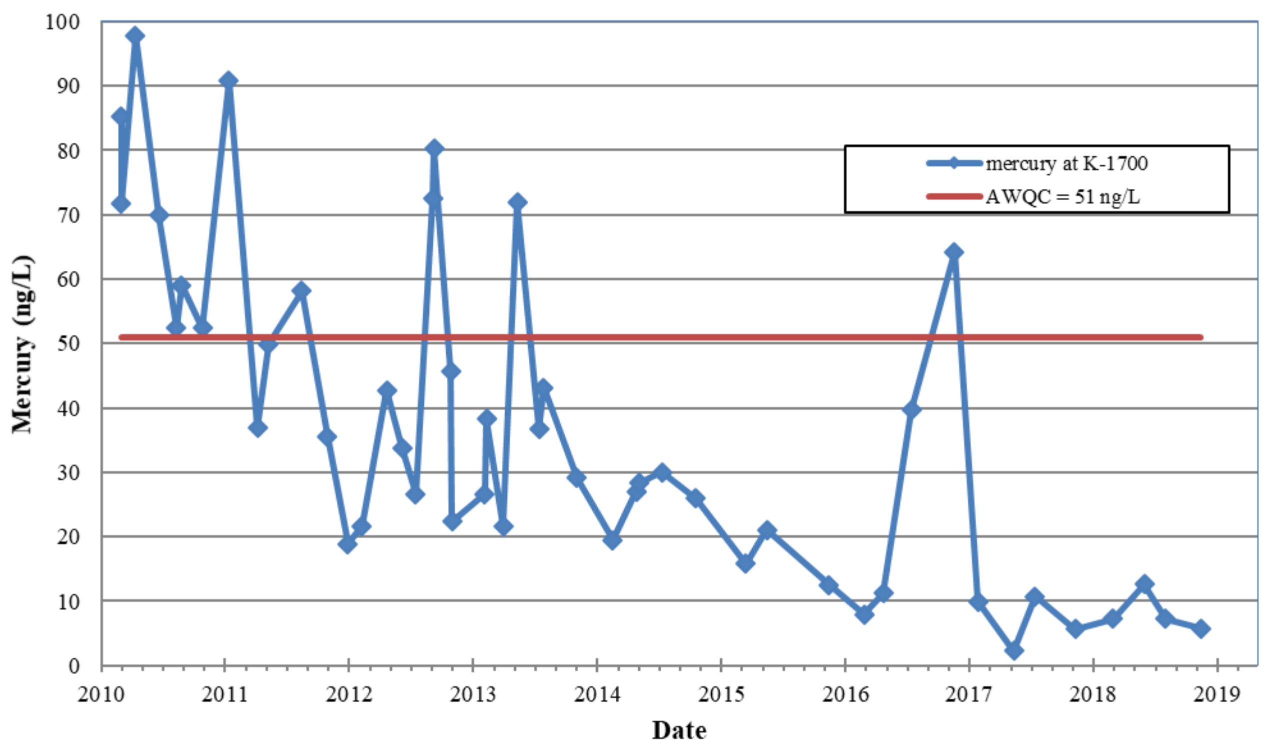


Figure 3.17. Mercury concentrations at the K-1700 Weir

3.6.8.3 Mercury Graph for Outfall 05A

Storm water Outfall 05A drains portions of the former K-1203 STP that discharge into the K-1203-10 sump. Soils and inactive piping from the K-1203 STP are contaminated with mercury from historical treatment operations from sources such as the plant laboratory discharges. The D&D of the former K-1203 STP was completed in early CY 2018. The D&D work conducted at the former K-1203 STP did not include the K-1203-10 sump, which collects the water that discharges through Outfall 05A. Additional monitoring of water, sediments, and soil was conducted at the K-1203-10 sump and other former K-1203 STP facilities and structures as part of the D&D activities, as described in Sect. 2.2.2 of this report. Figure 3.18 shows mercury concentrations at storm water Outfall 05A from CY 2010 through CY 2018.

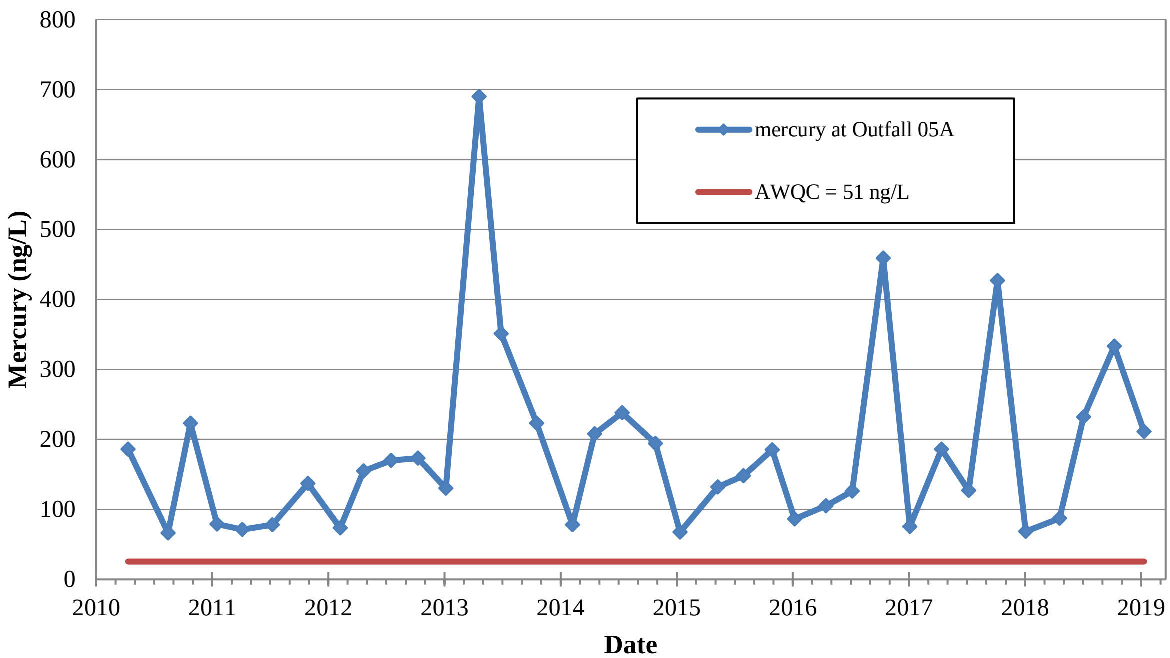


Figure 3.18. Mercury concentrations at Outfall 05A

3.6.8.4 Additional Mercury Sampling at Selected Storm Water Outfalls

Mercury levels that exceed the state of Tennessee AWQC of 51 ng/L at ETTP have been identified in the Mitchell Branch watershed, as well as in a number of storm water outfalls, surface water locations, and groundwater monitoring wells. Updated analytical techniques for mercury have resulted in much lower detection limits than were previously attainable. In addition, knowledge of known historical mercury processes at the facility has greatly expanded. These factors have led to an ongoing facility investigation to more precisely detect and quantify the extent of any mercury contamination that may exist.

Factors being considered as part of the mercury investigation are the weather conditions (wet versus dry), D&D activities (before, during, and after demolition of ETTP facilities), and types of monitoring locations chosen for sampling (in-stream, outfall, ambient, catch basin). Additionally, mercury is being sampled in other programs such as ETTP Environmental Monitoring Program (EMP), groundwater monitoring, the BMAP, D&D and RA activity support, and the NPDES permit application sampling efforts.

For the purpose of the mercury investigation activities, a dry-weather period was defined as being at least 72 h after a storm event of 0.1 in. or more. Wet weather conditions were defined as a storm event greater than 0.1 in. that occurred within a period of 24 h or less, and which occurred at least 72 h after any previous rainfall greater than 0.1 in. in 24 h. In addition, manual grab samples were defined as samples collected according to the guidelines specified in Sects. 3.1.2 and 3.3.1 of EPA 833-B-92-001 (EPA 1992) and applicable procedures that have been developed by the sampling subcontractor.

The mercury results from the samples collected at these outfalls are presented in Table 3.15.

Table 3.15. Analytical results from mercury sampling at storm water outfalls

Location	Mercury Screening level 51 ng/L
Outfall 200	15.4
Outfall 220	2.05
Outfall 250	**58.7**
Outfall 380	16.8
Outfall 382	7.78
Outfall 390	8.02
Outfall 410	25.1
Outfall 440	6.75
Outfall 530	46.1
Outfall 532	5.88
Outfall 570	11.3
Outfall 760	5.02
Outfall 780	**691**

*Results in bold exceed the screening criteria for mercury (51 ng/L).

As shown in Table 3.15, the only mercury results from this sampling effort that exceeded screening levels came from storm water Outfalls 250 and 780.

A mercury sample was collected at Outfall 250 in June 2018. Outfall 250 is an open ditch that receives storm water runoff from the K-802 area, which is located northwest of the K-25 building. An investigation into the potential sources of mercury at this outfall was undertaken, but no conclusive results were obtained. It is believed that the mercury at Outfall 250 may have come from historical discharge of mercury-contaminated sediments from Poplar Creek into the Outfall 250 drainage area as part of the operation of the K-802 pumphouse.

A mercury sample was collected at Outfall 780 in March 2018. Outfall 780 once carried storm water runoff from Bldgs. K-724 and K-725, which were located in the Powerhouse Area. These buildings were originally part of the S-50 Fercleve Thermal Diffusion Plant. Building K-725 was used for beryllium processing in its later life. However, K-725 also contained mercury traps that occasionally released mercury. The mercury was reportedly “swept down the floor drains” in cleanup activities performed at the building in the 1970s. Mercury may have also been present in the dust collection system of the building.

The floor drains of the building were likely tied to the storm drain system, so any mercury swept to the floor drains likely wound up in the storm drain network. In addition, any mercury present in the dust collection system of the building was likely disturbed during demolition of the building in the mid-1990s and may have been transported to the storm drain system via storm water runoff from the building dust collection system debris. Therefore, the mercury analyzed in the March 1, 2018, sample from Outfall 780 could have been present in sediments contained in the piping system for many years and flushed from the piping system with the > 5 in. of rain that fell in the week before this sample was collected.

No recent activities conducted in this area are suspected to have led to this elevated mercury level. The only ongoing activity being conducted in this drainage area is the Oak Ridge Forest Products wood chip mill, and it is extremely unlikely that the activities conducted at this facility would use mercury in their operations.

3.6.9 PCB Monitoring at ETTP Storm Water Outfalls

An evaluation of PCB data collected as part of the ETTP SWPP Program from CY 2000 to the present was performed to identify locations where PCBs have been detected at storm water outfall locations. Non-representative outfalls that have been grouped with representative outfalls where PCBs have been identified and have not been sampled in several years were selected to be sampled as part of the ETTP SWPP sampling program. This sampling effort was performed to determine if non-representative outfalls may be contributing PCBs to site waterways.

Manual grab samples were collected for PCB analysis at each of the outfalls selected for this sampling effort. Manual grab samples were collected according to the guidelines specified in Sections 3.1.2 and 3.3.1 of EPA 833-B-92-001 (EPA 1992) and applicable procedures that have been developed by the sampling subcontractor.

Analytical results from samples collected as part of this sampling effort are shown in Table 3.16.

Table 3.16. Analytical results from ETTP SWPP Program PCB sampling effort

Location	Parameter[a]	Date sampled	Screening level - Detectable Quantity
Outfall 144	Individual PCBs	1/29/18	No detectable PCBs
Outfall 220	Individual PCBs	4/16/18	No detectable PCBs
Outfall 382	Individual PCBs	3/12/18	No detectable PCBs
Outfall 440	Individual PCBs	3/12/18	No detectable PCBs
Outfall 530	Individual PCBs	6/28/18	No detectable PCBs
Outfall 720	Individual PCBs	4/24/18	No detectable PCBs
Outfall 780	Individual PCBs	3/1/18	**PCB-1260—0.626 µg/L**
Outfall 880	Individual PCBs	3/1/18	No detectable PCBs

*Results in bold exceed the screening criteria for PCBs (detectable quantity).

PCB-1260 was detected in samples collected from Outfall 780 in March 2018. Outfall 780 once carried storm water runoff from Buildings K-724 and K-725, which were located in the Powerhouse area. Outfall 780 also receives storm water runoff from the K-722 area. Approximately 1000 gal of oil was landfarmed for dust suppression in 1982 on the roads in the vicinity of the K-722 area. Oil used for landfarming in this area was required only to have a PCB content of 5 ppm or less. The analytical results from this sampling event may be showing the presence of low-level PCBs that could have been present in some of the oil that was landfarmed. In addition, the presence of PCBs at Outfall 780 could be due to the historic use of PCB-containing electrical equipment in the drainage area.

3.6.10 Investigative Sampling of Storm Drain Near Former K-1066-K UF_6 Cylinder Yard

A blue/greenish storm water drainage pipe is located south of the K-1065 complex near the former K-1066-K UF_6 Cylinder Yard. The pipe has never been given a designated storm drain number as other storm drains at ETTP have been given. In addition, the pipe is not listed individually as a storm water outfall on the current ETTP NPDES permit. It is believed that this pipe discharges to the Outfall 710 drainage system and is sampled for compliance with the ETTP NPDES permit as part of the Outfall 710 drainage area. The pipe appears to have been installed to assist in removing storm water that collects in a low grassy and graveled area on the west side of the former K-1066-K UF_6 Cylinder Storage Yard.

The pipe has been observed flowing on a routine basis during heavier rainfall events. In order to determine if the discharge from the pipe contained contaminants of concern, sampling of the pipe was conducted.

Samples from this pipe were collected on January 29, 2018, after a storm event of 0.89 in. Samples were analyzed for TSS, isotopic uranium, PCBs, and metals. No parameters exceeded screening levels as part of this sampling event.

3.6.11 Investigative Sampling in the Outfall 992 Drainage Area

A total of 5.97 million tons of coal were burned at the K-701 Powerhouse during its operation from 1944–1962. Bottom ash, coal fines, slag, and other by-products of coal combustion were buried at the K-720 coal ash pile. The K-720 coal ash pile is approximately 9 acres in size. In the mid-1990s, the coal ash pile was spread out, covered with soil, limed, and seeded.

Runoff and leachate from the K-720 coal ash pile have resulted in elevated levels of various heavy metals at storm water Outfall 992 for several years. Elevated levels of metals commonly identified in coal, including arsenic, selenium, etc., have been detected in storm water samples from the area. In order to obtain current information on possible contaminants that may be entering the Outfall 992 runoff from sources in the K-720 coal ash pile, samples were collected in two locations in the Outfall 992 drainage area. One of the locations that was sampled was the drainage system for the K-720 coal ash pile that was installed in the mid-1990s (location 3 on Figure 3.19). The second location that was sampled was the ash sluice ditch (location 4 on Figure 3.19). Both of these locations combine with other smaller flows to make up the total discharge that is monitored at Outfall 992.

No parameters exceeded screening levels as part of this sampling event. Arsenic and selenium, which are major contaminants of concern in coal ash, were not measured in detectable quantities in samples from either of the monitored locations.

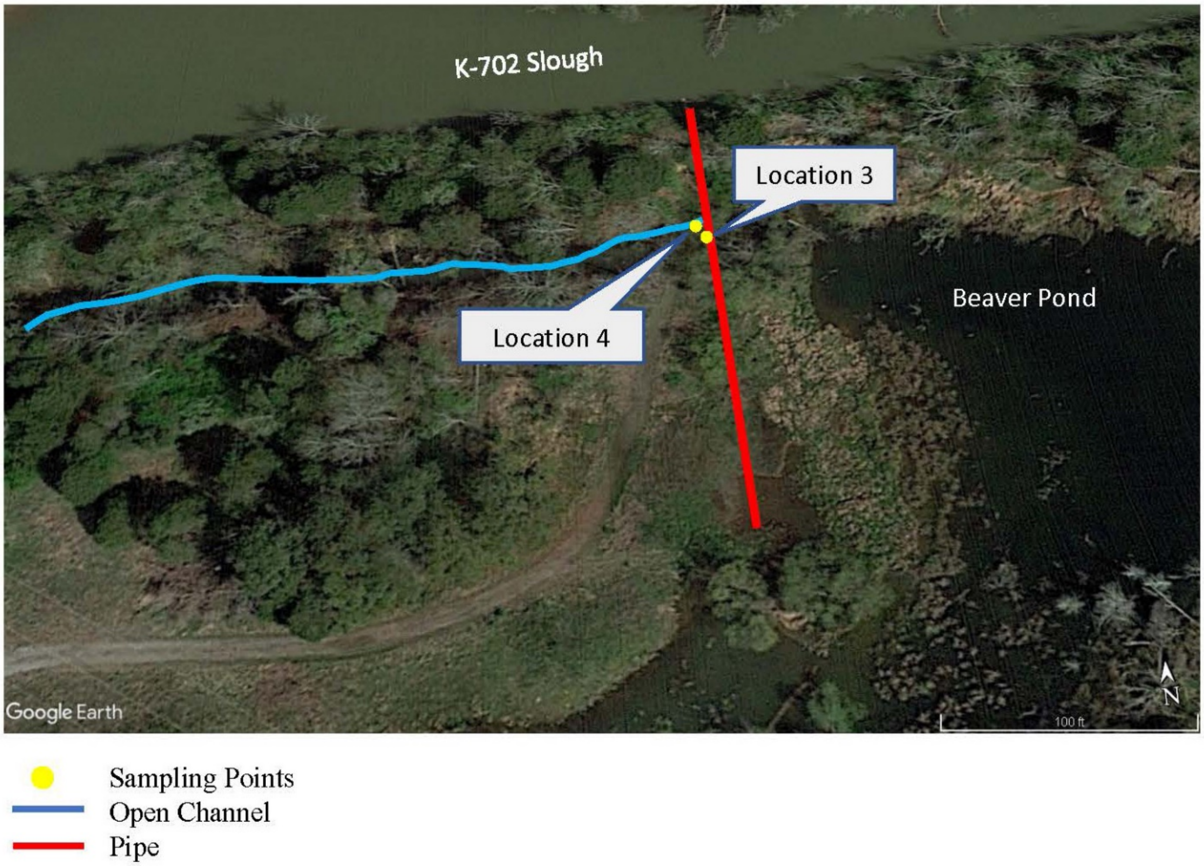


Figure 3.19. Sampling locations for Outfall 992 investigation

3.6.12 Chromium Water Treatment System and Plume Monitoring

In 2007, the release of hexavalent chromium into Mitchell Branch from Storm Water Outfall 170 and from seeps at the headwall of Outfall 170 resulted in levels of hexavalent chromium that exceeded state of Tennessee AWQC. Immediately below Outfall 170, hexavalent chromium levels were measured at levels as high as 780 µg/L, which exceeded the state of Tennessee hexavalent chromium water quality chronic criterion of 11 µg/L for the protection of fish and aquatic life. The levels of total chromium were at approximately the same value, indicating that the bulk of the release was almost entirely hexavalent chromium at the release point. The reason that the chromium was still in a hexavalent state is unknown, considering that hexavalent chromium has not been used in ETTP operations in over 30 years. On November 5, 2007, DOE notified EPA and TDEC of their intent to conduct a CERCLA time-critical removal action to install a grout barrier wall and groundwater collection system to intercept this discharge. This action reduced the level of hexavalent chromium in Mitchell Branch from 780 µg/L to levels consistently below the AWQC value of 11 µg/L. The time-critical removal action is documented in DOE/OR/01-2598&D2 (DOE 2013), *Removal Action Report for the Long-Term Reduction of Hexavalent Chromium Releases into Mitchell Branch at the East Tennessee Technology Park, Oak Ridge, Tennessee*.

In 2012, the treatment of the chromium collection system water was transitioned from the Central Neutralization Facility (CNF) to the CWTS. To monitor both the continued effectiveness of the collection system, as well as the effectiveness of the new CWTS, periodic monitoring is performed as part of the

ETTP SWPP Program. In CY 2018, samples were collected at Monitoring Well TP-289, the chromium collection system wells, Outfall 170, and Mitchell Branch kilometer (MIK) 0.79. Samples are collected at TP-289 to monitor the concentrations of chromium in the contaminated groundwater plume. Samples are collected from the chromium collection system wells to monitor the chromium in the water recovered by the groundwater collection system. Samples collected at Outfall 170 monitor the concentrations of the chromium and hexavalent chromium plume being discharged directly to Mitchell Branch. Figures 3.20 and 3.21 show the results for the analyses for total chromium and hexavalent chromium, respectively.

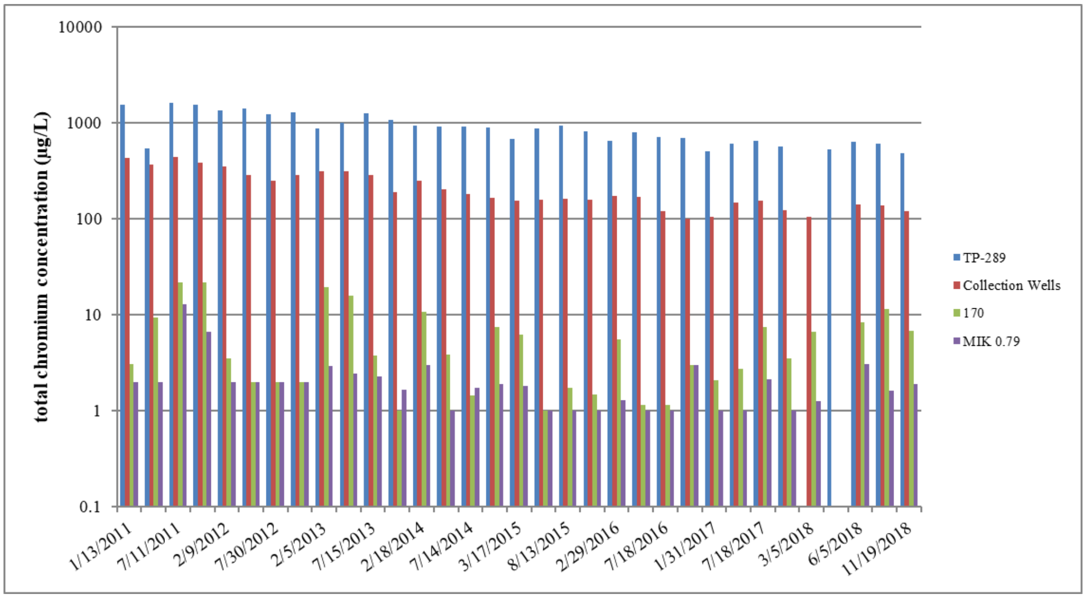


Figure 3.20. Total chromium sample results for the chromium collection system

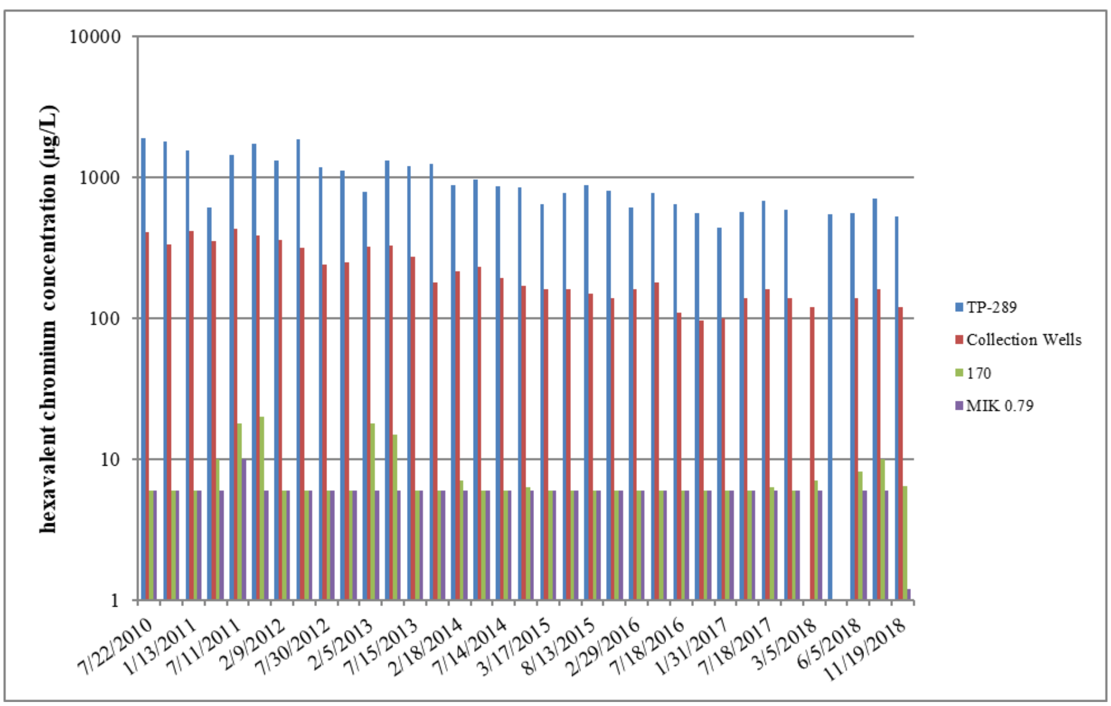


Figure 3.21. Hexavalent chromium sample results for the chromium collection system

The analytical data indicate that both total and hexavalent chromium levels may fluctuate slightly at TP-289 and the collection wells but are relatively consistent over the long term. Total chromium values at Outfall 170 and MIK 0.79 are slightly more variable. This is most likely due to the greater variability in flow rates at these two locations. Hexavalent chromium levels at Outfall 170 and MIK 0.79 have remained remarkably consistent since 2010, as shown earlier in Figure 3.21.

Additional monitoring of the CWTS will be performed as indicated in UCOR-4259, *East Tennessee Technology Park Chromium Water Treatment System Sampling and Analysis Plan, Oak Ridge, Tennessee* (UCOR 2018a). In addition to chromium treatment, the upgraded CWTS also has provisions for air stripping of the VOCs that are also found in the groundwater. The air stripper has demonstrated a removal efficiency of greater than 98 percent over the last several monitoring periods.

3.6.13 NPDES Permit Renewal Monitoring

Preparations for the NPDES permit application that will be submitted to TDEC in CY 2019 are being made. Additionally, DOE will require time to review the permit application before it is submitted to TDEC. In order for all of the required monitoring to be conducted in time for the permit application to be prepared and submitted, sampling required for the completion of the permit application was initiated as part of the FY 2015/2016 SWPP Program and continued as part of the FY 2017 and 2018 SWPP Programs. In CY 2018, NPDES permit application samples were collected at Outfall 210. Table 3.17 indicates results from the NPDES permit renewal sampling at Outfall 210 that exceeded screening levels.

Table 3.17. Analytical results exceeding screening levels for NPDES permit renewal sampling—CY 2018

Location	Copper	Cadmium	Lead	Mercury	Zinc	4-4′-DDT	Endosulfan
	Screening level 7 μg/L	Screening level Detectable	Screening level 1.8 μg/L	Screening level 51 ng/L	Screening level 75 μg/L	Screening level Detectable	Screening level Detectable
Outfall 210	17.6	1.33	197	80.6	310	0.00546	0.00536

Outfall 210 has been a representative outfall on previous ETTP NPDES permits, but was not selected as a representative outfall for the current ETTP NPDES permit. However, it was determined that all appropriate sampling would be performed to allow an EPA 2F form (EPA Form 2F) to be submitted for Outfall 210 as part of the ongoing application process for the next ETTP NPDES permit. Outfall 210 may become a representative outfall under the next ETTP NPDES permit. Outfall 210 collects runoff from the exterior portion of the northwest corner of the K-25 building slab. D&D activities for the K-25 building were completed in July 2014. Activities conducted in the K-25 building during its operation included the isotopic enrichment of uranium by gaseous diffusion. In addition, the building was known to be contaminated with various metals (copper, lead, cadmium, zinc, etc.) and with mercury due to the large numbers of electrical switches, gauges, and other instruments used while the building was operational. The source(s) of the herbicide contamination detected at Outfall 210 as part of this sampling effort have not yet been determined.

3.6.14 Sampling of Outfalls in the K-31/K-33 Area

D&D and RA activities that are ongoing at ETTP will likely result in a status change for several of the storm water outfalls. The outfalls that are currently present on the ETTP NPDES permit are the responsibility of DOE. After RAs have been completed in an area and the actions have been verified as being effective and approved through the CERCLA process, the parcel and its associated storm water outfalls will be managed under the DOE S&M Programs and can be considered for transfer by DOE to a private or municipal entity.

Storm water outfalls associated with the transferred properties will be evaluated for permitting as a commercial private property by applicable regulatory agencies such as TDEC and COR, as appropriate, under storm water-permitting programs. The entities that own or operate the properties will be responsible for obtaining the required permits and maintaining compliance with the issued permits. These outfalls will no longer be considered DOE's responsibility and will be removed from the ETTP NPDES permit. Outfalls may also be proposed for removal from the ETTP NPDES storm water permit 1) if it is determined that they discharge only uncontaminated storm water that is primarily sheet flow, or 2) where outfalls are plugged or removed as part of a RA. The continued reduction of permitted outfalls from the ETTP NPDES permit is consistent with the DOE ETTP cleanup program objectives, which are to clean up the site and eliminate ongoing DOE operations.

As the RAs are completed, a formal request will be made to TDEC by DOE to propose the removal of storm water outfalls from the ETTP NPDES permit. An outfall will remain on the ETTP NPDES permit until official notice to remove the outfall from the permit has been received from TDEC. For situations where the CERCLA actions are complete and the area has transitioned into the DOE S&M Program, the criteria that will be followed to evaluate when it is appropriate to remove outfalls from the ETTP NPDES permit are outlined in the following discussion. A criterion for a second scenario is also provided below where the cleanup actions are complete and the property is being transitioned to commercial entities or COR.

Criteria for storm drains within a subwatershed to be removed from the ETTP NPDES permit in areas managed under the DOE S&M Program include the following:

- No ongoing DOE operations, such as waste treatment facilities or maintenance work areas (office buildings, parking lots, and roads are not defined as ongoing industrial operations).
- Final DOE D&D and soil RAs are complete and has achieved "No Further Action" status (legacy soil contamination, storm water runoff, and CERCLA groundwater releases to the storm drains are not a concern based upon dry-weather and wet-weather sampling events).
- No reindustrialization lessee or property transfer industrial operations are located within the subwatershed.

At the point when the criteria have been completed, DOE can submit a request to TDEC for candidate outfalls to be removed from the ETTP NPDES permit. The outfalls being removed from the permit may then be regulated directly by TDEC through a separate permitting action or through the COR Stormwater Program.

Criteria for storm drains to be removed from the ETTP NPDES permit in areas where the only industrial operations within the storm drain network are being conducted by private companies within a property transfer area include the following:

- No ongoing DOE operations such as waste treatment facilities or maintenance work areas (office buildings, parking lots, and roads are not defined as ongoing industrial operations).
- Final DOE D&D and soil RAs are complete and has achieved "No Further Action" status (legacy soil contamination, storm water runoff, and CERCLA groundwater releases to the storm drains are not a concern based upon dry-weather and wet-weather sampling events).

- Land area where private industrial operations are being conducted has been transferred to a private entity.

At the point where the criteria are completed as noted above, DOE can submit a request to TDEC for candidate outfalls to be removed from the ETTP NPDES permit. As TDEC approves the outfalls to be removed from the ETTP NPDES permit, the outfalls may then be regulated directly by TDEC through a separate permitting action or through the COR Stormwater Program.

The K-31 parcel, which is comprised of 46.8 acres, was recently made available by DOE EM for transfer to CROET.Each of the outfalls that are located in the K-31/K-33 area were considered to determine whether they should be sampled as part of the investigation of storm water discharges from the area. Factors that were considered in determining which outfalls should be sampled included:

- Whether or not the outfall was designated as a representative outfall that is sampled for compliance with the ETTP NPDES permit.
- The size and extent of the drainage area served by the outfall.
- The past uses of the area or building that contributed storm water runoff to the outfall based on process knowledge.
- Analytical data from past sampling events that indicate the potential presence of contaminants of concern at the outfall.

In order to determine if storm water outfalls in the K-31/K-33 areas could be removed from the ETTP NPDES permit, sampling was performed at outfalls within the drainage areas of these building footprints. The following outfalls were samples as part of this effort: 510, 530, 560, 590, 600, 610, 660, 690, 694, 700, 710, and 720. The following parameters were analyzed in samples from each of these locations: gross alpha/gross beta radiation, polycyclic aromatic hydrocarbons, PCBs, metals, mercury, hexavalent chromium, TSS, and flow.

Because the sampling of the K-31/K-33 outfalls was time-critical, outfall sampling was designated as being weather dependent and did not require the occurrence of a qualifying rainfall event. These samples were collected when storm water runoff was observable from the outfalls that were to be sampled. The criteria for storm event sampling used for other SWPP Program sampling did not have to be met for this sampling effort. Even though the K-31/K-33 outfall samples did not have to be collected during a qualifying rainfall event, rainfall data for the periods when the samples are collected was noted. Precipitation data from the rain gauge on the K-1209 meteorological tower, which is present on site at ETTP, were used for the official measurement of the magnitude of a storm event. Meteorological information from these towers is sent electronically to the ETTP Park Shift Superintendent office, which is responsible for providing this information upon request. Rainfall readings from rain gauges operated by the Sampling Subcontract Organization (SSO) were used as a backup to the readings from the meteorological towers.

All samples from the K-31/K-33 sampling effort were collected as manual grab samples using guidelines specified in Sects. 3.1.2 and 3.3.1 of EPA 833-B-92-001 (EPA 1992) and applicable procedures that have been developed by the sampling subcontractor.

Table 3.18 contains information on the analytical results collected from the K-31/K-33 area storm water outfalls that exceeded screening criteria as part of this sampling effort. No other parameters exceeded screening levels at any of the outfalls sampled.

Table 3.18. Analytical results over screening criteria from K-31/K-33 area sampling effort

Location	Lead	PCB-1254
	Screening level 1.8 µg/L	Screening level Detectable
Outfall 510	5.68	
Outfall 660	3.68	0.0456

As part of the K-31/K-33 sampling effort, instantaneous manual flow measurements were collected at each of the outfalls sampled. These flow measurements were collected in accordance with the latest revision of PROC-ES-2200, *Surface Water Flow Measurements.* Information collected as part of these flow measurements is included in Table 3.19.

Table 3.19. Flow data collected as part of the K-31/K-33 sampling effort

Outfall	Date of manual flow measurement	Precipitation on date of manual flow measurement	Manual flow measurement (gallons per min)	Manual flow measurement (gallons per day)
510	4/23/2018	0.62	9.25	13320
530	6/28/2018	2.06	10	14400
560	4/24/2018	0.87	15.9	22896
590	4/24/2018	0.87	no flow	—
600	4/24/2018	0.87	no flow	—
610	4/24/2018	0.87	6.5	9360
660	4/23/2018	0.62	0.26	374
690	4/24/2018	0.87	22.5	32400
694	4/23/2018	0.62	0.2	288
700	4/23/2018	0.62	9.4	13536
710	4/23/2018	0.62	6.6	9504
720	4/24/2018	0.87	6.6	9504

At Outfall 510, analytical data from this sampling event indicated the presence of screening criteria exceedances; therefore, additional follow-up sampling was conducted. Outfall 510 was resampled for lead on November 6, 2018. Lead was not detected above screening criteria in this sample. In addition, catch basin 6014, which is located immediately upstream of Outfall 510, was also sampled for lead. Lead at basin 6014 exceeded screening levels with a result of 5.43 ug/L. To determine if lead exceeded screening criteria in the Outfall 510/Poplar Creek mixing zone, a corresponding lead sample was also collected from Poplar Creek at the K-1250-4 bridge. The lead result for this sample was well below screening levels.

Based on historical information, Outfall 600 is unlikely to flow except in the most extreme storm events. This outfall will likely be recommended for removal from coverage under the ETTP NPDES permit based on the criteria provided earlier in this section.

Several of the outfalls that were sampled as part of this effort meet the criteria for removal from the ETTP NPDES permit and have been proposed to be plugged and abandoned. These outfalls include 590, 650, 660, 670, and 694. Outfall 690 may also be plugged and abandoned if an evaluation of the outfall drainage area shows that this action will not adversely affect runoff flow. Cleanup actions to remove lead may be taken in the Outfall 510 piping network based on the results of this sampling. The responsibility for NPDES permitting of the K-31/K-33 portion of the ETTP storm drain system, including Outfalls 510, 520, 522, 530, 560, 600, 610, 690, 700, and 720, has not been determined. However, these outfalls have been included as part of the ETTP NPDES permit renewal application that is currently being prepared.

3.6.14.1 Flow and Flux Monitoring at Storm Water Outfalls Associated With NPDES Permit Requirements

In addition to periodic monitoring requirements specified in the ETTP NPDES permit, several additional monitoring efforts were included as part of the current ETTP NPDES permit to support the CERCLA actions that are ongoing at ETTP. This monitoring are being conducted as part of the SWPP Program.

Flow monitoring will be conducted at several outfalls, including Outfalls 100, 170, 180, and 190.Field-installed flow meters are used to gauge flows for various ranges of rainfall events at each of these outfalls. These flows are compared against ones generated by NRCS TR-55 (NRCS 1986), which is the current flow modeling technique in use at ETTP. These comparative values are used to increase the accuracy of the TR-55 flow modeling process. Mercury is sampled at Outfalls 180 and 190 using the flow-weighted sampling technique. The calibrated flow model will be used with the flow-paced mercury sampling results to determine mercury flux at the respective outfalls.

Flow data and rainfall data for the period from December 5, 2015–March 31, 2017, were collected at Outfall 190. All rainfall events that occurred during this time period were evaluated. As with Outfall 100, an ISCO tipping bucket type rainfall gauge that actuates after the first 0.01 in. of rainfall occurs was used for the collection of rainfall data. Flow and rainfall data was collected in 5-min intervals during this period of time. The data was divided up into 24-h periods based on the occurrence of rainfall events. These 24-h periods did not necessarily coincide with “midnight-to-midnight” daily intervals. In most instances, a 24-h data period began at the same time that the first recordable rainfall (0.01 in.) was measured.

A new base flow for Outfall 190 was determined by using the average of the flows measured by the ISCO flow meter immediately before the start of rainfall events that occurred in the December 5, 2015–March 31, 2017, timeframe. The flow measurements that were used for this calculation were made after a period of at least 72 h after the last previous rainfall of 0.1 in. or more. The newly recalculated base flow was 23,500 gpd. D&D actions that may have affected the base flow of Outfall 190 include demolition of the K-1401 building, remediation of the K-1070-B burial ground, etc. Each of these facilities provided additional flow to Outfall 190 from various sources, including impermeable surfaces such as roof drains and parking areas, discharges from sumps, etc.

In addition to the recalculation of base flow, the Soil Conservation Service (SCS) curve number for Outfall 190, which also must be considered in the TR-55 flow calculations, was refigured for Outfall 190. The SCS curve number is based on the runoff area’s hydrologic soil group, land use, treatment, and hydrologic condition. The previously used SCS curve number for Outfall 190 was 74, and the revised SCS curve number for the Outfall 190 drainage area is 86.

By using the newly calculated base flow of 23,500 gpd and the new SCS curve number of 86, a relatively close match was accomplished between the actual flow measured at Outfall 190 using ISCO flow measurement equipment and the calculated flow at Outfall 190 derived by using the TR-55 model. Both the newly calculated base flow and the newly refigured SCS curve number will be used with the TR-55 program to provide flow estimates that will be reported to TDEC in the ETTP NPDES Discharge Monitoring Report (DMR) on an annual basis. The base flow will be modified as additional flow information becomes available for Outfall 190. Furthermore, seasonal base flows may be recalculated to indicate potential changes due to events such as water table fluctuations, water retention in soil, etc.

As part of the flow-paced sampling effort at Outfall 190, aliquots were collected during a representative storm for the first three hours of the storm. Each aliquot collection was separated by a minimum of 15 min. Three sample aliquots were collected within each hour of discharge. The flow-paced composite mercury sample from Outfall 190 was analyzed using the low-level mercury detection method (EPA 2002, EPA-1631).

On February 2, 2016, a flow-paced composite mercury sample was collected at Outfall 190 after a storm event of 0.50 in. that occurred on February 1, 2016. This storm event meets the criteria for collection of mercury samples during a rainfall event of 0.1–0.5 in., as described in the ETTP NPDES permit. The result from the sample collected on February 2, 2016, is shown in Table 3.20.

On January 12, 2017, a flow-paced composite mercury sample was collected at Outfall 190 after a storm event of 0.73 in. that occurred on January 11, 2017. This storm event meets the criteria for collection of mercury samples during a rainfall event of 0.5–1.5 in., as described in the ETTP NPDES permit. The result from the sample collected on January 12, 2017, is shown in Table 3.20.

On September 7, 2017, a flow-paced composite mercury sample was collected at Outfall 190 after a storm event of 2.06 in. that occurred on September 5, 2017. This storm event meets the criteria for collection of mercury samples during a rainfall event of greater than 1.5 in., as described in the ETTP NPDES permit. The result from the sample collected on September 7, 2017, is shown in Table 3.20.

No flow-proportional composite samples were collected from Outfall 190 during calendar year 2018.

Table 3.20. Analytical results from flow-proportional composite sampling at Outfall 190

Location	Parameter	Date sampled	Rainfall event sampled	Results (ng/L)
Outfall 190	Mercury	2/2/16	0.1–0.5 in.	96.5
Outfall 190	Mercury	1/12/17	0.5–1.5 in.	162
Outfall 190	Mercury	9/7/17	Greater than 1.5 in.	566

Figure 3.22 shows the relationship between rainfall amounts and mercury concentrations that was determined from this sampling effort. The data indicates that mercury concentrations found in the samples collected at Outfall 190 went up as rainfall amounts went up. This may be due to an increased amount of mercury-contaminated sediments being flushed from the outfall during heavier rainfall events and the heavier flows from the outfall that are associated with these rainfall events. Additional flow-proportional sampling will be conducted to indicate potential changes due to seasonal events.

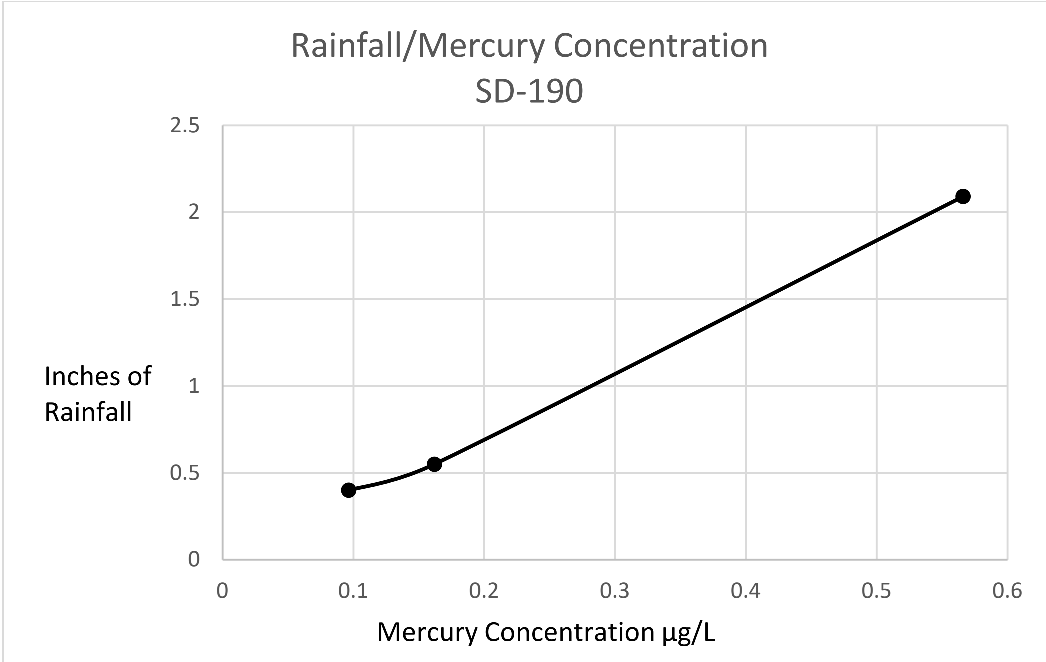


Figure 3.22. Mercury concentration at Outfall 190 as related to rainfall

Specifications for a flume to be installed at Outfall 180 were developed in late summer of 2016. This flume was purchased during FY 2017. Installation of the flume was completed in the summer of 2018, and flow data has been collected since that time.

Flow and rainfall data have been collected at Outfall 180 since August 30, 2018. An ISCO bubbler-type flow meter was used to obtain flow measurements at Outfall 180. An ISCO tipping bucket-type rainfall gauge that actuates after the first 0.01 in. of rainfall occurs was used for the collection of rainfall data. Flow and rainfall data have been collected in 5-min intervals during this time. The data are divided into 24-h periods based on the occurrence of rainfall events. These 24-h periods do not necessarily coincide with “midnight-to-midnight” daily intervals. In most instances, a 24-h data period began at the same time that the first recordable rainfall (0.01 in.) was measured.

Using the rainfall and flow data generated by the ISCO equipment, a new base flow for Outfall 180 will be determined by using the average of the flows measured by the ISCO flow meter immediately before the start of rainfall events that occurred within a selected timeframe. The flow measurements to be used for this calculation will be made after a period of at least 72 h, immediately following a rainfall of 0.1 in. or more.

The newly calculated base flow will be used with the TR-55 program to provide flow estimates that will be reported to TDEC in the ETTP NPDES DMR on an annual basis. The base flow will be modified as additional flow information becomes available for Outfall 180. Moreover, seasonal base flows may be recalculated to indicate potential changes due to events such as water table fluctuations, water retention in soil, etc.

In addition to recalculation of base flow at Outfall 180, other input for entry into the TR-55 model will be considered that will allow flow calculations from the model to better coincide with the actual flow measurements collected by the ISCO flow meter at Outfall 180. The final result of this effort is to match the flow calculated by TR-55 for a specified rainfall event as closely as possible to the flow measured by the ISCO flow meter for the corresponding rainfall event. Other information used by TR-55, such as the percentage of impermeable surfaces in the Outfall 180 drainage area, will also be recalculated.

As part of the flow-paced sampling effort at Outfall 180, aliquots were collected during a representative storm for the first 3 h of the storm. Each aliquot collection was separated by a minimum of 15 min. Three sample aliquots were collected within each hour of discharge. The flow-paced composite mercury sample from Outfall 180 was analyzed using the low-level mercury detection method (EPA 2002, EPA-1631).

On September 11, 2018, a flow-paced composite mercury sample was collected at Outfall 180 after a storm event of 0.33 in. that occurred on September 10, 2018. This storm event meets the criteria for collection of mercury samples during a rainfall event of 0.1–0.5 in., as described in the ETTP NPDES permit. The result from the sample collected on September 11, 2018, is shown in Table 3.21.

On September 25, 2018, a flow-paced composite mercury sample was collected at Outfall 180 after a storm event of 1.02 in. that occurred on September 24, 2018. This storm event meets the criteria for collection of mercury samples during a rainfall event of 0.5–1.5 in., as described in the ETTP NPDES permit. The result from the sample collected on September 25, 2018, is shown in Table 3.21.

On January 25, 2019, a flow-paced composite mercury sample was collected at Outfall 180 after a storm event of 1.57 in. that occurred on January 23, 2019. This storm event meets the criteria for collection of mercury samples during a rainfall event of greater than 1.5 in., as described in the ETTP NPDES permit. The result from the sample collected on January 25, 2019, is shown in Table 3.21.

Table 3.21. Analytical results from flow-proportional composite sampling at Outfall 180

Location	Parameter	Date sampled	Rainfall event sampled	Results (ng/L)
Outfall 180	Mercury	9/11/18	0.1–0.5 in.	497
Outfall 180	Mercury	9/25/18	0.5–1.5 in.	342
Outfall 180	Mercury	1/25/19	Greater than 1.5 in.	39.5

Specifications for a flume to be installed at Outfall 100 were developed in late summer of 2016. This flume was purchased during FY 2017. Installation of the flume was completed in early 2018, and flow data has been collected since that time.

Flow data and rainfall data have been collected at Outfall 100 since February 17, 2018. An ISCO bubbler-type flow meter was used to obtain flow measurements at Outfall 100. An ISCO tipping bucket-type rainfall gauge that actuates after the first 0.01 in. of rainfall occurs was used for the collection of rainfall data. Flow and rainfall data have been collected in 5-min intervals during this time. The data are divided into 24-h periods based on the occurrence of rainfall events. These 24-h periods do not necessarily coincide with "midnight-to-midnight" daily intervals. In most instances, a 24-h data period began at the same time that the first recordable rainfall (0.01 in.) was measured.

Using the rainfall and flow data generated by the ISCO equipment, a new base flow for Outfall 100 will be determined by using the average of the flows measured by the ISCO flow meter immediately before the start of rainfall events that occurred within a selected timeframe. The flow measurements to be used for this calculation will be made after a period of at least 72 h after the last previous rainfall of 0.1 in. or more.

The newly calculated base flow will be used with the TR-55 program to provide flow estimates that will be reported to TDEC in the ETTP NPDES DMR on an annual basis. The base flow will be modified as additional flow information becomes available for Outfall 100. Seasonal base flows may be recalculated to indicate potential changes to the base flow related to seasonal events such as water table fluctuations, water retention in soil, etc.

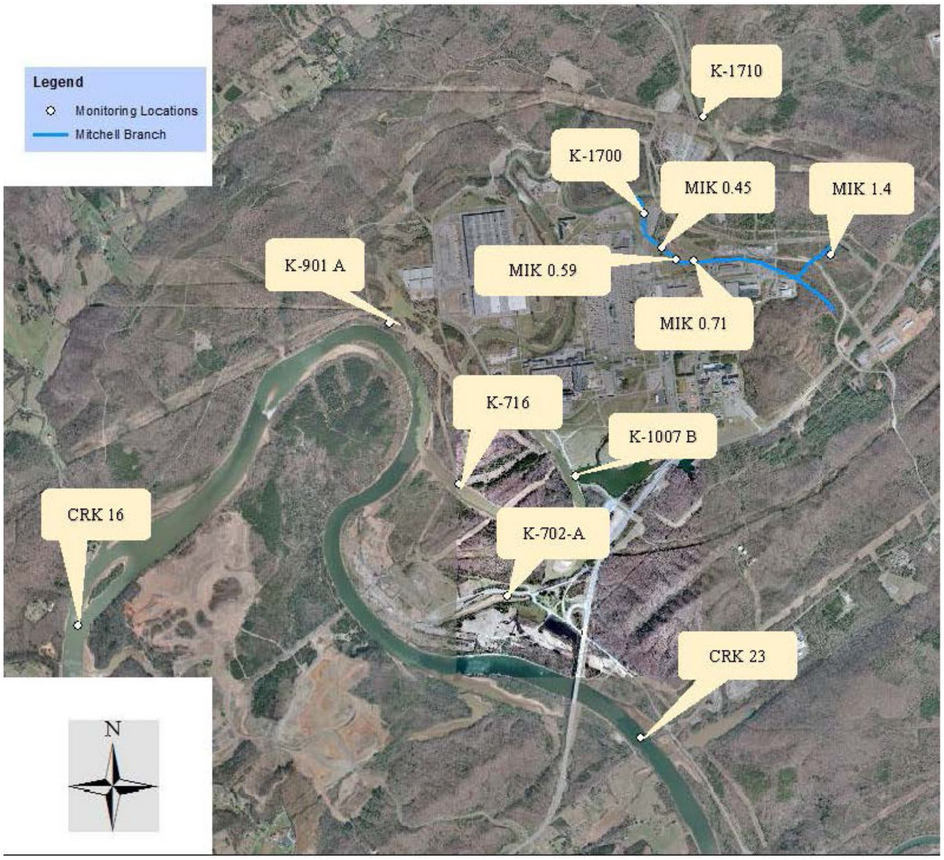
In addition to recalculation of base flow at Outfall 100, other input for entry into the TR-55 model were considered that will allow flow calculations from the model to better coincide with the actual flow measurements collected by the ISCO flow meter at Outfall 100. The final result of this effort is to match the flow calculated by TR-55 for a specified rainfall event as closely as possible to the flow measured by the ISCO flow meter for the corresponding rainfall event. Other information used by TR-55, such as the percentage of impermeable surfaces in the Outfall 100 drainage area, will also be recalculated.

3.6.15 Surface Water Monitoring

During 2018, the ETTP EMP personnel conducted environmental surveillance activities at 12 surface water locations (Figure 3.23) to monitor groundwater and storm water runoff at watershed exit pathway locations (K-1700, K-1007-B, and K-901-A) or ambient stream conditions (Clinch River kilometers [CRKs] 16 and 23; K-1710; K-716; the K-702-A slough; and MIKs 0.45, 0.59, 0.71, and 1.4). As part of monitoring the ambient stream conditions, K-1700 and MIKs 0.45, 0.59, 0.71, and 1.4 were sampled quarterly; and CRKs 16 and 23, K-716, and the K-702-A slough were sampled semiannually.

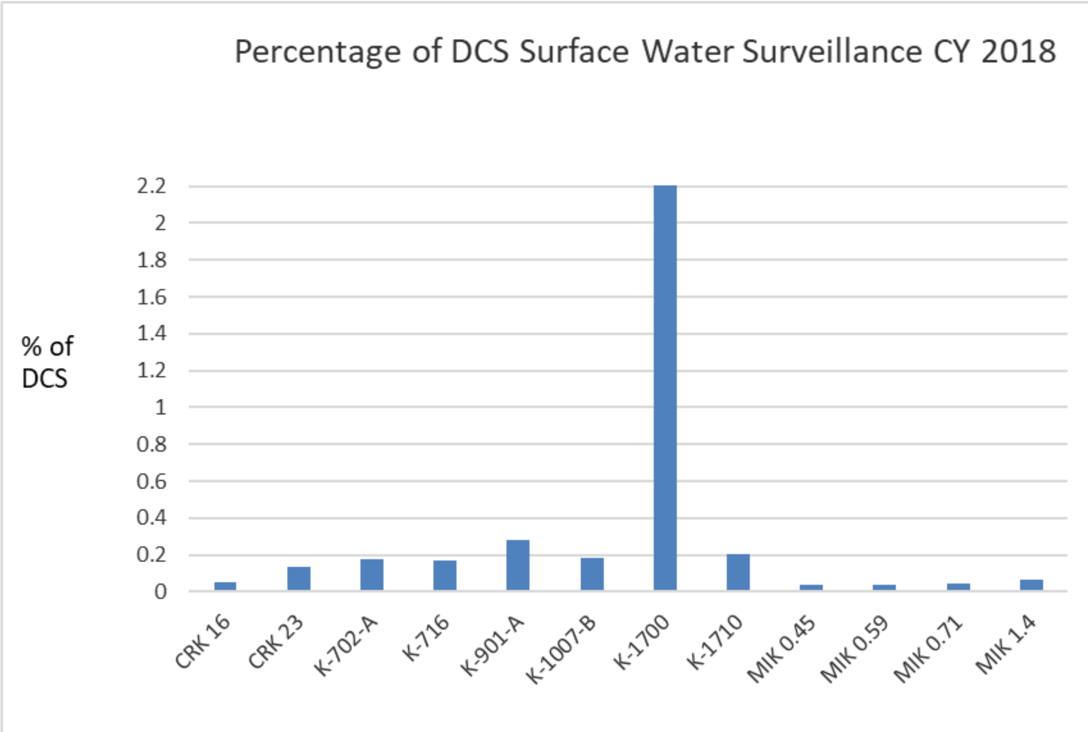
At MIKs 0.45, 0.59, and 0.71, quarterly monitoring is conducted for ^{99}Tc only. Results of radiological monitoring were compared with the DCS values in DOE Standard 1196 (DOE 2011b). Radiological data are reported as fractions of DCSs for reported radionuclides, and the fractions for all of the isotopes are added together to produce the SOF and averaged to produce a rolling 12-month average. The average SOF is recalculated whenever new data become available. If the average SOF for a location exceeds the DCS requirement of remaining below 1.0 (100 percent) for the year, a formal source investigation is required. Sources exceeding DCS requirements would need an analysis of the best available technology to reduce the SOF of the radionuclide concentrations to less than 1.0 (100 percent). In 2018, the monitoring results yielded SOF values of less than 0.01 (1 percent of the allowable DCS) at all surface water surveillance locations at ETTP, with the exception of monitoring location K-1700 (Figure 3.24). At K-1700, the annual average SOF was 0.022 (2.2 percent).

Depending on the monitoring location, water samples may be analyzed for pH, selected metals, and VOCs. In 2018, results for most of these parameters were well within the appropriate AWQC. There were nine exceptions in 2018. During the second quarter of 2018, there was an exceedance of the AWQC for mercury. At K-1710, which monitors Poplar Creek, mercury was measured at 62.9 ng/L, which exceeds the AWQC for mercury of 51 ng/L. During the third quarter, there were six failures to meet the minimum level of dissolved oxygen (5.0 mg/L). Dissolved oxygen levels were measured at 3 mg/L at K-901-A, at 2.9 mg/L at K-1700, at 4.5 mg/L at MIK 0.45, at 4.2 mg/L at MIK 0.59, at 4.1 mg/L at MIK 0.71, and at 4.8 mg/L at MIK 1.4. These readings were collected at a time of elevated temperatures and very low flow due to the drought conditions, which favor high biological activity and the resulting depletion of dissolved oxygen. In the fourth quarter, elevated levels of mercury were detected at both K-716 (66 ng/L) and K-1710 (96.3 ng/L). Both of these locations monitor Poplar Creek. No obvious signs of distress (e.g., dead fish) were observed to be associated with any of these exceedances in 2018.



CRK = Clinch River kilometer
MIK = Mitchell Branch kilometer

Figure 3.23. East Tennessee Technology Park Environmental Monitoring Program surface water monitoring locations

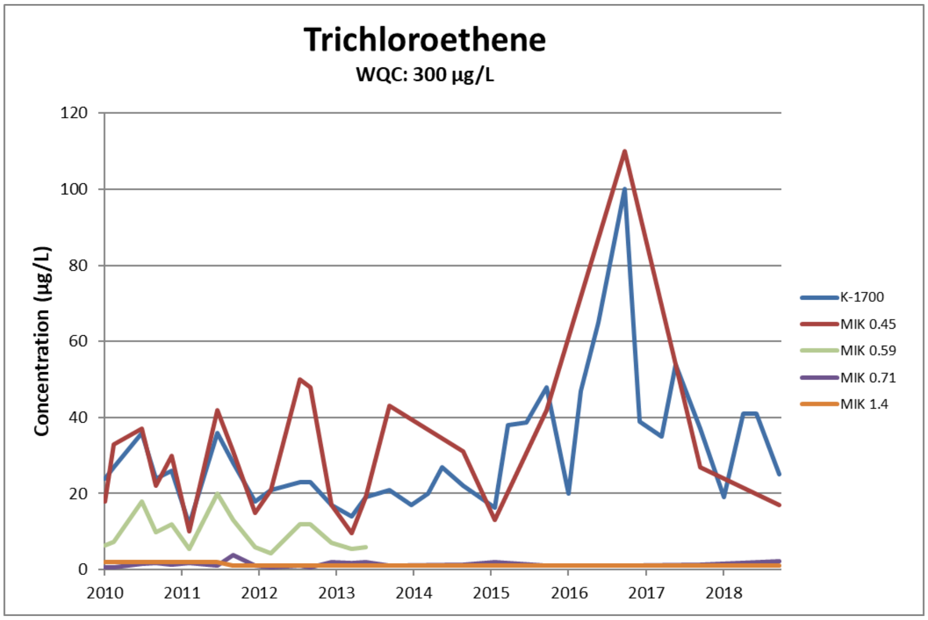


CRK = Clinch River kilometer
DCS = derived concentration standard
MIK = Mitchell Branch kilometer

Figure 3.24. Annual average percentage of derived concentration standards at surface water monitoring locations, 2018

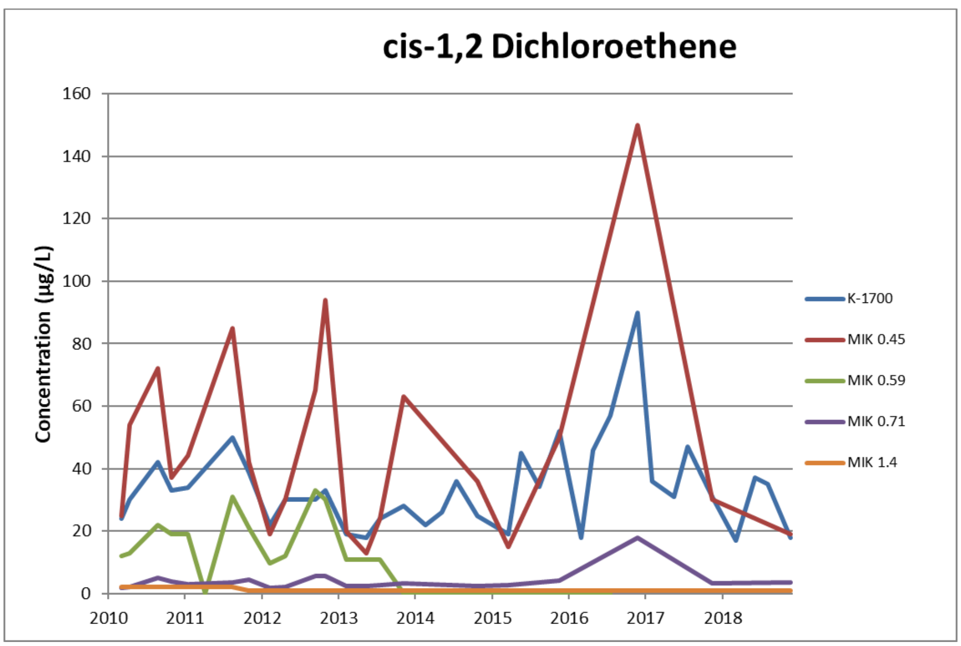
Figures 3.25 and 3.26 illustrate the concentrations of TCE (trichloroethene) and cis-1,2-dichloroethene (cis-1,2-DCE) from the Mitchell Branch monitoring locations., Although VOCs are routinely detected at K-1700 and MIK 0.45, they are rarely detected at other surface water surveillance locations across the ETTP. In the samples collected on November 22, 2016, results for several VOCs, including TCE and cis-1,2-dichloroethene, at several of the Mitchell Branch monitoring locations were reported at levels significantly higher than seen in recent monitoring. It should be noted that the November 22, 2016 sample date was at the end of an extended dry weather period that began in August of 2016. Although there had been a short 48-hour test of the CWTS in October 2016, in which the collection well pumps had been intentionally stopped, the test had been completed and the pumps restarted over a month before these samples were collected. The Sample Management Office (SMO) has reviewed these data points and they did not discover any indication of a laboratory error, and all other sources of error have been ruled out, leaving the investigation inconclusive. It should be noted that even at the increased levels, the results are still well within the AWQC. Concentrations of TCE and total 1,2-DCE are below the AWQCs for recreation, organisms only (300 µg/L for TCE and 10,000 µg/L for trans-1,2-DCE), which are appropriate standards for Mitchell Branch. Moreover, the standards for 1,2-DCE apply only to the “trans” form of 1,2-DCE; almost all of the 1,2-DCE is in the cis- isomer. In addition, vinyl chloride has sometimes been detected in Mitchell Branch water (Figure 3.27). VOCs have been detected in groundwater in the vicinity of Mitchell Branch and in building sumps discharging into storm water outfalls that discharge into the stream; however, storm drain network monitoring generally has not detected these compounds in the storm water discharges. Therefore, it appears that the primary source of these compounds is contaminated groundwater.

Since CWTS was installed, chromium levels in Mitchell Branch have dropped dramatically, with levels of total chromium being routinely measured at less than 6 µg/L (Figure 3.28). In 2018, hexavalent chromium levels in Mitchell Branch were all below the detection limit of 6 µg/L.



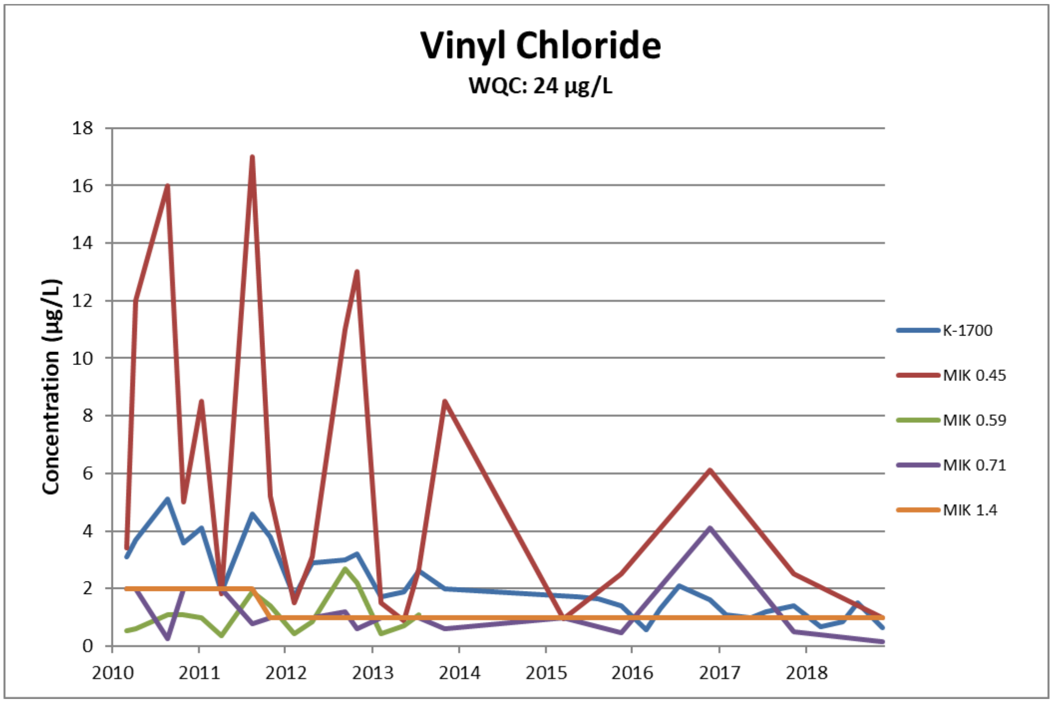
MIK = Mitchell Branch kilometer

Figure 3.25. Trichloroethene concentrations in Mitchell Branch



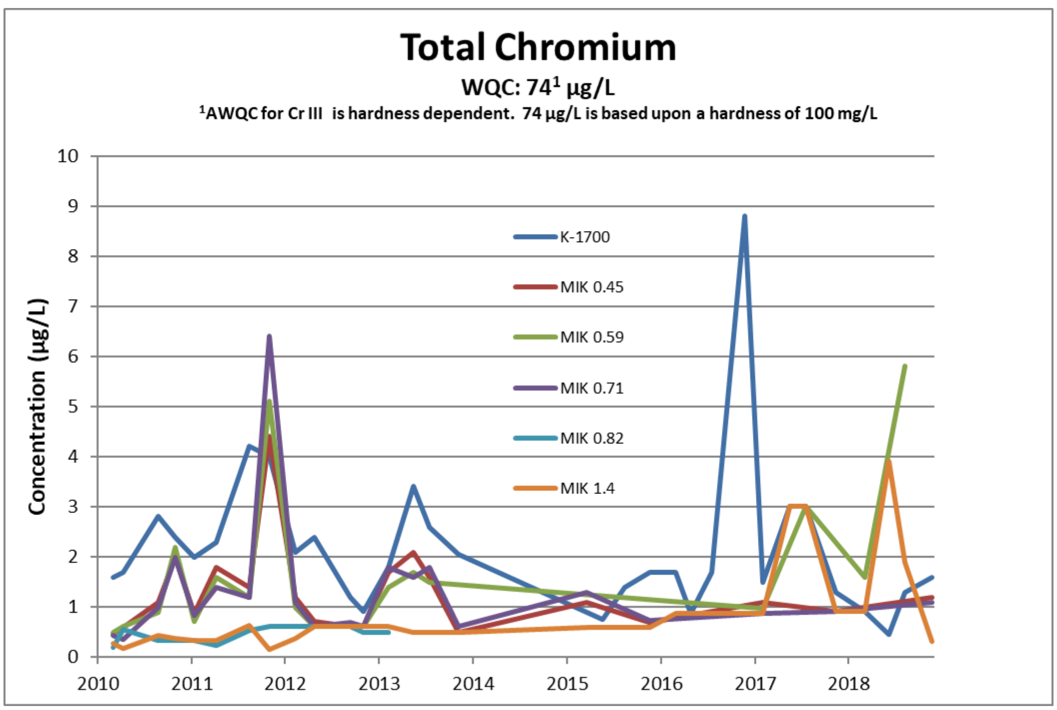
MIK = Mitchell Branch kilometer

Figure 3.26. Concentrations of cis-1,2-dichloroethene in Mitchell Branch



MlK = Mitchell Branch kilometer

Figure 3.27. Vinyl chloride concentrations in Mitchell Branch



The AWQC for Cr(III), which is hardness-dependent, is 74 µg/L, based on a hardness of 100 mg/L. The AWQC for Cr(IV) is 11 µg/L.

AWQC = ambient water quality criterion, MIK = Mitchell Branch kilometer

Figure 3.28. Total chromium concentrations in Mitchell Branch

3.6.16 Groundwater Monitoring

3.6.16.1 General Groundwater Monitoring at ETTP

VOC concentrations in wells monitored downgradient of K-1070-C/D show that a broad area is affected by releases from the past disposal of liquid VOCs at G-Pit. While concentrations along one portion of the affected area associated with Wells UNW-114 and UNW-064 continue to decrease, there remains a known area with very high concentrations that affect Wells DPT-K1070-5 and DPT-K1070-6. The persistent, high concentrations of these VOCs suggest an ongoing contaminant source release.

Contaminant conditions in the groundwater exit pathway areas are generally stable and similar to conditions in recent years. In the K-31/K-33 area, chromium continues to be measured at levels near or slightly above screening level MCLs although during FY 2018, all chromium results were less than the 0.1 mg/L MCL. Nickel is present in groundwater samples from one well (UNW-043) at concentrations greater than the state of Tennessee screening criterion of 0.1 mg/L.

In the K-1064 Peninsula, arsenic exceeded its screening level MCL in groundwater samples collected during FY 2018. TCE concentrations continued to decrease with a maximum detected concentration less than the screening level MCL in FY 2018.

In the K-27/K-29 area, chromium continues to exceed its 0.1 mg/L MCL screening level in unfiltered samples from Wells UNW-038 and UNW-096, although concentrations in filtered samples are less than the MCL screening level. Nickel exceeds the state of Tennessee water quality screening criterion in Wells UNW-038 and UNW-096. TCE continues to gradually decrease in Wells UNW-038 and UNW-096.

Samples from spring PC-0, which discharges groundwater into Poplar Creek, had TCE concentrations greater than the 5 µg/L MCL during November 2017 and February 2018, but concentrations were less than the MCL in April 2018. At spring 10-895, TCE was detected at concentrations less than the MCL screening level during FY 2018.

In the K-770 area, alpha activity concentrations have decreased to levels less than the 15 pCi/L screening level.

At wells near the K-1007-P1 Holding Pond, alpha activity was detected at a concentration less than the 15 pCi/L screening concentration in Well UNW-108 and TCE was not detected, although in previous years it was measured at concentrations greater than its 0.005 mg/L screening concentration.

Monitoring results from wells in the K-1407-B/C Ponds area are generally consistent with results from previous years and show several fold concentration fluctuations in seasonal and longer-term periods. The detection of VOCs at concentrations well above 1,000 µg/L and the steady concentrations over recent years suggest the presence of dense nonaqueous phase liquid (DNAPL) in the vicinity of Well UNW-003 (Figure 3.29).

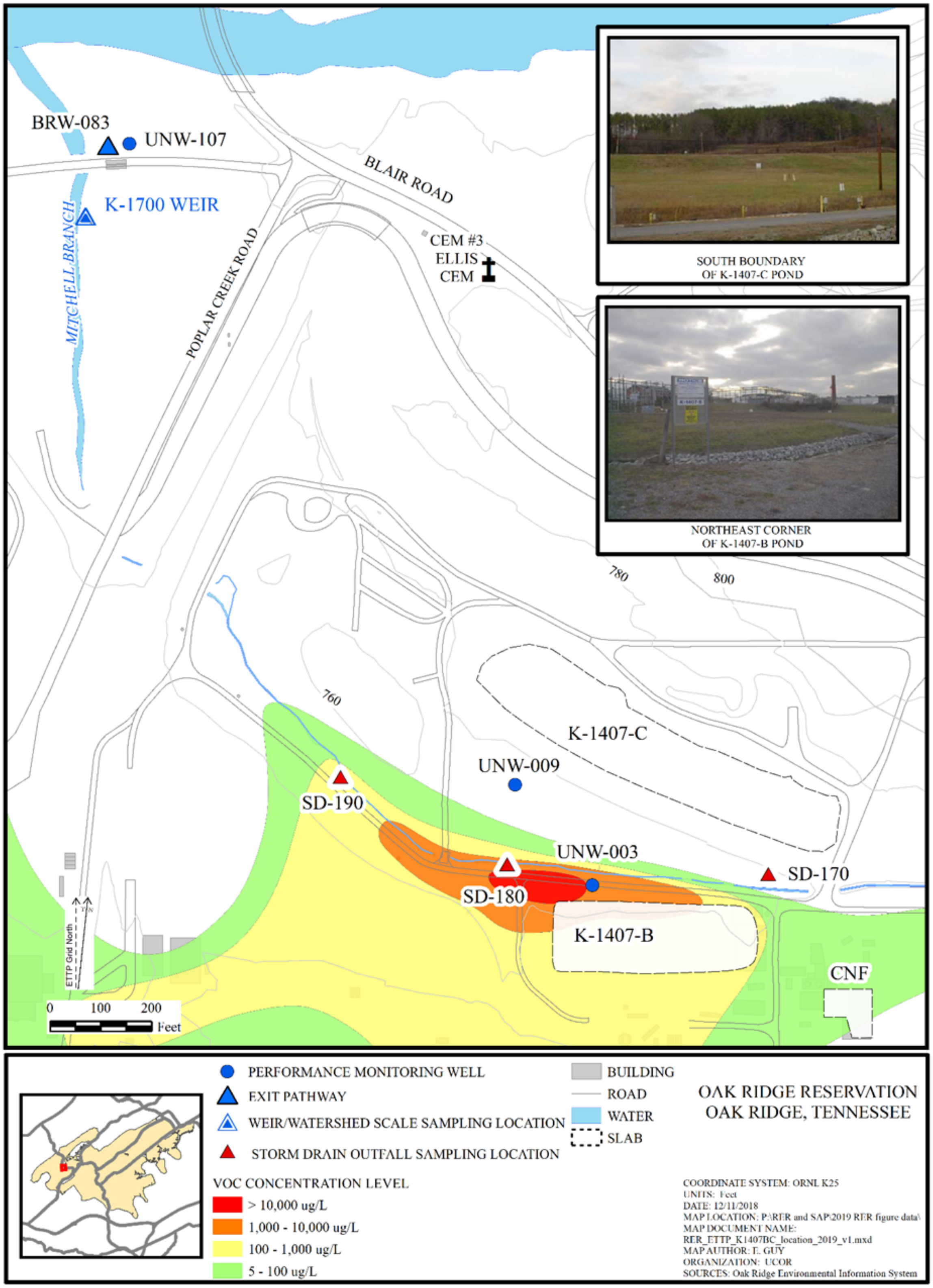


Figure 3.29. Location of K-1407-B/C Ponds

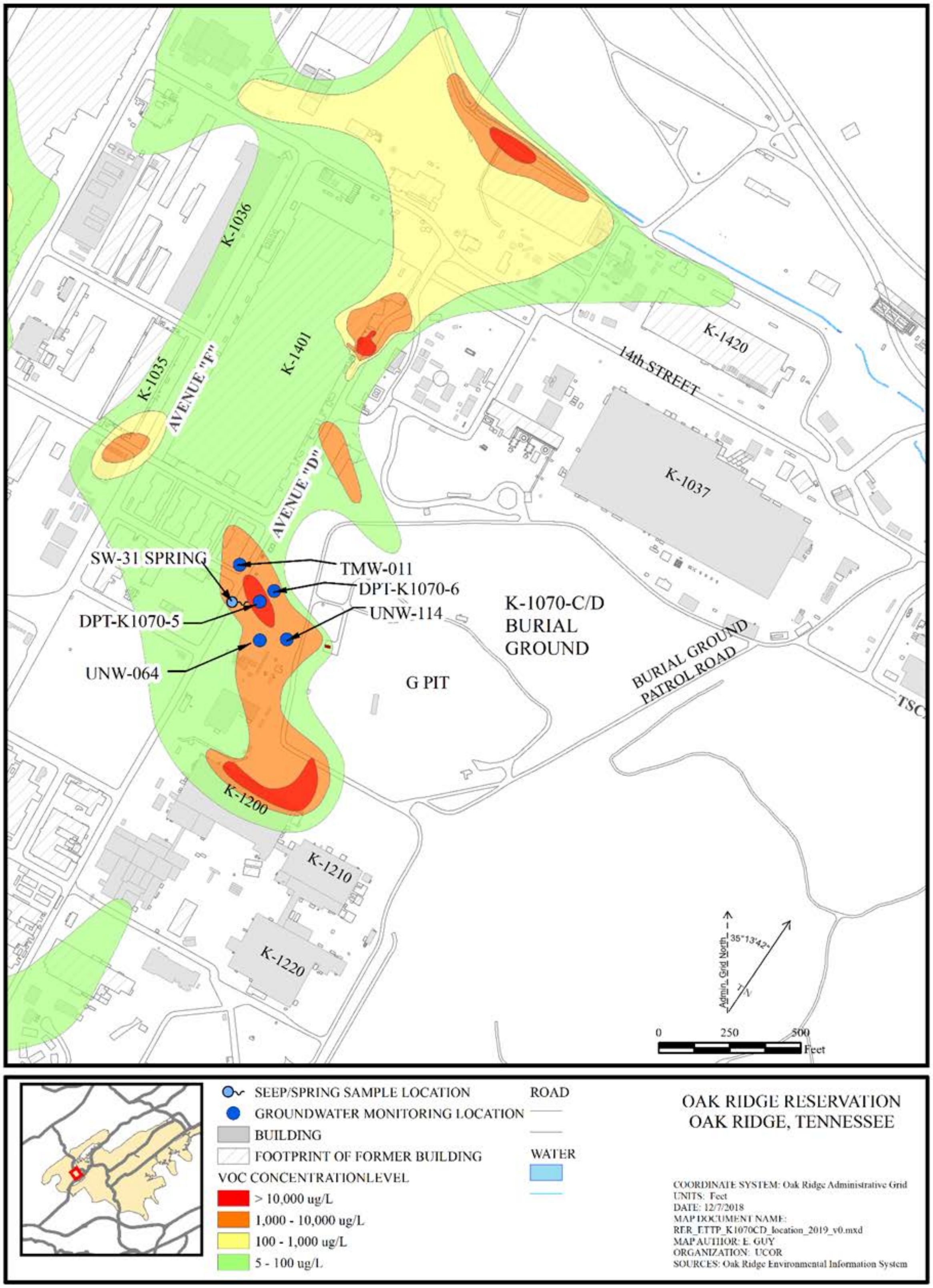


Figure 3.30. Location map for K-1070-C/D Burial Ground

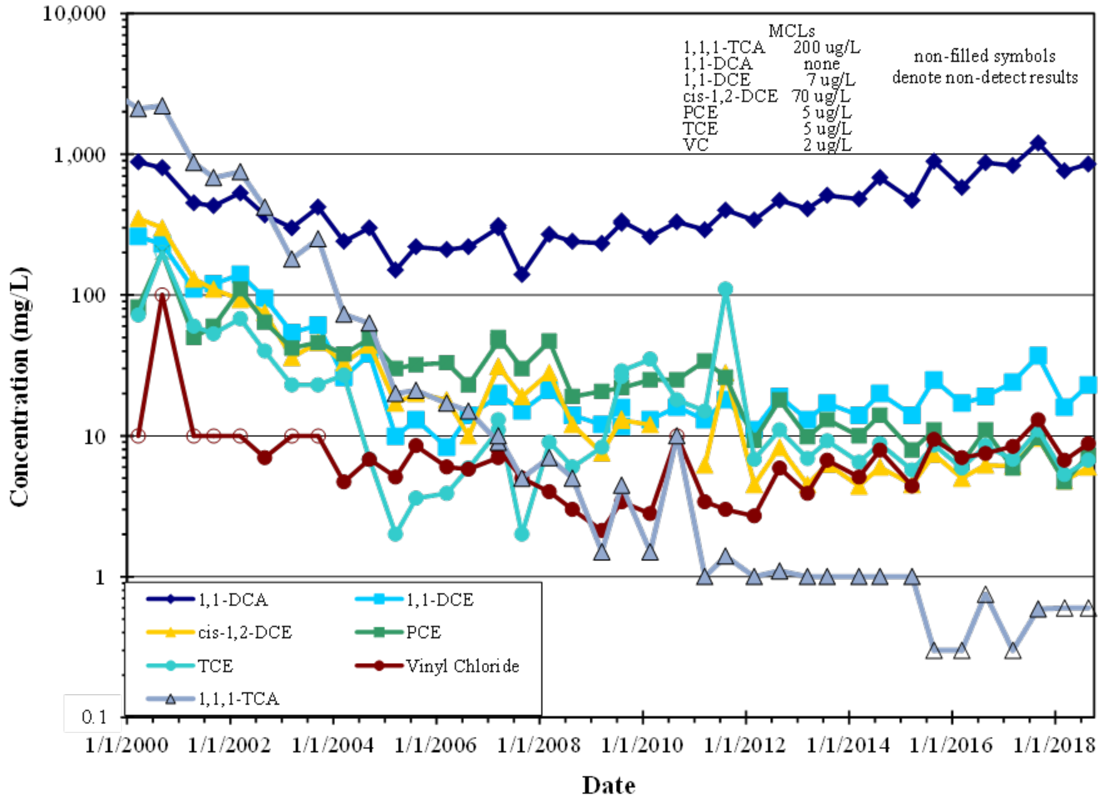


Figure 3.31. VOC concentrations in Well UNW-114, FYs 2000–2018

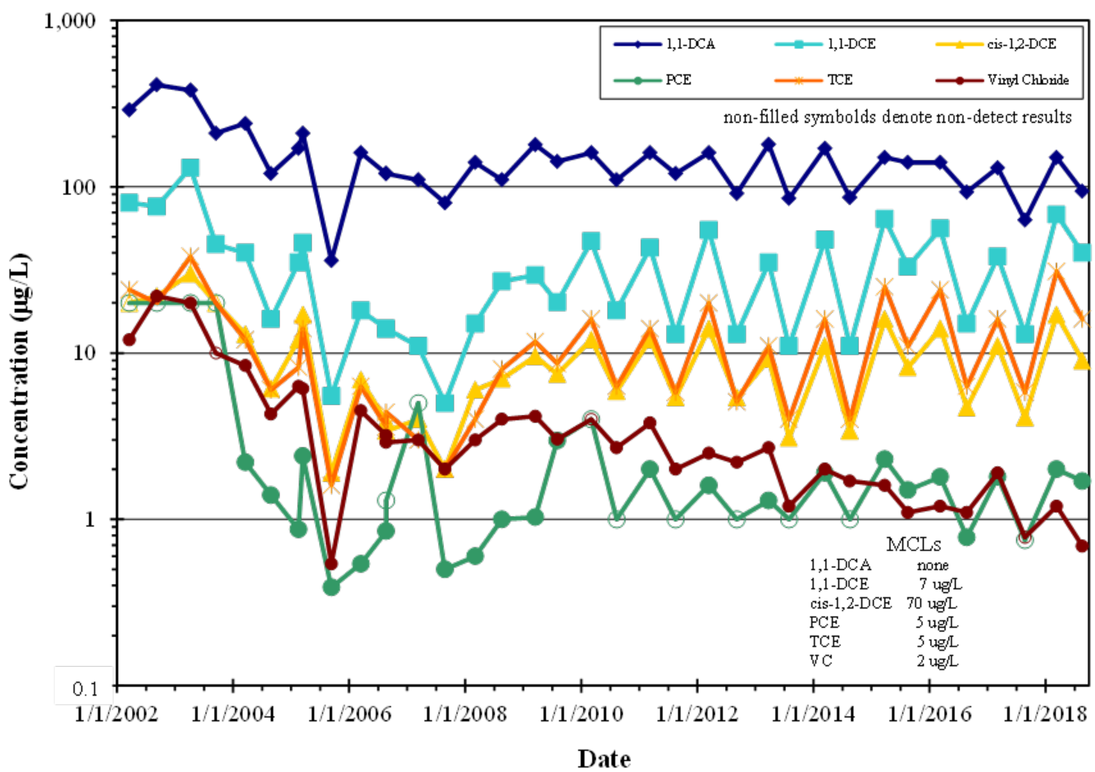


Figure 3.32. VOC concentrations in Well UNW-064, FYs 2002–2018

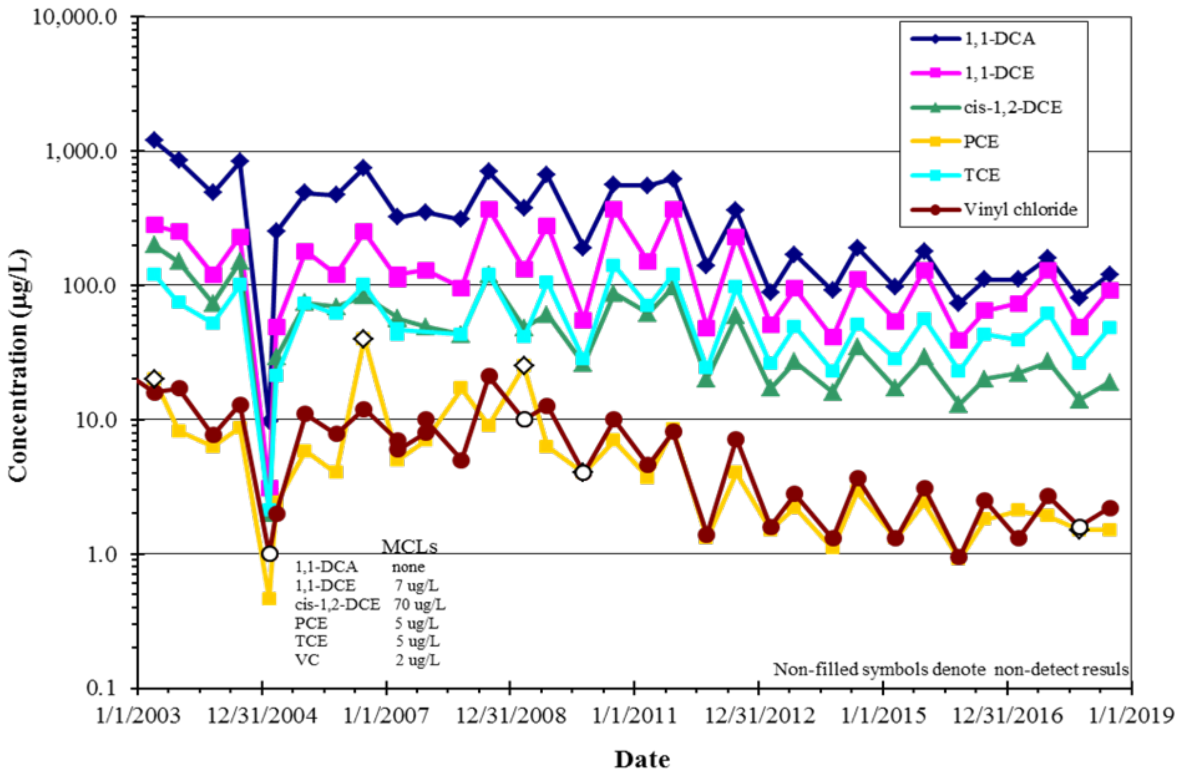


Figure 3.33. VOC concentrations in Well TMW-011, FYs 2002–2018

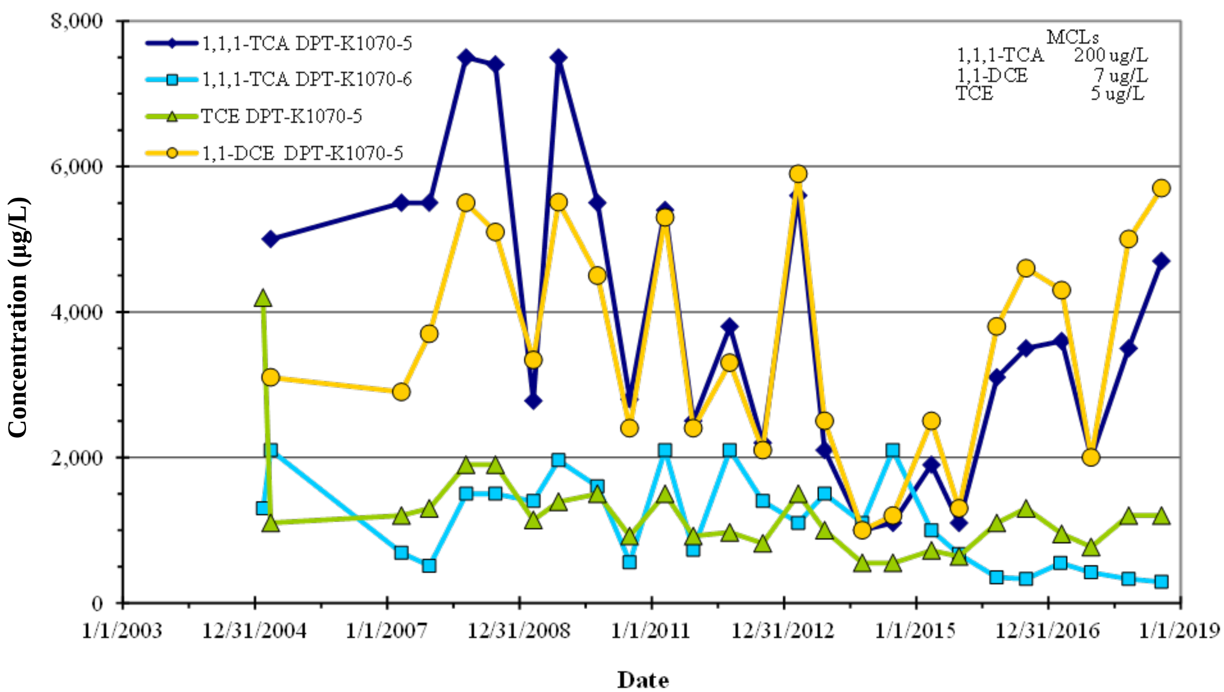


Figure 3.34. VOC concentrations in DPT-K-1070-5 and DPT-K-1070-6, FYs 2002–2018

Monitoring requirements for completed CERCLA includes monitoring for sites—such as the K-1070-C/D Burial Grounds, K-1407-B/C Ponds, K-901-A and K-1007-P1 Holding Ponds—and monitoring to determine the effectiveness of the Chromium Water Treatment Facility. Monitoring results of these actions are discussed in the following sections.

K-1407-B/C Ponds

The K-1407-B Pond (Figure 3.29), constructed in 1943, was primarily used for settling metal hydroxide precipitates generated during neutralization and precipitation of metal-laden solutions treated in the K-1407-A Neutralization Unit. It also received discharge from the K-1420 Metals Decontamination Building and wastes from the K-1501 Steam Plant. The K-1407-C Pond, constructed in 1973, was primarily used to store potassium hydroxide scrubber sludge generated at K-25. It also received sludge from the K-1407-B Pond. When the K-1407-B Pond reached maximum sludge capacity, it was dredged, and the sludge was transferred to the K-1407-C Pond. The primary groundwater contaminants in the K-1407-B/C Ponds area are VOCs. VOCs are widespread in this portion of ETTP, including contaminant sources upgradient of the ponds. Groundwater samples were collected at Wells UNW-003 and UNW-009 in March and August 2018. VOCs are infrequently detected in shallow groundwater north of Mitchell Branch in Well UNW-009 because the upgradient K-1407-C Pond was principally used as a sludge holding area rather than as primary wastewater holding unit. During FY 2018, cis-1,2-DCE was detected at concentrations of 0.82 J µg/L and 0.98 µg/L in March and August, respectively, and TCE was detected at 0.5 J µg/L in August in Well UNW-009. Alpha activity has a history of measurements greater than 80 percent of its 15 pCi/L MCL although maximum measured concentrations within the past five years have been less than 10 pCi/L. Arsenic also has a history of being present in groundwater in Well UNW-003 although it was apparently associated with filterable particulates as indicated by non-detect results in filtered sample aliquots. Over the past five years, VOC concentration trends have been predominantly stable with decreasing trends for 1,1-DCE and vinyl chloride (VC). DOE suspects a DNAPL source exists somewhere beneath the former pond site based on persistent, high VOC concentrations in both shallow and deeper groundwater wells. The K-1407-C Pond was excavated in accordance with the Zone 2 record of decision (ROD) (DOE 2005b, DOE/OR/01-2161&D2) in 2017, and therefore, performance inspections are no longer necessary and are no longer performed. Inspections of K-1407-B Pond will continue until RA is taken. Components of K-1407-B Pond inspected in FY 2018 by the ETTP S&M Program include: access controls and sign conditions; condition of vegetation exhibiting dead spots, excessive weeds or deep-rooted vegetation, grass mowing, and discoloration or withering vegetation; and soil/surface conditions with evidence of soil erosion, gullies or rills, staining, and debris or trash. The site underwent routine mowing. Maintenance included cleaning the K-1407-B Pond sign so contact information is legible.

K-1070-C/D G-Pit and Concrete Pad

The K-1070-C/D G-Pit is the primary source of organic contaminant releases to soil and groundwater in the area. The K-1071 Concrete Pad, located in the southeastern portion of the K-1070-C/D area, was determined to pose an unacceptable health risk to workers from future exposure to soil radiological contaminants. Monitoring locations, analytical parameters, and cleanup levels were not specified for groundwater monitoring at the K-1070-C/D Burial Ground, although the primary contaminants of concern (COCs) in that area are VOCs. Semiannual samples collected at wells and surface water locations outside the perimeter of the K-1070-C/D Burial Ground are analyzed for VOCs and general water quality parameters (Figure 3.30). Monitoring at the site is focused on providing data for evaluating changes in contaminant concentrations near the source units or potentially discharging to surface water within the boundaries of ETTP. Approximately 9,100 gal of mixed volatile organic liquids were disposed in G-Pit during its period of use between 1977 and 1979. Site characterization data collected at G-Pit in the mid-1990s showed the presence of 1,1,1-TCA (840 mg/L); 1,1-DCA (43 mg/L); toluene (74 mg/L); and TCE (220 mg/L). A RA was conducted in December 1999 − January 2000 to remove container remnants from

G-Pit (DOE 2002b, DOE/OR/01-1964&D2). The pit was backfilled with soil following the excavation. DOE's conceptual model for the G-Pit site includes probable DNAPL permeation of the unconsolidated and bedrock zones beneath the former liquid waste disposal site. The 1,1,1-TCA is amenable to biodegradation to 1,1-DCA by microbes in the *Dehalobacter* genus. Although 1,1-DCA is also amenable to degradation by some species of *Dehalobacter*, the presence of cis-1,2-DCE and VC tend to inhibit the biodegradation of 1,1-DCA. Cis-1,2-DCE and VC are common biodegradation products of PCE and TCE, which are also present in groundwater at the site, along with 1,1-DCE, another biodegradation product of PCE and TCE.

Following remediation of G-Pit, Monitoring Wells UNW-114, TMW-011, and UNW-064 (Figure 3.30) were selected to monitor the VOC plume leaving the K-1070-C/D Burial Grounds because they were located in the principal known downgradient groundwater pathway. Results of monitoring at these wells show elevated VOC concentrations. VOC concentrations at these three wells were decreasing prior to the excavation of the G-Pit contents (during FY 2000) and continue to decrease. Although 1,1,1-TCA was formerly present at concentrations far greater than its 200 µg/L MCL, natural biodegradation has reduced 1,1,1-TCA concentrations to less than the drinking water standard. Several direct push technology (DPT) monitoring points were installed to the west of UNW-114 during investigations conducted in support of a Sitewide Groundwater remedial investigation (RI) in 2005. The purpose of these monitoring points was to investigate groundwater contamination in an area along potential geologically controlled seepage pathways that may have connected the G-Pit contaminant source to the former SW-31 spring. DOE continues to monitor two of these points (DPT-K1070-5 and DPT-K1070-6) to measure VOC concentrations and their fluctuations.

Long-term contaminant concentration graphs are provided for three wells monitored closest to the G-Pit contaminant source. Well UNW-114 is closest to the source area and has a screen interval elevation of 774.95–784.95 ft above mean sea level (aMSL) in unconsolidated material. Monitoring data for Well UNW-114 show that concentrations of most VOCs have been variable since 2005 (Figure 3.31). Contaminant concentration trends in Well UNW-114 show that 1,1-DCE and VC exhibited increasing concentration trends in the 10-year evaluation period, although concentration variability of both these compounds has been great enough over the most recent five years so that a statistically confident trend direction could not be assigned. PCE and TCE both exhibit a decreasing trend in the 10-year evaluation. PCE continued that decreasing trend in the 5-year evaluation, although the trend for TCE was stable. The increasing trend for 1,1-DCE and VC is attributed to natural degradation of chlorinated VOCs at the site. Metals analysis was added to UNW-114 fairly recently and nickel exceeds the state of Tennessee water quality criterion (WQC) in both unfiltered and filtered sample aliquots, which indicate that nickel is present as a dissolved contaminant in Well UNW-114.

Well UNW-064 (Figure 3.30; well screen elevation 783.87 – 788.87 ft aMSL) is located slightly further downgradient from the contaminant source area than UNW-114 and its monitoring data exhibit a slightly different behavior. Similar to the overall trend observed at UNW-114, the majority of VOC concentrations at UNW-064 decreased from about 2002 through 2005 (Figure 3.32). Although 1,1-DCE and TCE are always detected in samples from Well UNW-064, their concentrations are sufficiently variable to prevent assignment of concentration trend direction with statistical confidence. VC concentration trends have been decreasing in both the 10-year and 5-year evaluations. The FY 2018 maximum measured VC concentration in Well UNW-064 was less than the MCL. At UNW-064, the 1,1-DCA, 1,1-DCE, cis-1,2-DCE, and TCE exhibit seasonal concentration fluctuations with higher concentrations during winter than during summer. This seasonal fluctuation suggests that contaminant mass transport responds to increased groundwater recharge and seepage through the plume. DOE suspects that increased seasonal recharge drives mass transfer in the plume through two combined mechanisms. One mechanism is a rise in groundwater elevation in the source area (residuals from liquid waste beneath G-Pit), which allows groundwater seepage through fractures of higher permeability at a somewhat shallower depth. The second mechanism is simply a higher flow volume through the source area and downgradient fractures caused by the higher head imposed on the whole saturated zone.

Well TMW-011 (Figure 3.30; screen just above bedrock at elevation 762.8 ft aMSL) is located furthest from the contaminant source area near the base of the hill below K-1070-C/D. VOC concentrations at TMW-011 tend to fluctuate in a fashion similar to those at UNW-064 except that the seasonal signature is reversed, with higher concentrations in summer than during winter (Figure 3.33). This relationship suggests that groundwater recharge during winter tends to dilute the VOCs near TMW-011 rather than cause a pulse of higher concentration groundwater as was observed at the mid-slope location near UNW-064. Trend evaluations in Well TMW-011 show a decrease for cis-1,2-DCE and VC for the 10-year evaluation although the trends are stable in the 5-year evaluations for these two contaminants. Although the maximum measured TCE concentrations progressively decrease in the 10-year, 5-year, and FY 2018 results, the TCE trend evaluations are stable over the 10-year period and no statistically confident trend could be assigned over the most recent five years. Since 2012, VC has fluctuated, with wet season concentrations below the MCL and dry season concentrations exceeding the MCL.

Monitoring locations DPT-K1070-5 and DPT-K1070-6 (Figure 3.30; screened intervals 776.93 – 781.93 and 777.48 – 782.48 ft aMSL, respectively) were installed using DPT and therefore they sample groundwater just at, and somewhat above, the top of bedrock downgradient of the G-Pit VOC source. Both sample locations exhibit a fairly wide range of VOC contaminants, with DPT-K1070-5 being more highly contaminated than DPT-K1070-6. Figure 3.34 shows the concentration history for those constituents with the highest concentrations in the monitored K-1070-C/D DPT wells. Seasonal fluctuation signatures are apparent in the contaminant concentrations in these DPT wells prior to about 2016, before there was an unexplained change in behavior evidenced by increases in 1,1-DCE and 1,1,1-TCA in DPT-K1070-5, which coincided with decreases in 1,1,1-TCA at DPT-K1070-6 and an increase in TCE at DPT-K1070-5. No activities other than grounds maintenance (mowing) occurred in the area upgradient of these wells during that time period.

Contaminant trends over the past 10 years have been predominantly decreasing or stable while nine results have been sufficiently variable to preclude assignment of a concentration trend. Three contaminants (1,1-DCE and VC at UNW-114 and cis-1,2-DCE at DPT-K1070-5) have exhibited increasing trends. Increasing trends for degradation products of the parent solvent compounds is an indication that natural degradation processes are ongoing in the area. Within the most recent five years, somewhat more variability in trend directions has been observed with 10 decreasing trends, 8 increasing trends, 11 stable trends, and 10 indeterminate trends.

The elevation and VOC concentration relationships among the monitoring wells demonstrate that the G-Pit plume is a heterogeneous flow system and that DPT-K1070-5 and DPT-K1070-6 lie in a different flow path from the area monitored by UNW-064 and UNW-114. Although the screen elevations of the two DPTs and Well UNW-114 are essentially the same, the VOC concentrations in the DPT samples are much higher than those in Well UNW-114. Bedrock wells have not been installed in the area to date to evaluate deeper groundwater conditions.

Extensive groundwater monitoring at the ETTP site, using the Safe Drinking Water Act (SDWA) MCLs as groundwater screening values, has identified VOCs as the most significant groundwater contaminant on site. The principal chlorinated hydrocarbon chemicals that were used at ETTP were PCE, TCE, and 1,1,1-TCA. While preparing a remedial investigation/feasibility study (RI/FS) in 2007 to support CERCLA decision-making for the ETTP site, the human health risk assessment summarized "*priority COCs in groundwater . . . for the industrial worker, which is the most likely of the future scenarios assessed for exposure to groundwater*." (DOE 2007, DOE/OR/01-2279&D3) The evaluation of priority groundwater COCs identified the major groundwater contaminant source areas and associated plumes.

Figure 3.35 shows the distribution and generalized concentrations of the sum of the primary chlorinated hydrocarbon chemicals and their degradation products at ETTP. Specific compounds included in the summation of chlorinated VOCs include chloroethenes (PCE, TCE, cis-1,2-DCE, trans-1,2-DCE, and VC), chloroethanes (1,1,1-TCA, 1,1,2-TCA, 1,2-DCA, 1,1-DCA, and chloroethane), and chloromethanes (carbon tetrachloride, chloroform, and methylene chloride). Several plume source areas are identified within the regions of the highest VOC concentrations. In these areas, the primary chlorinated hydrocarbons have been present for decades and mature contaminant plumes have evolved. The degree of degradation, of the primary chlorinated hydrocarbon compounds is highly variable across the site. In the vicinity of the K-1070-C/D source (G-Pit and Concrete Pad, Section 3.6.17.1), a high degree of degradation has occurred, although a strong source of contamination still remains in the vicinity of the G-Pit, where approximately 9,000 gal of chlorinated hydrocarbon liquids were disposed in an unlined pit. Other areas where degradation is significant include the K-1401 Acid Line leak site, and the K-1407-B Pond area. Degradation processes are weak or inconsistent at the K-1004 and K-1200 area, K-1035, K-1413, and K-1070-A Burial Ground, and little degradation of TCE is observed in the K-27/K-29 source and plume area.

VOC plumes shown on Figure 3.35 include significant revisions in the K-1401 area where subsurface characterization activities in support of the *Design Characterization Completion Report for the Sitewide Groundwater Treatability Study at the East Tennessee Technology Park, Oak Ridge, Tennessee* (DOE 2018a, DOE/OR/01-2768&D1) completed during FY 2018 defined the nature and extent of DNAPL and high concentrations of chlorinated solvent compounds in groundwater. In addition, ongoing soil characterization identified an area of TCE contaminated soil and groundwater within the footprint of the former K-25 building. Figure 3.35 also shows the locations of monitoring wells throughout the ETTP site that are routinely sampled for known COCs. Designated groundwater exit pathway monitoring wells are identified and general facility areas are shown within which groundwater contaminant trends are discussed later in this section.

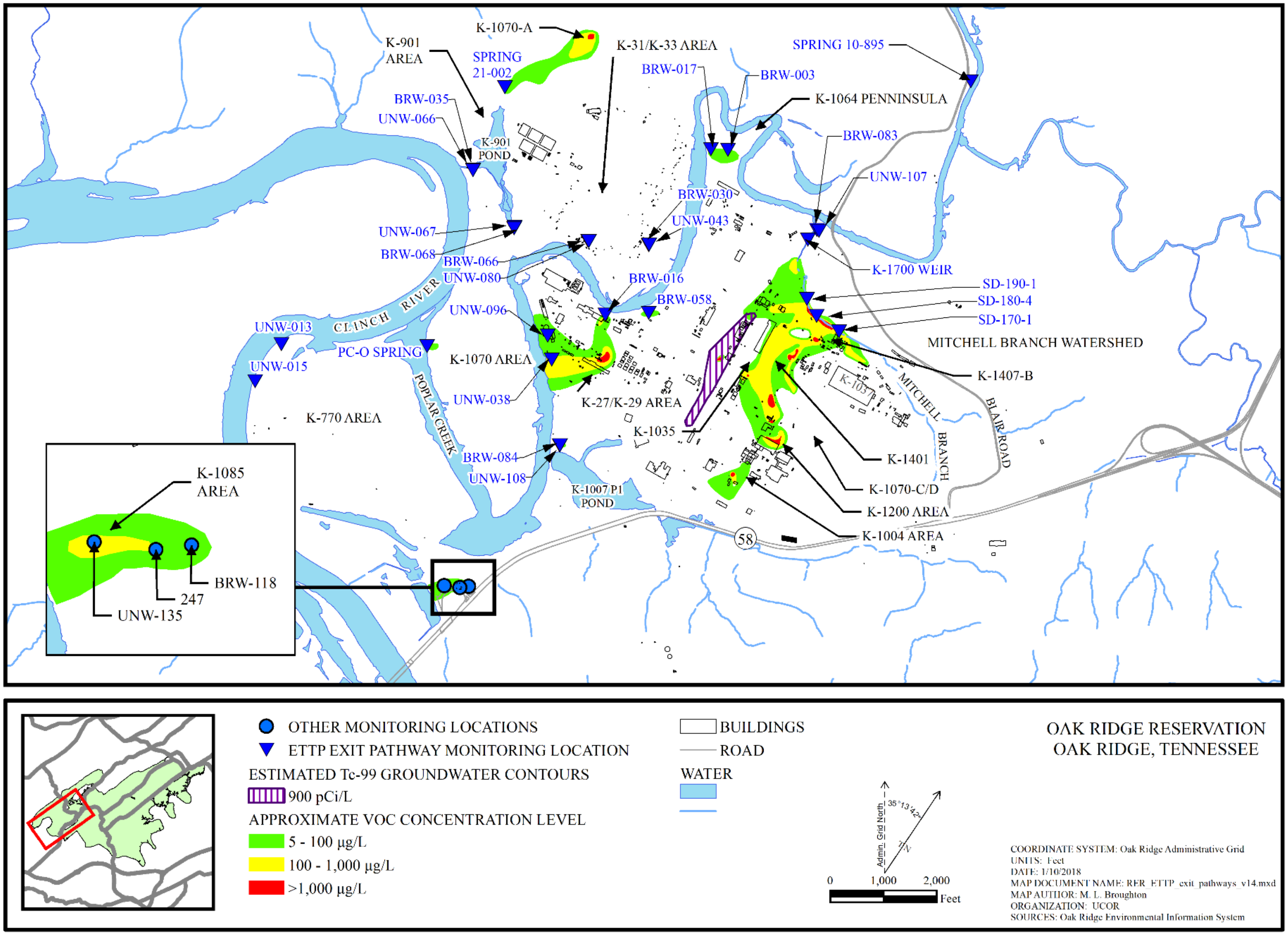


Figure 3.35. ETTP exit pathways monitoring locations

Mitchell Branch

The Mitchell Branch groundwater exit pathway is monitored using surface water data from the K-1700 Weir on Mitchell Branch and Wells BRW-083 and UNW-107.

Wells BRW-083 and UNW-107, located near the mouth of Mitchell Branch, have been monitored since 1994. Detection of VOCs in groundwater near the mouth of Mitchell Branch is considered an indication of the migration of the Mitchell Branch VOC plume complex. The intermittent detection of VOCs in this exit pathway is thought to be a reflection of variations in groundwater flow paths that can fluctuate with seasonal hydraulic head conditions that are strongly affected by rainfall. During FY 2018, no chlorinated VOCs were detected in Wells BRW-083 or UNW-107 and no concentrations of VOCs in the 5-year evaluation period exceeded 80 percent of their respective MCLs (Table 3.22).

K-1064 peninsula area

Wells BRW-003 and BRW-017 monitor groundwater at the K-1064 peninsula burn area. Metals and VOCs are monitored at the site. Metals detected in groundwater at the site include antimony, zinc, chromium, and arsenic, however, only arsenic concentrations exceeded 80 percent of its MCL. Arsenic was detected in both wells with maximum concentrations of 15 µg/L in Well BRW-003 in the filtered sample in March 2018 and 14 µg/L in the filtered sample from Well BRW-017 in September 2018. Arsenic concentrations in both unfiltered and filtered samples from Well BRW-003 have shown long-term decreases during the period between 2004 and 2018 (Figure 3.36, Table 3.22). In the past, VOC contaminants exceeded MCLs in Wells BRW-003 and BRW-017; however, regulated VOC concentrations have declined to levels below screening levels with the exception of TCE, which has not exceeded its 0.005 mg/L MCL within the past five years (Table 3.22).

K-31/K-33 area

Groundwater is monitored in four wells (BRW-066, BRW-030, UNW-080, and UNW-043) that lie between the K-31/K-33 area and Poplar Creek. VOCs are not COCs in this area. Within the past 10 years, five metals (antimony, arsenic, chromium, lead, and nickel) have exceeded 80 percent of their MCLs. Antimony, arsenic, chromium, and lead have decreased to concentrations less than their respective MCLs or have become non-detectable. Nickel exceeds the state of Tennessee water quality concentration (0.1 mg/L) in Well UNW-043 in both the unfiltered and field filtered sample aliquots. Table 3.22 shows the trends of chromium concentrations in the groundwater in this area.

K-27/K-29 area

Groundwater discharges toward Poplar Creek in both a northward pathway beneath the K-1232 area and in a south to westward pathway as shown on Figure 3.35. Two wells (BRW-016 and BRW-058) in the northern plume near K-27/29 and two wells (UNW-038 and UNW-096) in the south/western plume have been designated for exit pathway monitoring. VOCs have exceeded MCLs in the K-27/K-29 area northern pathway (Table 3.22). TCE has decreased to concentrations less than its 0.005 mg/L MCL although cis-1,2-DCE and VC continue to exceed their respective MCLs. The presence of cis-1,2-DCE and VC in the area are indicative that natural degradation of the parent TCE is occurring in this part of the ETTP site. In the south/west exit pathway from the K-27/K-29 area, TCE is persistent in the exit pathway wells with decreasing or indeterminate trends. Chromium and nickel exceed their respective MCLs. An increasing concentration in the unfiltered sample chromium content has been detected for the 5-year evaluation although the filtered aliquot data from that well have been below the 0.1 mg/L MCL. Nickel exceeds the state of Tennessee water quality criterion of 0.1 mg/L in unfiltered samples from Wells UNW-038 and UNW-096 and also exceeds that criterion in the filtered samples from UNW-096, indicating that nickel is a dissolved phase contaminant at that location. Filtered and unfiltered nickel concentrations in Well UNW-096 have increasing trends in both the 10-year and most recent 5-year evaluations.

Table 3.22. Exit pathway groundwater contaminant screening results and trend evaluations

Chemical	Well	Units	Freq. of detection		Maximum detection limit[a]	Maximum detected			MCL[b]	Freq. > MCL[b]		Freq. > 80% of MCL[b]		Significant trend[c]	
			10 yr	5 yr		10 yr	5 yr	FY 2018		10 yr	5 yr	10 yr	5 yr	10 yr	5 yr
Mitchell Branch Exit Pathway															
Alpha activity	UNW-107	pCi/L	16 / 20	10 / 10	2.61	14.3	14.3	2.48	15	0 / 20	0 / 10	1 / 20	1 / 10	No trend	No trend
Chromium	UNW-107	mg/L	10 / 20	5 / 10	0.005	**0.11**	0.064	0.002	0.1	1 / 20	0 / 10	1 / 20	0 / 10	No trend	No trend
	UNW-107(F)	mg/L	9 / 20	4 / 10	0.005	0.027	0.009	0.002	0.1	0 / 20	0 / 10	0 / 20	0 / 10	No trend	No trend
Tetrachloroethene	BRW-083	mg/L	3 / 20	0 / 10	0.003	**0.007**	ND	ND	0.005	2 / 20	0 / 10	2 / 20	0 / 10	No trend	--
Trichloroethene	BRW-083	mg/L	4 / 20	0 / 10	0.001	**0.022**	ND	ND	0.005	3 / 20	0 / 10	3 / 20	0 / 10	Down	--
K-1064 Peninsula Exit Pathway															
Arsenic	BRW-003	mg/L	20 / 20	10 / 10	--	**0.035**	**0.024**	**0.011**	0.01	18 / 20	8 / 10	19 / 20	9 / 10	Down	Down
	BRW-003(F)	mg/L	20 / 20	10 / 10	--	**0.031**	**0.023**	**0.015**	0.01	19 / 20	9 / 10	20 / 20	10 / 10	Down	Stable
	BRW-017	mg/L	8 / 20	8 / 10	0.005	**0.016**	**0.016**	0.008	0.01	2 / 20	2 / 10	2 / 20	2 / 10	Up	No trend
	BRW-017(F)	mg/L	6 / 20	6 / 10	0.005	**0.014**	**0.014**	**0.014**	0.01	1 / 20	1 / 10	3 / 20	3 / 10	Up	Up
Trichloroethene	BRW-017	mg/L	20 / 20	10 / 10	--	**0.005**	0.004	0.003	0.005	2 / 20	0 / 10	6 / 20	0 / 10	Down	Down
K-31/K-33 Area Exit Pathway															
Alpha activity	UNW-080	pCi/L	2 / 6	2 / 6	4.72	**16.1**	**16.1**	2.35	15	1 / 6	1 / 6	1 / 6	1 / 6	No trend	No trend
Antimony	UNW-043	mg/L	5 / 20	4 / 10	0.003	**0.02**	0.00045	ND	0.006	1 / 20	0 / 10	1 / 20	0 / 10	No trend	No trend
	UNW-043(F)	mg/L	4 / 20	4 / 10	0.003	3.7E-04	0.00037	0.00034	0.006	0 / 20	0 / 10	0 / 20	0 / 10	Stable	No trend
	UNW-080	mg/L	2 / 20	2 / 10	0.003	**0.026**	**0.026**	0.00005	0.006	1 / 20	1 / 10	1 / 20	1 / 10	No trend	No trend
	UNW-080(F)	mg/L	2 / 20	2 / 10	0.003	0.00017	0.00017	0.00008	0.006	0 / 20	0 / 10	0 / 20	0 / 10	Stable	No trend
Arsenic	UNW-043	mg/L	3 / 20	2 / 10	0.025	**0.035**	0.006	0.006	0.01	1 / 20	0 / 10	1 / 20	0 / 10	No trend	No trend
	UNW-043(F)	mg/L	1 / 20	1 / 10	0.005	**0.011**	**0.011**	--	0.01	1 / 20	1 / 10	1 / 20	1 / 10	No trend	No trend
Chromium	BRW-030	mg/L	20 / 20	10 / 10	--	**0.11**	**0.11**	0.091	0.1	1 / 20	1 / 10	7 / 20	3 / 10	Stable	No trend
	BRW-030(F)	mg/L	20 / 20	10 / 10	--	0.12	0.12	0.096	0.1	2 / 20	2 / 10	6 / 20	3 / 10	Stable	No trend
	UNW-043	mg/L	20 / 20	10 / 10	--	**21**	**3.6**	0.057	0.1	17 / 20	7 / 10	17 / 20	7 / 10	Down	Down
	UNW-043(F)	mg/L	18 / 20	10 / 10	0.005	0.046	0.046	0.046	0.1	0 / 20	0 / 10	0 / 20	0 / 10	No trend	No trend
	UNW-080	mg/L	20 / 20	10 / 10	--	**1.2**	**1.2**	0.019	0.1	4 / 20	4 / 10	4 / 20	4 / 10	No trend	Down
	UNW-080(F)	mg/L	20 / 20	10 / 10	--	0.027	0.022	0.015	0.1	0 / 20	0 / 10	0 / 20	0 / 10	Stable	Stable

Table 3.22. Exit pathway groundwater contaminant screening results and trend evaluations (continued)

Chemical	Well	Units	Freq. of detection		Maximum detection limit[a]	Maximum detected			MCL[b]	Freq. > MCL[b]		Freq. > 80% of MCL[b]		Significant trend[c]	
			10 yr	5 yr		10 yr	5 yr	FY 2018		10 yr	5 yr	10 yr	5 yr	10 yr	5 yr
Lead	UNW-080	mg/L	4 / 20	4 / 10	0.003	**0.015**	**0.015**	ND	0.015	0 / 20	0 / 10	2 / 20	2 / 10	No trend	No trend
	UNW-080(F)	mg/L	0 / 20	0 / 10	0.003	ND	ND	ND	0.015	0 / 20	0 / 10	0 / 20	0 / 10	--	--
Nickel	UNW-043	mg/L	20 / 20	10 / 10	--	**3.4**	**1.3**	**0.55**	0.1	20 / 20	10 / 10	20 / 20	10 / 10	Stable	No trend
	UNW-043(F)	mg/L	20 / 20	10 / 10	--	**0.96**	**0.74**	**0.53**	0.1	20 / 20	10 / 10	20 / 20	10 / 10	Stable	Stable
	UNW-080	mg/L	8 / 20	8 / 10	0.01	0.099	0.099	0.005	0.1	0 / 20	0 / 10	1 / 20	1 / 10	No trend	No trend
	UNW-080(F)	mg/L	6 / 20	6 / 10	0.01	0.004	0.004	0.003	0.1	0 / 20	0 / 10	0 / 20	0 / 10	Stable	Stable
Trichloroethene	BRW-066	mg/L	1 / 20	0 / 10	0.003	0.004	ND	ND	0.005	0 / 20	0 / 10	1 / 20	0 / 10	No trend	--
K-27 North Exit Pathway															
cis-1,2-Dichloroethene	BRW-058	mg/L	20 / 20	10 / 10	--	**0.11**	**0.11**	**0.11**	0.07	4 / 20	4 / 10	9 / 20	8 / 10	Up	Up
Trichloroethene	BRW-058	mg/L	15 / 20	9 / 10	0.003	**0.006**	**0.006**	0.00067	0.005	2 / 20	1 / 10	3 / 20	1 / 10	No trend	Stable
Vinyl chloride	BRW-016	mg/L	6 / 22	5 / 12	0.001	**0.002**	**0.002**	**0.002**	0.002	0 / 22	0 / 12	1 / 22	1 / 12	No trend	No trend
	BRW-058	mg/L	20 / 20	10 / 10	--	**0.028**	**0.028**	**0.028**	0.002	19 / 20	10 / 10	20 / 20	10 / 10	Up	No trend
K-27 South/West Exit Pathway															
Chromium	UNW-038	mg/L	20 / 20	10 / 10	--	**0.46**	**0.13**	**0.018**	0.1	3 / 20	1 / 10	4 / 20	1 / 10	Down	No trend
	UNW-038(F)	mg/L	15 / 20	10 / 10	0.005	0.014	0.013	0.01	0.1	0 / 20	0 / 10	0 / 20	0 / 10	No trend	No trend
	UNW-096	mg/L	20 / 20	10 / 10	--	**0.16**	**0.16**	**0.16**	0.1	3 / 20	3 / 10	12 / 20	8 / 10	No trend	Up
	UNW-096(F)	mg/L	20 / 20	10 / 10	--	0.092	0.092	0.081	0.1	0 / 20	0 / 10	9 / 20	5 / 10	Stable	Stable
Nickel	UNW-038	mg/L	16 / 20	7 / 10	0.01	**0.86**	**0.13**	**0.13**	0.1	4 / 20	2 / 10	5 / 20	3 / 10	No trend	No trend
	UNW-038(F)	mg/L	13 / 20	5 / 10	0.01	**0.85**	0.093	0.067	0.1	2 / 20	0 / 10	4 / 20	2 / 10	No trend	No trend
	UNW-096	mg/L	8 / 20	8 / 10	0.01	**0.27**	**0.27**	**0.27**	0.1	3 / 20	3 / 10	3 / 20	3 / 10	Up	Up
	UNW-096(F)	mg/L	6 / 20	6 / 10	0.01	**0.23**	**0.23**	**0.23**	0.1	3 / 20	3 / 10	3 / 20	3 / 10	Up	Up
Trichloroethene	UNW-038	mg/L	20 / 20	10 / 10	--	**0.135**	**0.1**	**0.083**	0.005	20 / 20	10 / 10	20 / 20	10 / 10	Down	Down
	UNW-096	mg/L	20 / 20	10 / 10	--	**0.026**	**0.026**	**0.026**	0.005	20 / 20	10 / 10	20 / 20	10 / 10	Down	No trend
K-1007-P1 Holding Pond Exit Pathway															
Alpha activity	UNW-108	pCi/L	15 / 20	8 / 10	3.7	**18.6**	**18.6**	9.28	15	1 / 20	1 / 10	1 / 20	1 / 10	Stable	No trend
Trichloroethene	BRW-084	mg/L	1 / 20	1 / 10	0.003	**0.007**	**0.007**	ND	0.005	1 / 20	1 / 10	1 / 20	1 / 10	No trend	No trend

Table 3.22. Exit pathway groundwater contaminant screening results and trend evaluations (continued)

Chemical	Well	Units	Freq. of detection		Maximum detection limit[a]	Maximum detected			MCL[b]	Freq. > MCL[b]		Freq. > 80% of MCL[b]		Significant trend[c]	
			10 yr	5 yr		10 yr	5 yr	FY 2018		10 yr	5 yr	10 yr	5 yr	10 yr	5 yr
K-901 Holding Pond Area Exit Pathway															
Alpha activity	UNW-066	pCi/L	15 / 20	8 / 10	3.75	**68.7**	**68.7**	7.16	15	4 / 20	3 / 10	4 / 20	3 / 10	No trend	No trend
	UNW-067	pCi/L	8 / 20	5 / 10	4.06	**52.8**	**52.8**	ND	15	1 / 20	1 / 10	1 / 20	1 / 10	No trend	No trend
K-770 Area Exit Pathway															
Alpha activity	UNW-015	pCi/L	15 / 15	10 / 10	--	**45.4**	12.7	8.02	15	**3 / 15**	0 / 10	**4 / 15**	**1 / 10**	Stable	**Up**

[a]The maximum detection limit is highest value assigned to a non-detect over the 10-year evaluation period. Dashes "--" for the maximum detection limit indicates that all results were detections and the maximum detection limit does not apply. Detection limits assigned to non-detects were used in evaluation of the M-K trends.
[b]MCL as of May 2018
[c]Significant linear trend from the M-K test at the 0.10 significance level. Dashes "--" for significant trends indicates that all results were non-detect and no trend analysis was conducted.

Notes:
1. **Bold** table entries indicate results that exceed MCL or MCL-DC values.
2. (F) denotes metals analysis results from field filtered sample aliquots from the designated sample location.
3. The M-K Test statistic (S) for each time series trend is calculated and plotted on a 90% confidence level chart. When the calculated S statistic (positive or negative) plots above the equivalent 90% confidence interval for the applicable number of sampling events, the time-series data define an *Increasing* trend if S >0, or a *Decreasing* trend if S <0. When the calculated S statistic plots below the equivalent 90% confidence interval and the associated CV is <1, then the time series data define a *Stable* trend. When the calculated S statistic is > 0 but confidence is < 90% or S is ≤0 and CV is ≥0 the conclusion is no trend can be confidently assigned to the data.

-- = not applicable
CV = coefficient of variation
Freq. = frequency
FY = fiscal year
MCL = maximum contaminant level
MCL-DC = maximum contaminant level derived concentration
M-K = Mann-Kendall
ND = not detected

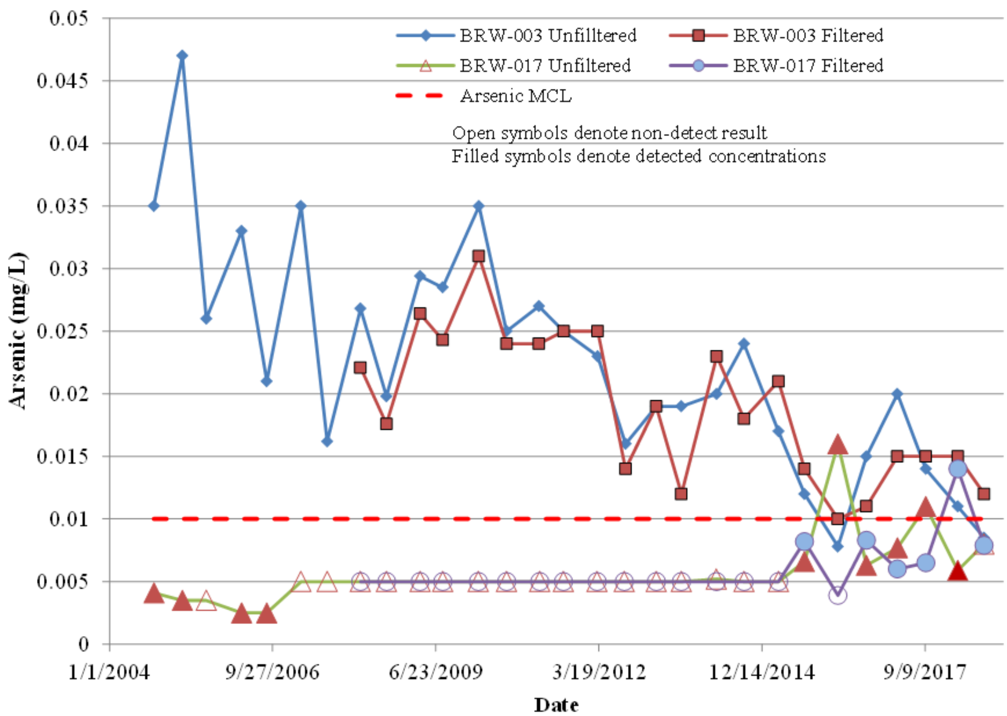


Figure 3.36. Arsenic concentrations in groundwater in the K-1064 peninsula area

K-1007-P1 Holding Pond area

Wells BRW-084 and UNW-108 are exit pathway monitoring locations at the northern edge of the K-1007-P1 Holding Pond (Figure 3.35). Within the past 10 years, alpha activity and TCE have exceeded 80 percent of their respective MCLs. Alpha activity in Well UNW-108 is measureable in nearly all samples and although the FY 2018 maximum concentration was substantially below the 15 pCi/L MCL, the alpha activity levels are sufficiently variable to prevent assignment of a trend direction with statistical confidence. No trend can be assigned to a single, detected concentration.

K-901-A Holding Pond area

Exit pathway groundwater in the K-901-A Holding Pond area (Figure 3.35) is monitored by four wells (BRW-035, BRW-068, UNW-066, and UNW-067) and two springs (21-002 and PC-0). Alpha activity is the only regulated contaminant that exceeded 80 percent of its 15 pCi/L MCL at Wells UNW-066 and UNW-067. The maximum measured FY 2018 alpha activity in the semiannual samples from Well UNW-066 was 7.16 pCi/L and alpha activity was not detected in the samples from Well UNW-067. TCE is the most significant groundwater contaminant detected in the springs, and the historic TCE concentrations are shown in Figure 3.37. Spring PC-0 was added to the sampling program in 2004. During April through October each year, spring PC-0 is submerged beneath the Watts Bar Lake level. In the late winter of 2012, DOE installed a sampling pump in the spring mouth to allow year-round sampling. The contaminant source for the PC-0 spring is presumed to be disposed waste at the former Construction Spoil Area (K-1070-F) located on Duct Island. The TCE concentrations in PC-0 spring have varied between non-detectable levels and 26 µg/L and have decreased from their highest measured value in 2006 to concentrations less than or several times the drinking water standard.

TCE that originates from the now-remediated K-1070-A Burial Ground is the principal contaminant detected at spring 21-002, as well as the TCE at spring 10-895 located on the Poplar Creek floodplain along Blair Road (Figure 3.35). The TCE concentration at spring 21-002 tends to vary between less than 5 and 25 µg/L, and this variation appears to be related to rainfall, which affects groundwater discharge from the K-1070-A VOC plume. During FY 2018, the TCE detected concentrations ranged from a high of 19 µg/L detected in December 2017 to a low of 4.9 µg/L measured in April 2018.

Since the water that discharges from the springs monitored in the ETTP area originates mostly from shallow flow systems, the flow rates and dissolved contaminant concentrations are highly variable. For this reason no contaminant trend direction can be confidently assigned to the spring data.

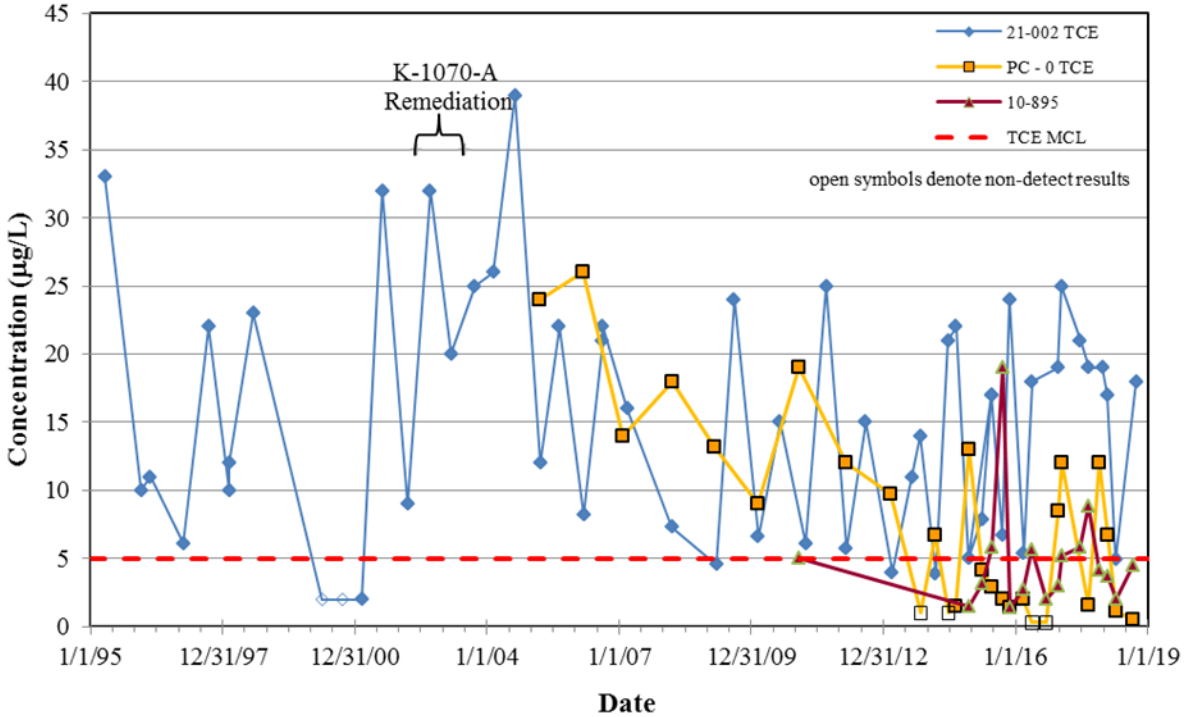


Figure 3.37. TCE concentrations in selected East Tennessee Technology Park area springs

K-770 area

Exit pathway groundwater monitoring is also conducted at the K-770 area, where Wells UNW-013 and UNW-015 are used to assess radiological groundwater contamination along the Clinch River (see earlier Figure 3.35). Alpha activity measured in samples from Well UNW-015 within the past 10 years have exceeded the 15 pCi/L MCL. Although the maximum measured alpha activities in Well UNW-015 appear to have decreased sequentially in the 10-year, 5-year, and FY 2018 screening periods an upward trend is assigned for the most recent five years. Figure 3.38 shows the history of measured alpha activity in Wells UNW-013 and UNW-015.

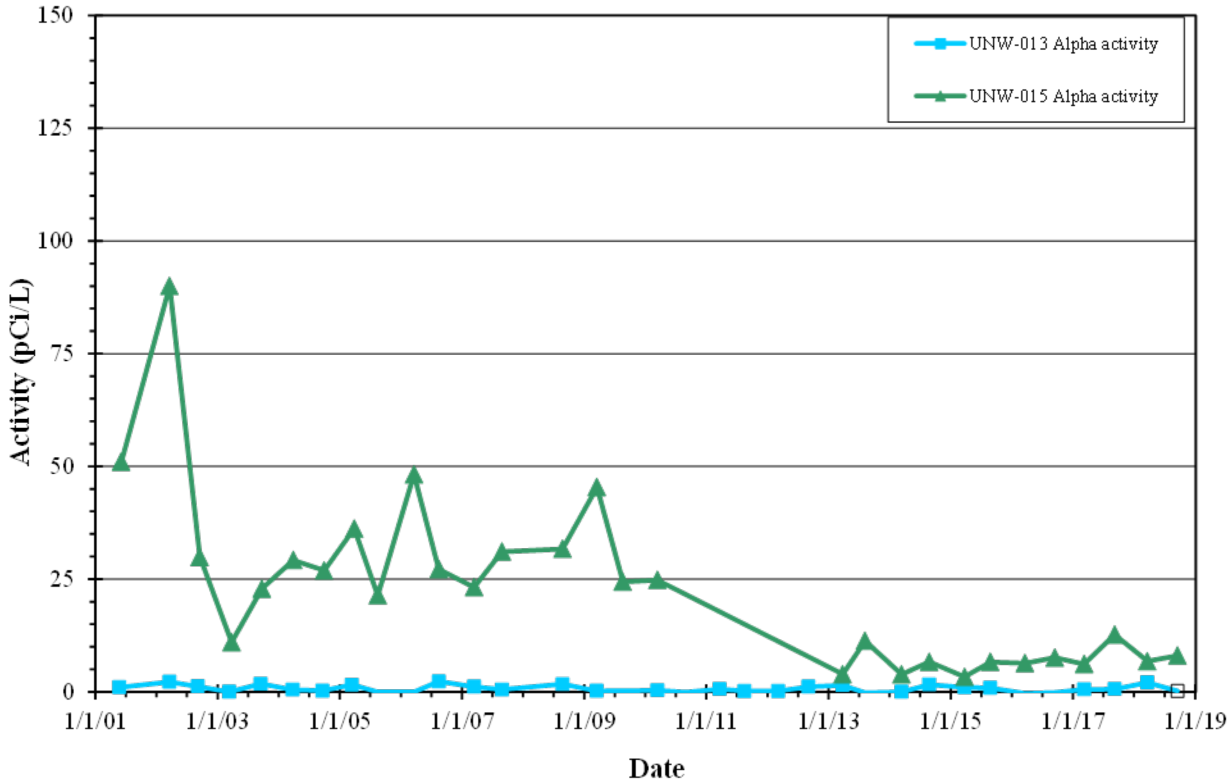


Figure 3.38. History of measured alpha and beta activity in the K-770 area

3.6.16.2 Technetium-99 in ETTP Site Groundwater

Technetium-99 is a beta particle-emitting radionuclide. There is not a specific drinking water MCL for ^{99}Tc, but its MCL-DC concentration is 900 pCi/L. Technetium-99 has been a known groundwater contaminant at the ETTP site for many years. Past CERCLA investigations have sampled and analyzed for ^{99}Tc in groundwater. In the past, the highest ^{99}Tc activity levels (as high as 6,000+ pCi/L) have been observed beneath the K-1070-A Burial Ground, where concentrations at a couple of wells remain in the 200–500 pCi/L range. The area along Mitchell Branch near the former K-1407 Ponds has residual ^{99}Tc-contaminated groundwater from the operational era of the ponds, and possibly from K-1420, with much lower activity levels (< 100 pCi/L). The K-25 building also contained some areas with elevated levels of ^{99}Tc. These areas were exposed to the environment during the demolition of the building.

The environmental fate of some metal contaminants in groundwater is strongly dependent on the pH and oxidation-reduction potential state of the water. A summary review of the environmental behavior of ^{99}Tc in the environment was published by Pacific Northwest National Laboratory (PNNL 2005; PNNL-15372) related to tank wastes at Hanford. Background information from that report is used in preparation of the following interpretation of potential ^{99}Tc mobility in groundwater at the ETTP site.

In summary, the report concluded that microbial processes often occur in very localized regions in the subsurface where chemical conditions are favorable. This fact is evident in groundwater at the ETTP site where intrinsic microbial communities are known to slowly degrade chlorinated organic compounds in some areas but not in other areas. Factors that may favor microbial reduction of dissolved compounds include relatively slow groundwater movement, which limits influx of dissolved oxygen via groundwater recharge; presence of organic carbon that can serve as electron donor material; and presence of microbes capable of affecting the required molecular transformations.

During demolition of the K-25 building east wing in the winter of 2013, fugitive dust suppression misting and rainfall carried ^{99}Tc off the work area. Contaminated runoff apparently percolated through soil and into subsurface utility lines and probably into backfill surrounding the buried utilities. Groundwater sampling for ^{99}Tc was increased in wells in the general vicinity of the east wing and where wells were available along potential groundwater transport pathways.

Investigations conducted to understand the movement of ^{99}Tc away from the K-25 building east wing area documented that contamination entered and traveled through the sanitary sewer and the storm drain that discharges to the K-1007-P1 Holding Pond and that the amount of ^{99}Tc transport in backfill outside those pipes was minimal. The investigation also found that ^{99}Tc transport through the abandoned underground electrical duct bank was an important transport pathway along the east side of the K-25 building, as far south as duct bank manhole row 21. RAs conducted in Zone 1 included plugging the duct bank manholes with cement grout from row 21 to the south and west to the former steam plant located near the Clinch River in the K-770 Area. To minimize the remaining available transport flow path, 38 additional manholes in Zone 2 were grouted starting with manhole row 22, moving northward all the way through the demolition area and beyond.

Consistent with requirements of the ETTP Zone 2 ROD for soil cleanup, ^{99}Tc contaminated soils beneath the K-25 building east wing slab are being excavated to protect groundwater from further contamination. The ^{99}Tc plume extent shown on Figure 3.39 is based on current data and understanding of areas where ^{99}Tc exceeds the 900 pCi/L MCL-DC. Most of the area where the ^{99}Tc MCL is exceeded lies beneath, or very near, the source area at the K-25 east wing.

During FY 2018, groundwater was analyzed by the Water Resources Restoration Program (WRRP) for ^{99}Tc in samples from 49 wells and two springs across the ETTP area. Figure 3.39 shows the resulting maximum FY 2018 ^{99}Tc concentration ranges in groundwater. Technetium-99 concentrations have decreased significantly in the area along the inactive electrical duct bank as the ^{99}Tc contamination either disperses or is attenuated through geochemical adsorption or other attenuation processes.

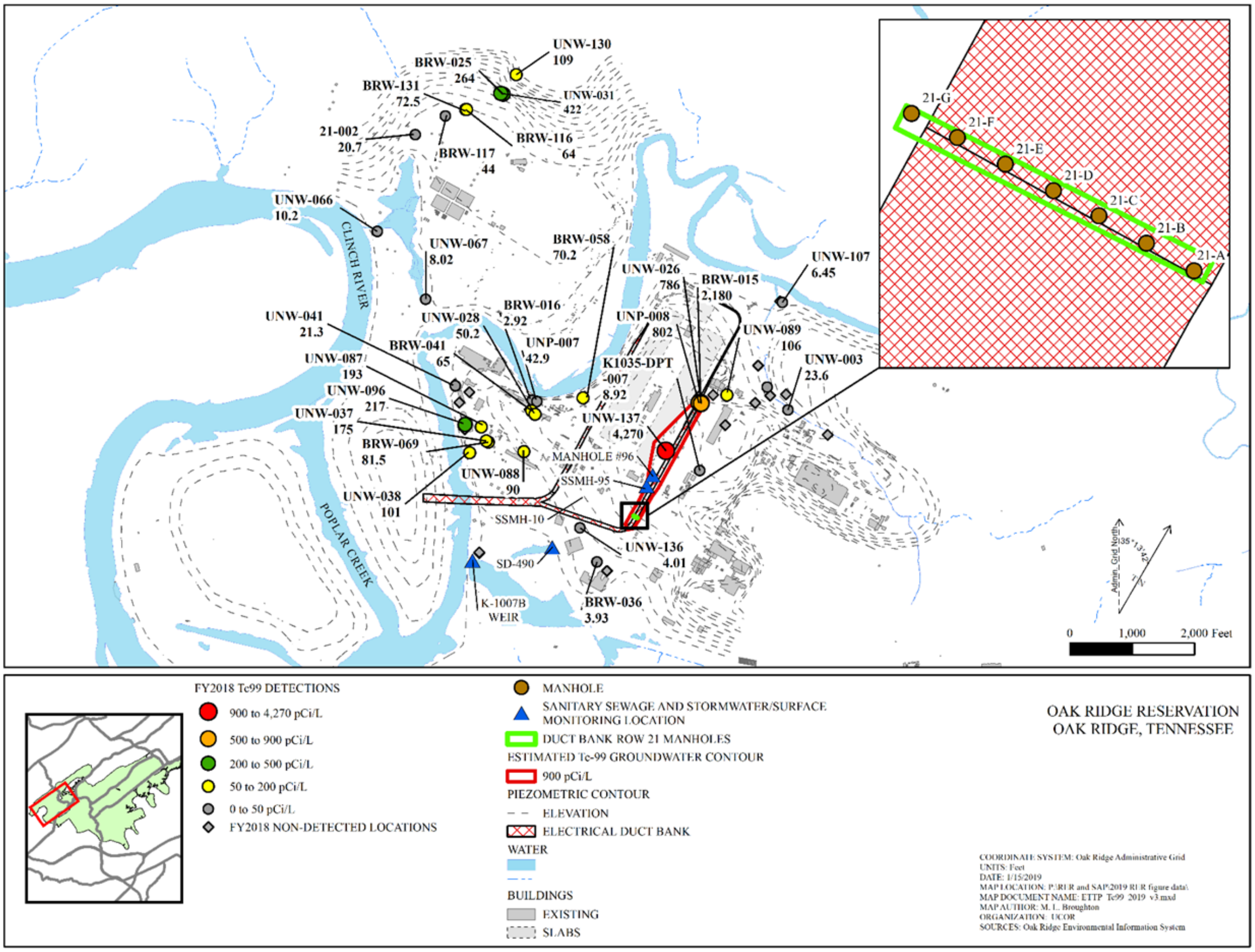


Figure 3.39. Sample locations and maximum detected ^{99}Tc in ETTP groundwater

3.7 Biological Monitoring

The ETTP BMAP consists of two tasks designed to evaluate the effects of ETTP legacy operations on the local environment, identify areas where abatement measures would be most effective, and test the efficacy of the measures. The results from this program will support future CERCLA cleanup actions. These tasks are (1) bioaccumulation studies, and (2) instream monitoring of biological communities. Figure 3.40 shows the major water bodies at ETTP and Figure 3.41 shows the BMAP monitoring locations along Mitchell Branch.

3.7.1 Bioaccumulation Studies

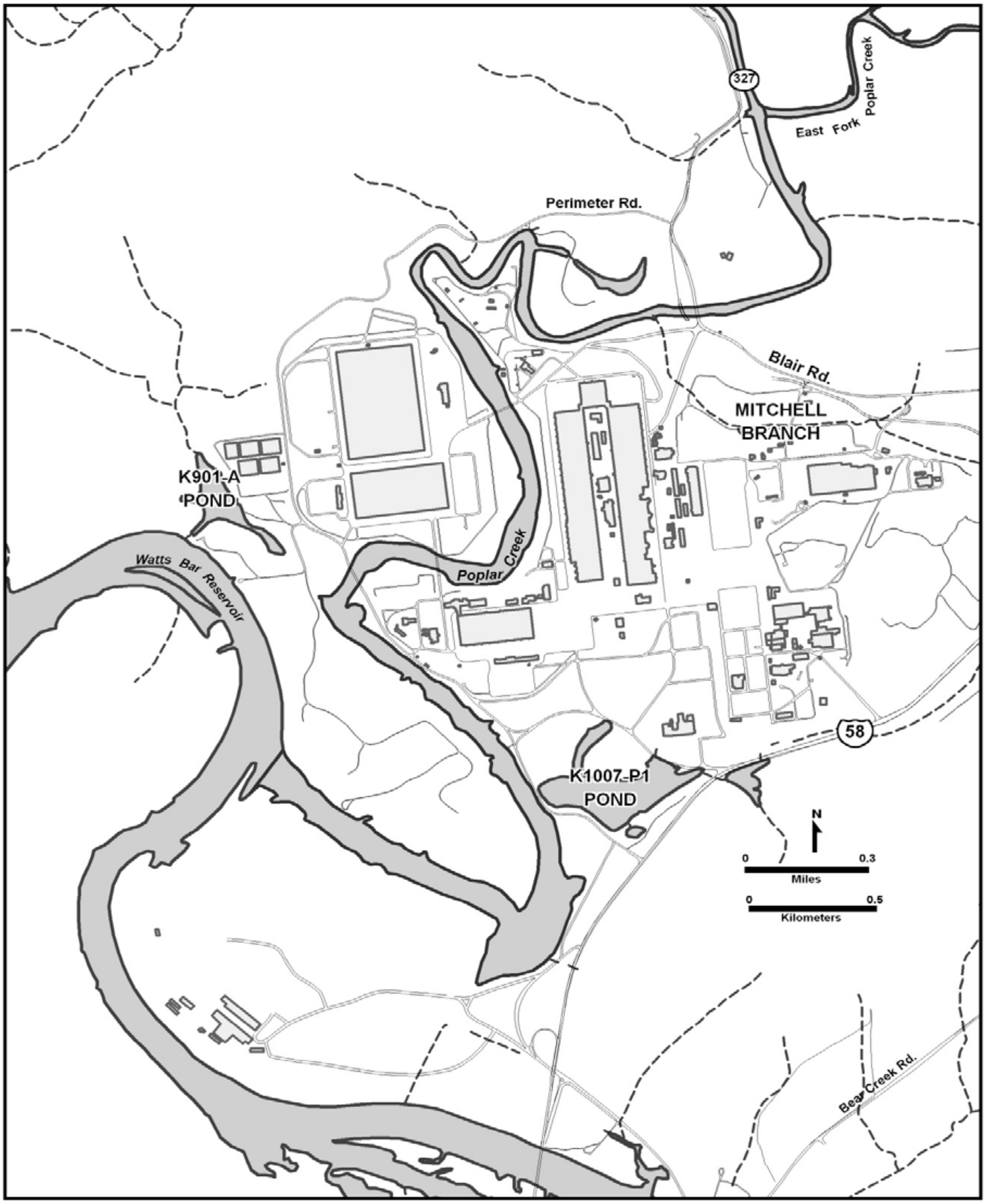
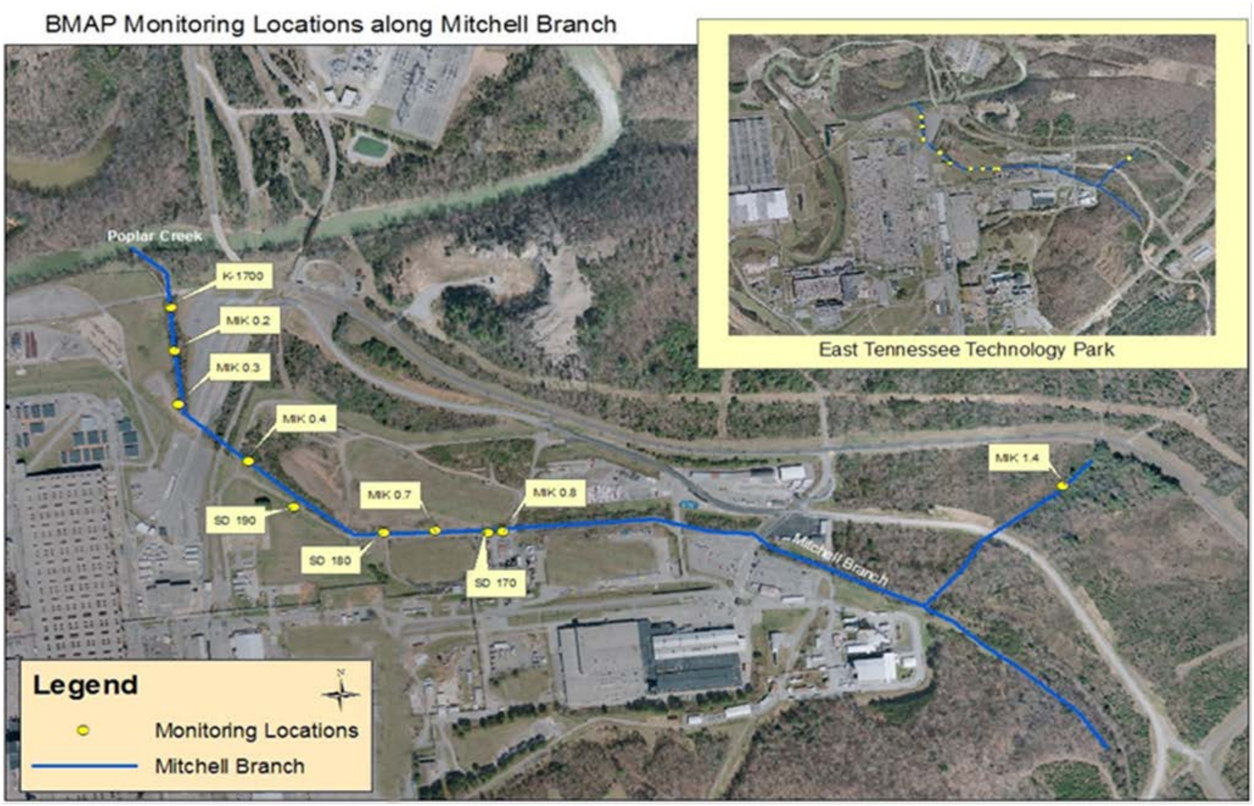


Figure 3.40. Water bodies at the East Tennessee Technology Park



BMAP = Biological Monitoring and Abatement Program
MIK = Mitchell Branch kilometer
SD = storm drain/storm water outfall

Figure 3.41. Major storm water outfalls and biological monitoring locations on Mitchell Branch

3.7.2 Task 1: Bioaccumulation Monitoring

Bioaccumulation monitoring for the ETTP BMAP has focused on evaluating the impact of polychlorinated biphenyl (PCB) discharges into the environment because of historical operations at the ETTP complex. It was previously assumed that mercury (Hg) flux into Poplar Creek and the Clinch River originated largely from Y-12 Complex discharges into East Fork Poplar Creek (EFPC). However, more recently monitoring has shown that water in ETTP storm drains and biota from lower Mitchell Branch have elevated mercury concentrations. Mercury bioaccumulation monitoring is routinely conducted in the watersheds adjacent to ETTP by the Y-12 and ORNL BMAPs, both on and off the Oak Ridge Reservation (ORR). The available Hg bioaccumulation monitoring data will be presented in the following subsections with long-term trends in PCB contamination in resident fish and caged clams from ETTP waters. Recent tabular results were provided in the FY 2018 ETTP BMAP Report.

Because the consumption of contaminated fish represents the largest dose of Hg and many other bioaccumulative contaminants to humans, fish fillet concentrations are relevant to assessing human health risks, whereas whole body fish are relevant to assessing ecological risks. Largemouth bass (*Micropterus salmoides*) and various sunfish species are used to monitor Hg and PCB fillet concentrations, and gizzard shad (*Dorosoma cepedianum*) and bluegill (*Lepomis macrochirus*) are used to monitor whole body concentrations at various locations over time. Largemouth bass are larger, upper trophic level predatory fish and are, therefore, susceptible to Hg and PCB bioaccumulation. Fillet concentrations in these fish represent the near maximum potential dose to humans, if eaten. Largemouth bass tend to live in larger, deeper pools of water and are collected in the ponds at ETTP (K-1007-P1 Pond, K-901-A Pond, and K-720 Slough) as well as in offsite river and reservoir locations. Sunfish are short-lived and have small home ranges, so fillet Hg and PCB concentrations in these fish are representative of exposure at the site of collection. These fish are used in long-term studies to monitor changes in bioaccumulation at a given site over time. Collections of sunfish are restricted to sizes large enough to be taken by sport anglers (generally 50–150 g total weight) to minimize effects of covariance between size and contaminant concentrations, as well as for spatial and temporal comparability. The target sunfish species for bioaccumulation studies in Mitchell Branch and other ORR stream sites is redbreast sunfish (*Lepomis auritus*), but where these fish are not present, other species with similar feeding habits (e.g., bluegill sunfish [*Lepomis macrochirus*]) are collected.

For bioaccumulative contaminants such as Hg and PCBs, US fish bioaccumulation data have become important measures of compliance for both the Clean Water Act and the Comprehensive Environmental Response, Compensation, and Liability Act. For Hg, the US Environmental Protection Agency's (EPA's) National Recommended Water Quality Criterion for Hg in fish (0.3 µg/g) is used as the trigger point for fish consumption advisories in Tennessee, the target concentration for National Pollutant Discharge Elimination System permit compliance, and the threshold for impairment designations that require a Total Maximum Daily Load (TMDL) assessment. In addition to fish Hg limits, the State of Tennessee continues to use the statewide Ambient Water Quality Criterion (AWQC) for Hg of 51 ng/L in water, based on organisms only, and 50 ng/L for recreation-water and organisms (Tennessee Department of Environment and Conservation 2013). Regulatory guidance and human health risk levels have varied more widely for PCBs, depending on the regulatory program and the assumptions used in the risk analysis. The Tennessee water quality criteria for individual Aroclors and total PCBs are both 0.00064 µg/L under the recreation designated use classification and are the target for PCB-focused TMDLs, including for local reservoirs (Melton Hill, Watts Bar, and Fort Loudon) (Tennessee Department of Environment and Conservation 2010a, 2010b, 2010c). However, most conventional PCB water analyses have detection limits much higher than the PCB AWQC. Therefore, in Tennessee and in many other states, assessments of impairment for water body segments as well as public fishing advisories for PCBs are based on fish tissue concentrations. Historically, the US Food and Drug Administration threshold limit of 2 µg/g in fish fillet was used for PCB advisories; then for many years in Tennessee, an approximate range of 0.8 to 1 µg/g was used, depending on the data available and factors such as the fish species and size. The remediation goal for fish fillet at the ETTP K-1007-P1 Pond is 1 µg/g. Most recently, the water quality criterion has been used by the Tennessee Department of Environment and Conservation (TDEC) to calculate the fish tissue concentration triggering a determination of impairment and a TMDL, and this concentration is 0.02 µg/g in fish fillet (Tennessee Department of Environment and Conservation 2010a, 2010b, 2010c). The fish PCB concentrations at and near ETTP are well above this most conservative concentration.

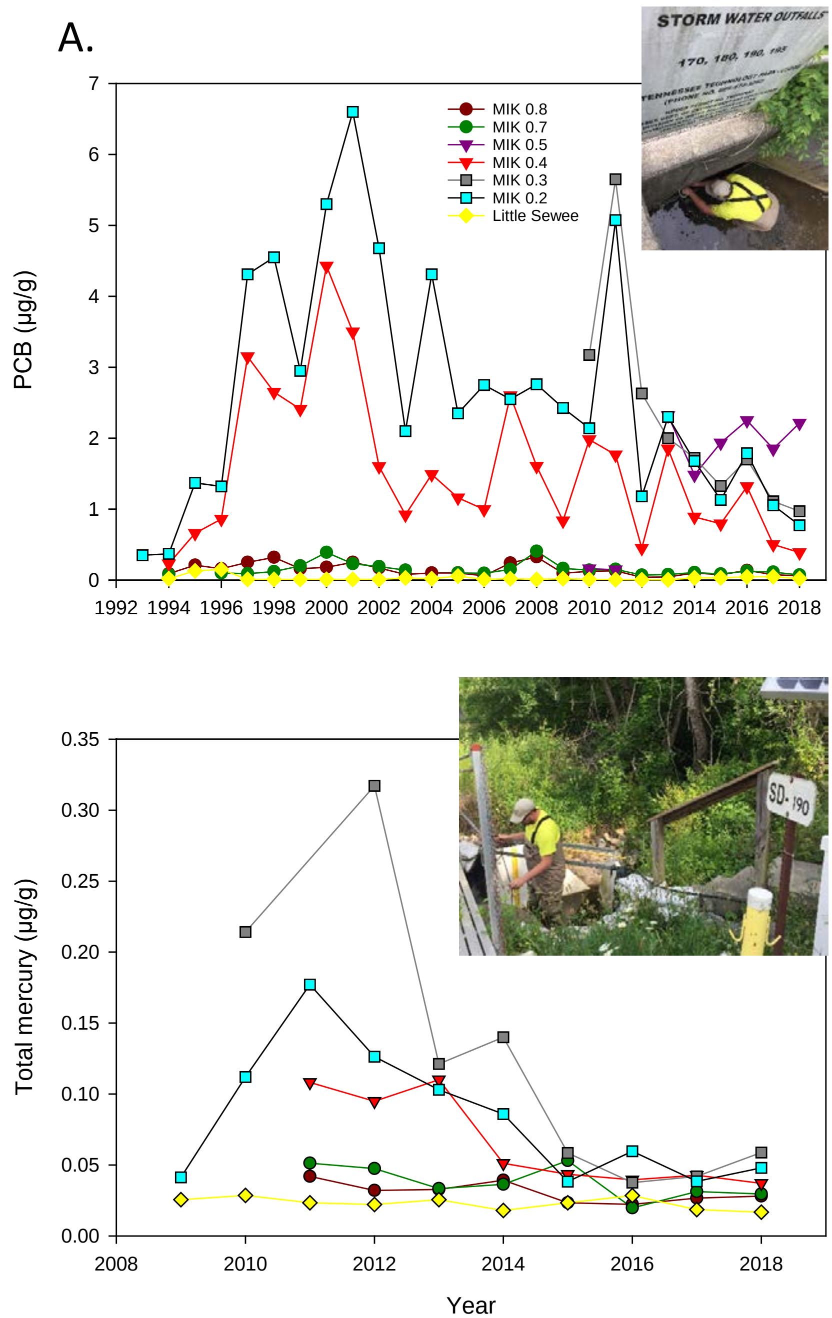
In addition to monitoring for human health and ecological risks as well as long-term trends, bioaccumulation monitoring also includes investigations of sources of contamination to ETTP waterways. Caged Asiatic clams (*Corbicula fluminea*) are used as bioindicators of contaminant sources in Mitchell Branch and other sites around ETTP. These clams are collected from an uncontaminated reference site (Little Sewee Creek in Sweetwater, Meigs County, Tennessee) and are divided into groups of 10 clams of equal mass. In 2018, clams were placed in baskets to be deployed at strategic locations around ETTP (i.e., in and around storm drains) for a 4 week exposure period (May 10-June 7, 2018). Two clam baskets were placed at each site with 10 clams in each basket.

Because these animals are sedentary filter feeders, they accumulate contaminants that are present in the water and in suspended particles at a given site. They are useful indicators of the bioavailable (and therefore potentially toxic) portion of contaminants that enter the environment at a given location, and they provide spatial resolution of contamination on a finer scale than is possible with fish bioaccumulation studies. Caged clams have been used for more than 20 years to evaluate the importance of storm drains and other inputs of PCBs into the waterways around ETTP and for the past 10 years to monitor total mercury (Hg_T) and methylmercury (MeHg) inputs to Mitchell Branch. Whereas most of the Hg in the environment is inorganic mercury (Hg^{2+}), a small fraction of Hg^{2+} is converted to the more toxic and bioaccumulative MeHg. Because MeHg biomagnifies in aquatic systems, increasing in concentration as it moves up through the food chain, more than 90 percent of the Hg in upper trophic level fish is MeHg. Clams, which feed on periphyton and detritus at the base of the food chain, have a much smaller proportion of MeHg in their tissues but are still good indicators of MeHg hotspots and sources. The soft tissues of the clams from each cage were homogenized, and aliquots were taken for PCB and Hg analysis.

To assess spatial and temporal variability in exposure to PCBs following remediation activities, water samples have been collected for analysis of aqueous PCBs and total suspended solids (TSS) from the outfall of K-1007-P1 and an uncontaminated reference site (upper First Creek, ORNL). Samples from K-1007-P1 are collected four times each year (March, June, July, and August) and twice each year from First Creek (June and August). In 2018, a water sample was also collected from storm drain 100, to evaluate PCB inputs into the K-1007-P1 Pond. For PCBs, 2 L of water are collected in certified clean 1-L amber glass bottles and held in a secure refrigerator until delivery to a subcontract laboratory for analysis of 209 congeners using US EPA method 1668. TSS samples are collected concurrently with PCB samples in clean 1-L Nalgene bottles and processed at ORNL the same day.

Mitchell Branch

Figure 3.42 shows long-term monitoring results in caged clams at various sites in Mitchell Branch. The lower portion of this stream (MIK 0.5, SD 190, MIK 0.2) has historically been a “hot spot” for both Hg and PCB contamination, and in 2018 PCB concentrations continued to be elevated (~1–2 µg/g) with respect to other Mitchell Branch and reference sites with concentrations remaining comparable to those seen in recent years. Although there is considerable interannual variability, PCB concentrations in clams placed in lower Mitchell Branch appear to be generally trending downward since peak years in 2000-2001. While there was a slight bump up in PCB concentrations at Mitchell Branch sites in 2016, concentrations since then have dropped back down, continuing the overall decreasing trend. The only exception to this recent trend was a slight increase at MIK 0.5 in 2018 (from 1.8 to 2.2 µg/g). PCB concentrations in the upper portion of Mitchell Branch were similar to previous years’ concentrations and were slightly elevated (0.08 µg/g) with respect to the reference site (0.05 µg/g). PCB concentrations in clams deployed in two skimmers serving the storm drain (SD) 600 and 510 networks, K-897-D and K-897-E (respectively), were comparable to, or slightly elevated (0.01 and 0.20 µg/g, respectively) with respect to the reference site.



MIK = Mitchell Branch kilometer

Notes:

1. N = 2 composites of 10 clams each per year.
2. Shown in yellow are data for clams collected from the reference site, Little Sewee Creek (Sweetwater, Tennessee).
3. Figure A shows total PCBs defined as the sum of Aroclors 1248, 1254, and 1260.

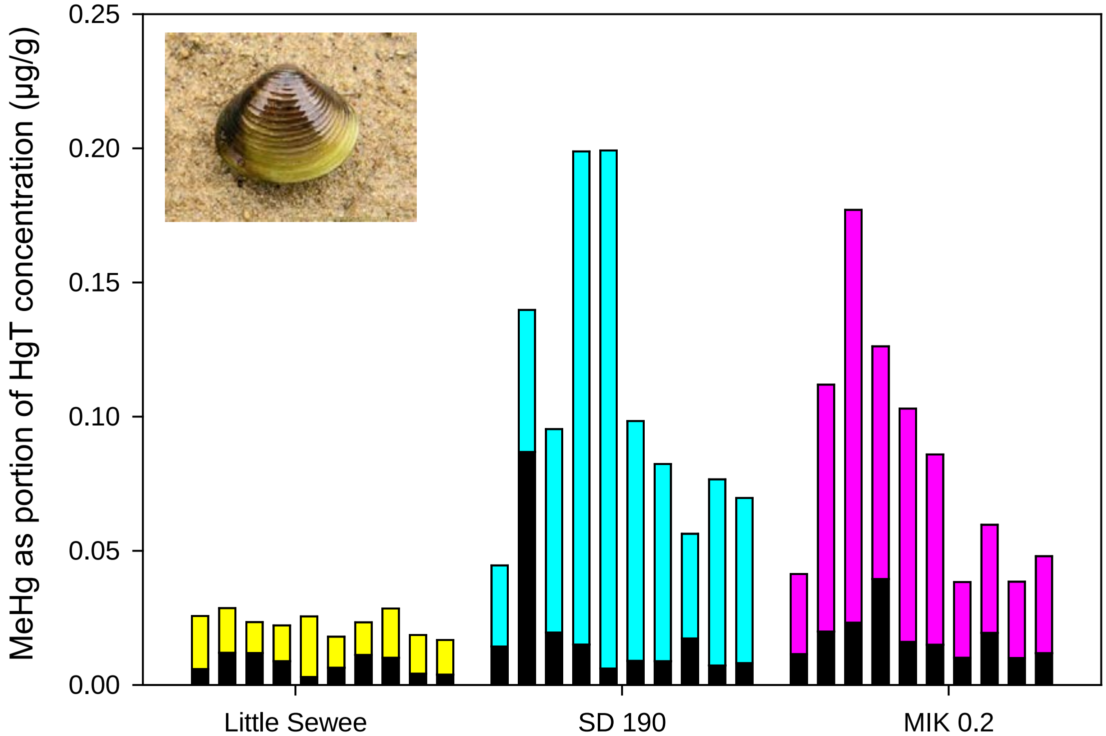
Figure 3.42. Mean total polychlorinated biphenyl (PCB) (A; µg/g, wet wt; 1993–2018) and mercury (B; µg/g wet wt; 2009–2018) concentrations in the soft tissues of caged Asiatic clams deployed in Mitchell Branch

Surface water monitoring conducted by various programs (e.g., ETTP Compliance, WRRP) has shown that aqueous Hg concentrations in Mitchell Branch fluctuate significantly, with concentrations often exceeding the AWQC. This level of variability is typical of stream systems because aqueous Hg concentrations can change with various environmental factors (e.g., flow, suspended solids, etc.) as well as with sample collection methods. Variation in aqueous Hg concentrations is not uncommon and illustrates that aqueous concentrations in a grab sample taken on a certain day reflect a snapshot of the conditions during that sampling period. Research at ORNL has found changes in aqueous Hg concentrations between day and night, for example. In addition, the relationship between aqueous Hg concentrations and MeHg concentrations is not a straightforward one, leading to further complexities with respect to Hg bioaccumulation. Although monitoring aqueous concentrations is still indicative of gauging the relative importance of different Hg sources to a given watershed, bioaccumulation data are informative in that they reflect an integrative measure of the bioavailable portion of Hg exposure at a given site. Monitoring MeHg concentrations in clams is illustrative in that they highlight the complexity of Hg bioaccumulation—whereas Hg_T concentrations in clams varied greatly between sites, MeHg concentrations in Mitchell Branch were elevated with respect to the reference site but did not vary as much as total Hg between sites or between years.

Mercury concentrations in clams deployed in Mitchell Branch in 2018 were similar to concentrations seen in 2017. Concentrations were only slightly higher than the reference site throughout Mitchell Branch in 2018. Mercury concentrations in clams deployed at the K-1007-P1 and K-901-A ponds were again comparable to reference site concentrations. Within the Mitchell Branch system, the highest Hg concentrations were seen in clams deployed at SD 180 (0.12 µg/g), and SD 190 (0.07 µg/g). Clams deployed at two skimmers serving the SD 510 network, K897-D and K-897-E, had Hg concentrations similar to those of the reference site. Unlike in fish tissue, MeHg generally makes up a small proportion of Hg_T found in soft tissues of clams (Figure 3.43). Although MeHg concentrations in clams remained low in 2018, they were either comparable to or slightly higher than concentrations in 2017.

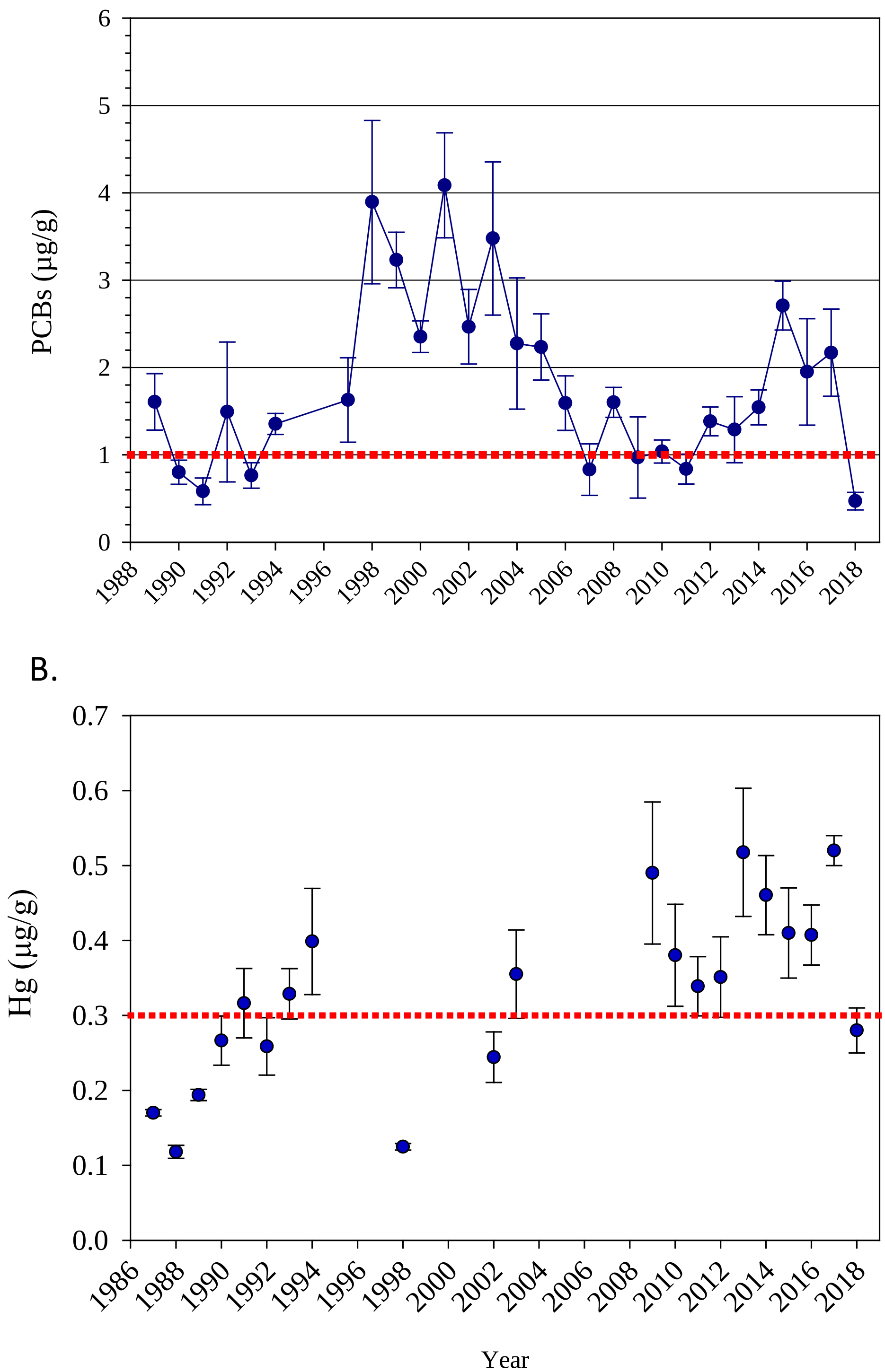
Figure 3.44 shows long-term monitoring results in redbreast sunfish (*Lepomis auritus*) at MIK 0.2. Average PCB concentrations in fish collected at MIK 0.2 in 2018 (0.48 ± 0.10 µg/g) were significantly lower than those seen in 2017 (2.17 ± 0.50 µg/g) and were among the lowest concentrations reported for the past 30 years at this site (Figure 3.44A). Although there is not a regulatory limit for PCBs in fish, the level most often used in practice to issue fish consumption advisories in the state of Tennessee, as previously stated, is 1 µg/g. In 2018, the mean PCB concentration in sunfish fillets was below this limit. While the observed fish tissue concentrations in Mitchell Branch are lower than they have historically been, they are still 2-3 orders of magnitude higher than concentrations seen in the same species at the Hinds Creek reference site.

Total mercury has been monitored more sporadically in redbreast sunfish fillets at MIK 0.2. Figure 3.44B shows long-term trends in Hg_T concentrations (µg/g) in these fish. A rapid increase in fillet Hg_T concentrations was observed in the early 1990s and generally remained elevated, with mean concentrations exceeding the AWQC (0.3 µg/g) in most years. Similar to the PCB concentrations in fish from this site, Hg_T concentrations at MIK 0.2 have been oscillating around the EPA's recommended AWQC for the past several years. Similar to the trends seen for PCBs, mean mercury concentrations in redbreast at this site decreased significantly, dropping slightly below the criterion in 2018, averaging 0.28 ± 0.03 µg/g.



SD = storm drain
MIK = Mitchell Branch kilometer
Notes:
1. N = 2 composites of 10 clams each per year.
2. Shown in yellow are data for clams collected from the reference site, Little Sewee Creek (Sweetwater, Tennessee).
3. Black bars denote MeHg concentrations, where the total height of bars (color and black band) represents Hg_T concentration.

Figure 3.43. Methylmercury (MeHg) as a portion of total mercury (Hg_T) concentrations in the soft tissues of caged Asiatic clams deployed in Mitchell Branch (µg/g wet wt; 2009–2018)



Notes:
1. 1989–2018, N = 6 fish per year.
2. Shown in red is the fish advisory level for PCBs (1 µg/g) and mercury (0.3 µg/g).
3. The photograph shows fish electrofishing activities in lower Mitchell Branch.

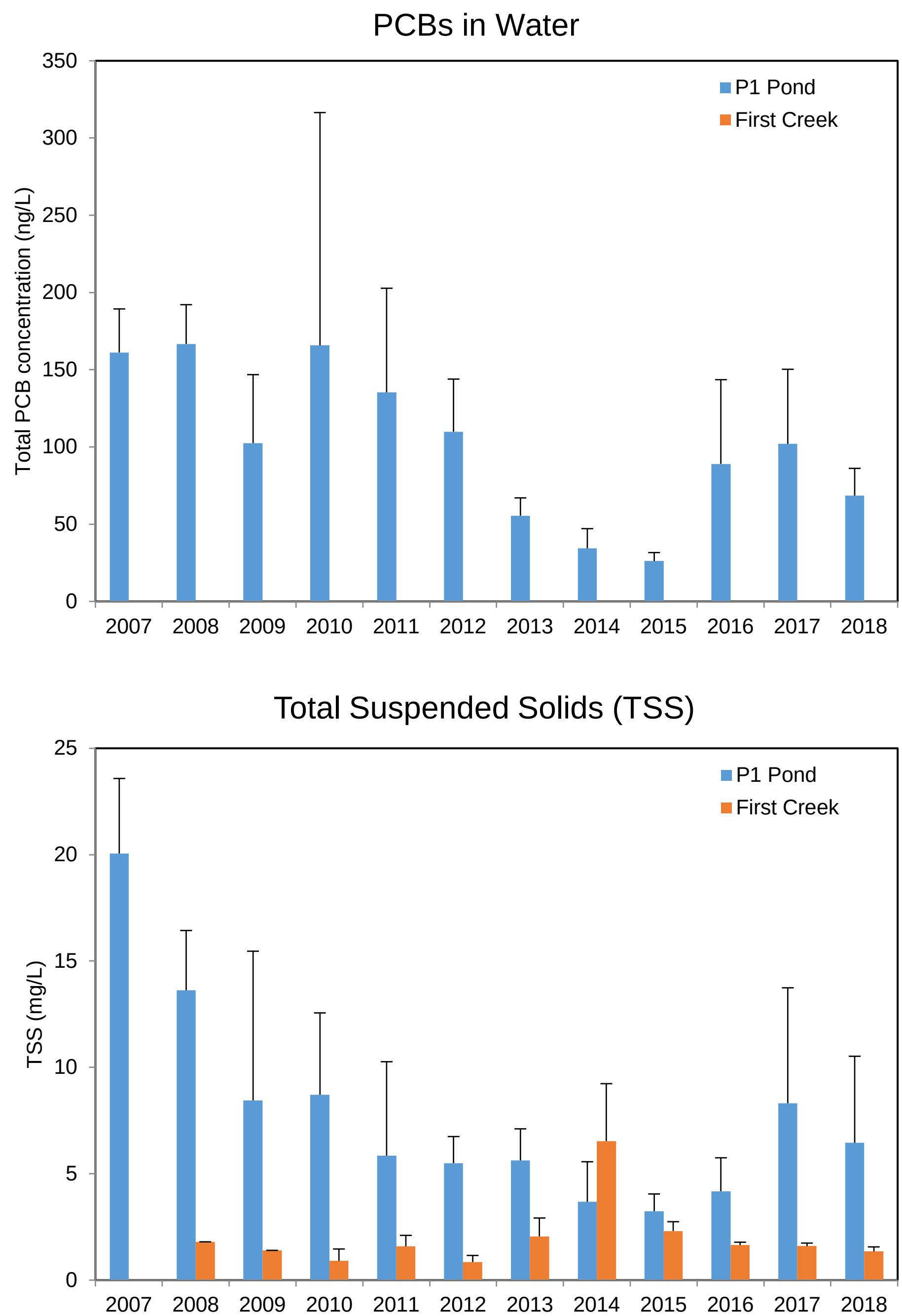
Figure 3.44. Mean polychlorinated biphenyl (PCB; A) and mercury (Hg; B) concentrations (µg/g, wet wt) in redbreast sunfish fillets in Mitchell Branch (MIK 0.2)

K-1007-P1 Pond

Aqueous PCB concentrations in the K-1007-P1 Pond have fluctuated significantly over the past decade, but have generally been lower (68 ng/L in 2018) than concentrations seen prior to 2009 remediation activities (e.g. 161 ng/L in 2007) (Figure 3.45). While concentrations decreased steadily from 2010 to a low of 26 ng/L in 2015, they have been higher the past 3 years. PCBs tend to be particle associated. Aqueous PCB concentrations are correlated with total suspended solids, with increases in TSS seen over the past three years when increases in PCBs were observed. The increase in PCB and TSS concentrations in water in since 2016 could be related to a reduction in rooted plants in the pond, leading to less stability in sediment. Another possibility is that increases in PCBs could also be due, in whole or in part, to increased aqueous PCB inputs from SD100.

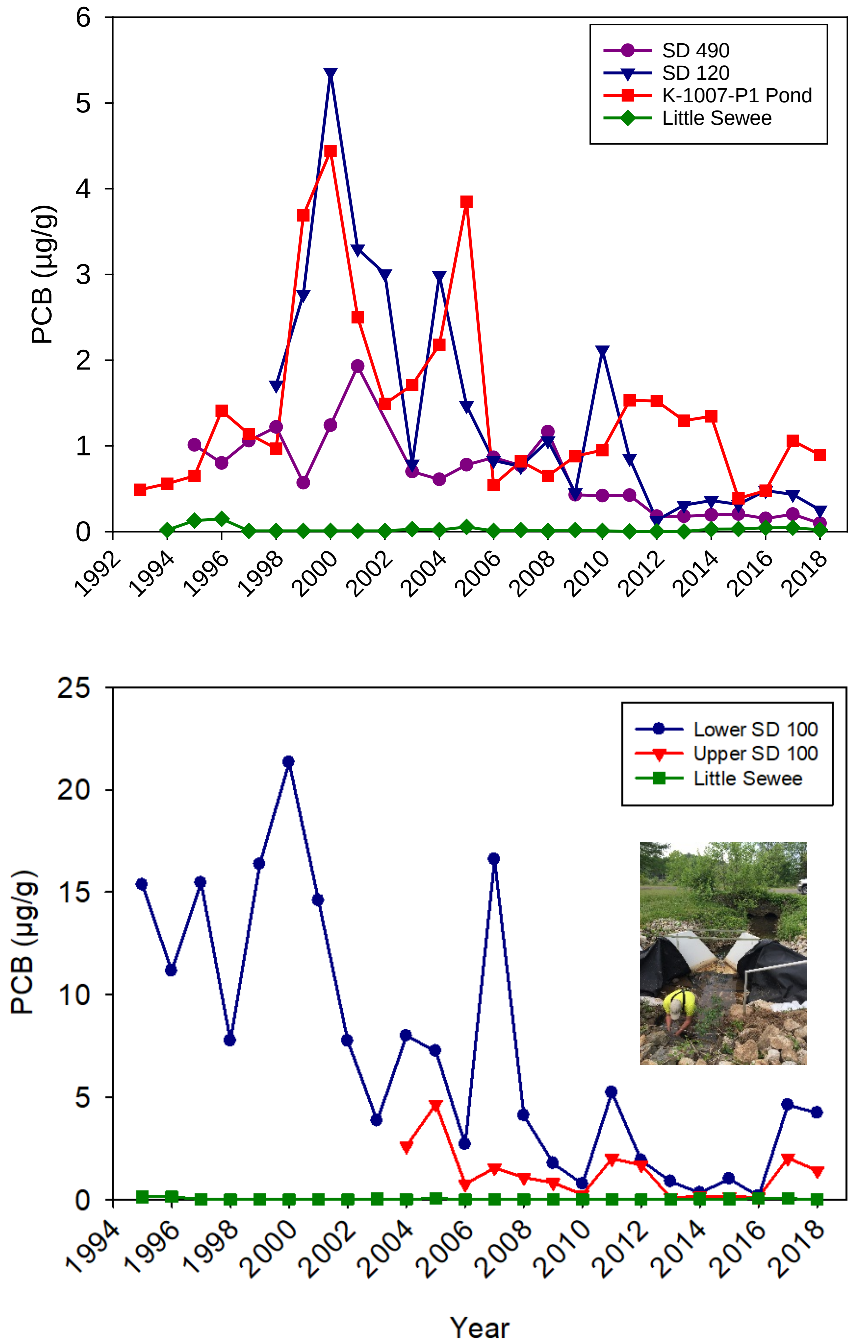
PCB concentrations in clams placed at lower and upper SD-100 locations have fluctuated significantly since remediation actions in 2009, and were on an overall decreasing trajectory until the significant increases seen in 2017 and 2018 (Figure 3.46). PCB concentrations in clams placed at the K-1007-P1 outfall were also higher the past two years, but were comparable to concentrations seen just after remediation actions in this pond (Figure 3.46).

Similar trends have been observed in fish tissue PCB concentrations in the K-1007-P1 Pond. Since 2009, the target species for bioaccumulation monitoring in the K-1007-P1 Pond has been bluegill sunfish (*Lepomis macrochirus*). As in previous years, fillets from 20 individual bluegill and six whole body composites (10 bluegill per composite) from the K-1007-P1 Pond were analyzed for PCBs in 2018 to assess the ecological and human health risks associated with PCB contamination in this pond. Average PCB concentrations in fish fillets and whole body composites have decreased significantly over the past 10 years since remediation activities, with significant fluctuations. Concentrations were lowest in the 2013-2015 time period, but have slightly increased over the past three years. The mean concentration in whole body composites of bluegill collected from the K-1007-P1 Holding Pond was significantly higher in 2018 (4.00 µg/g) than in 2017 (2.58 µg/g), this concentration is still below whole body concentrations seen at the time of pre-remediation activities at this site (>5 µg/g) (Table 3.23, Figures 3.47 and 3.48). The mean concentration (1.21 µg/g) in bluegill fillets in 2018 increased above the remediation goal of 1 µg/g after a falling below this level in 2017. The interannual fluctuations in PCB concentrations could be due to water quality changes that have taken place in this pond, (e.g. higher TSS, PCB inputs; Figures 3.47 and 3.48). The observed fluctuations in PCB concentrations seen in biota suggest that this system is still in transition and that as the fish and plant communities stabilize, further decreases in PCB bioaccumulation may become apparent.



Notes:
1. Means for PCBs in water and TSS are based on results across all collections made each year.
2. Note that mean concentrations of PCBs in water from First Creek were <0.3 ng/L in all years.

Figure 3.45. Means (± standard deviation) for total polychlorinated biphenyl (PCB) concentrations in water (top) and total suspended solids (TSS; bottom), 2007–2018

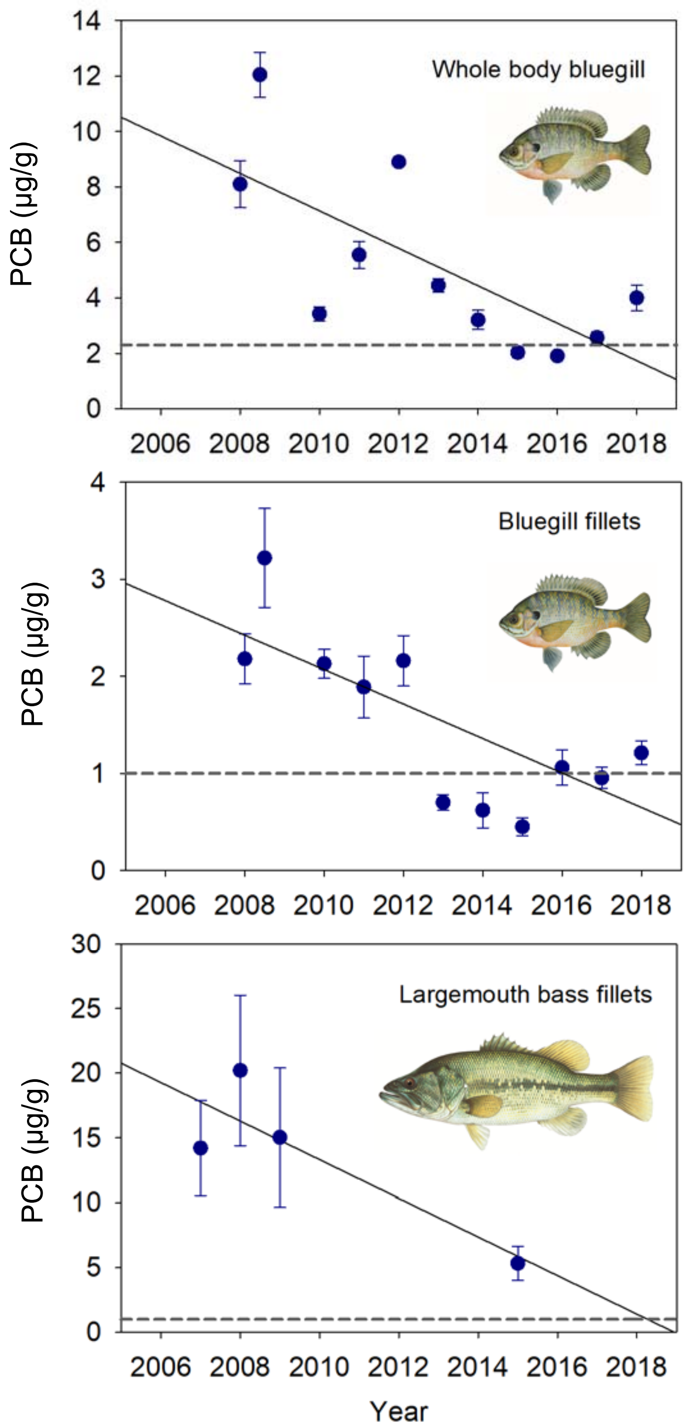


SD = storm drain

Notes:

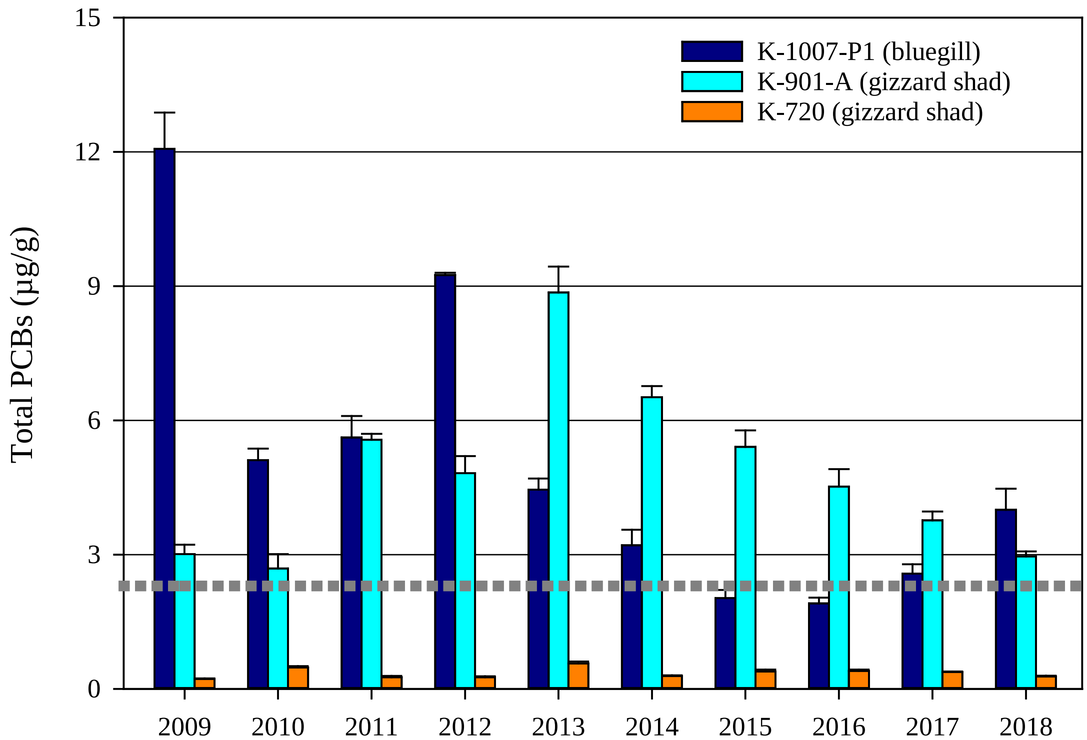
1. N = 2 clam composite samples per site/year.
2. Total PCBs defined as the sum of Aroclors 1248, 1254, and 1260.
3. Photos upper graph show a clam basket in a storm drain, and Little Sewee Creek, lower graph photos show placement of clam cages in Upper SD-100 (upper photo) and Lower SD-100 locations.

Figure 3.46. Mean total polychlorinated biphenyl (PCB) concentrations (µg/g, wet wt) in caged clams placed at K-1007-P1 outfalls compared with reference stream clams (Little Sewee Creek), 1993–2018



Notes:
1. For largemouth bass, N = 6 fish per site/year. For bluegill sunfish, N = 20 for fillets and N = 6 composites of 10 whole body fish.
2. The target for fillet (1 µg/g) and whole body concentrations (2.3 µg/g) is shown with the gray dotted lines.

Figure 3.47. Mean polychlorinated biphenyl (PCB) concentrations (µg/g, wet wt) in fish from the K-1007-P1 Pond, 2007–2018



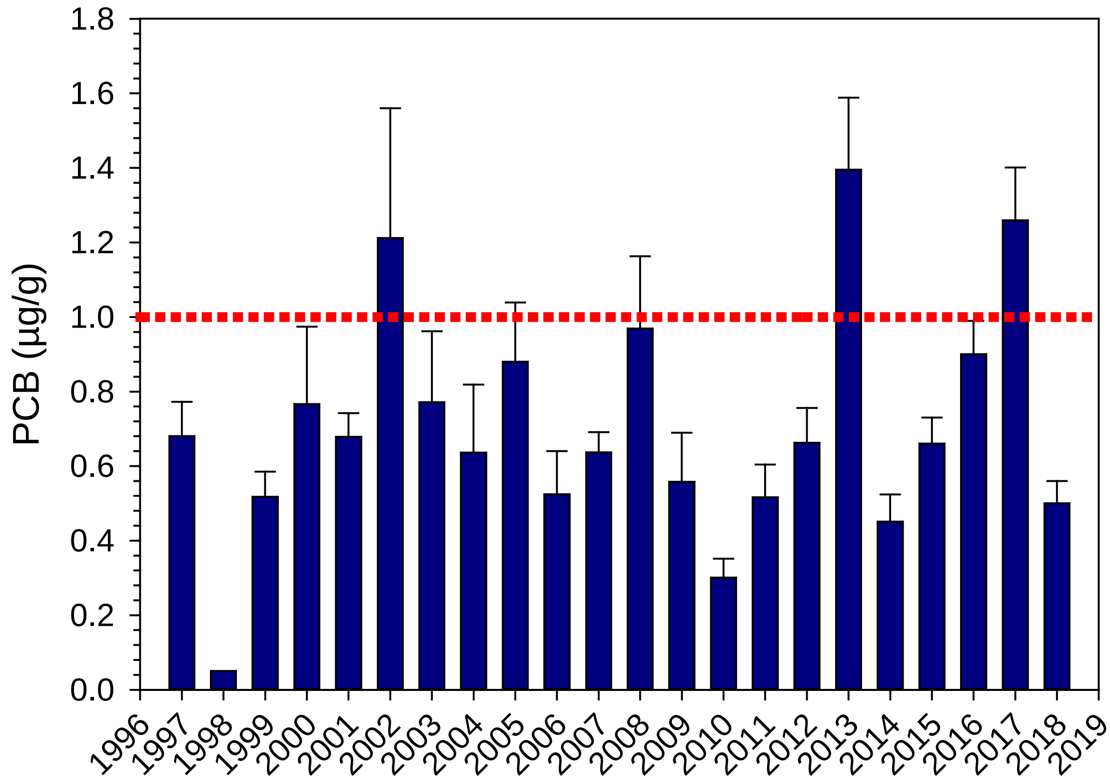
Notes:
1. Total PCBs are defined as the sum of Aroclors 1248, 1254, and 1260.
2. The dotted line signifies the target PCB concentration of 2.3 µg/g in whole body fish.

Figure 3.48. Mean (+ 1 standard error) total polychlorinated biphenyl (PCB) concentrations (µg/g, wet wt) in whole body fish from K-1007-P1 Pond, K-901-A Holding Pond, and K-720 Slough, 2009–2018

K-901-A Pond

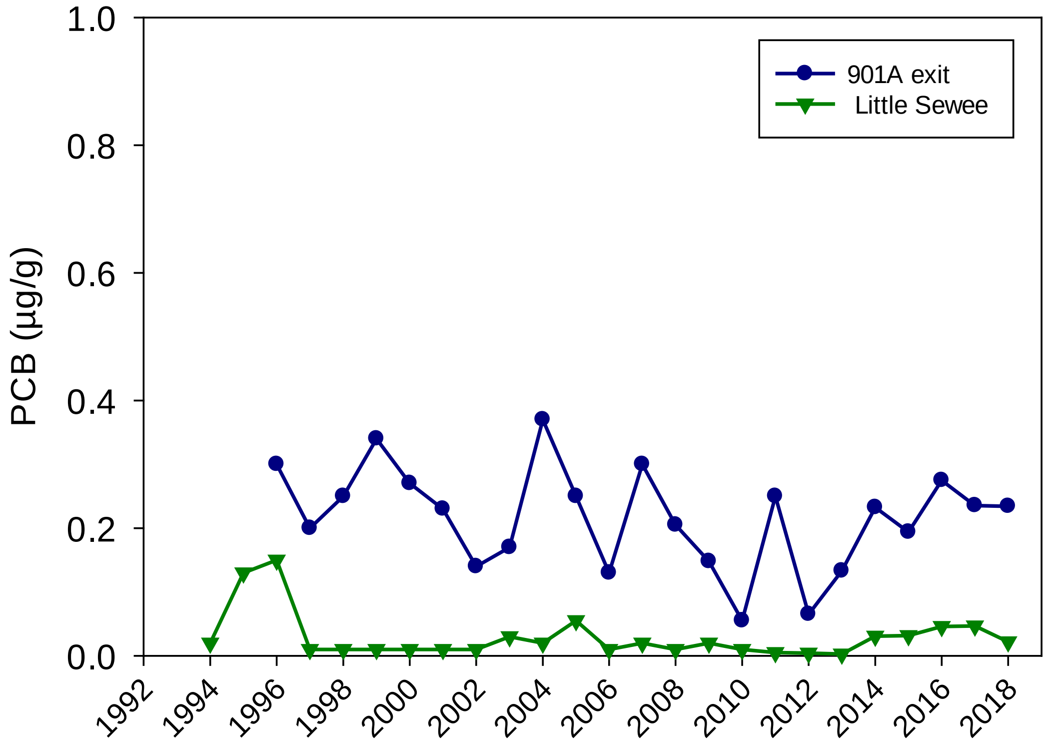
The target fish species for analysis of PCBs in the K-901-A Holding Pond and K-720 Slough were gizzard shad (*Dorosoma cepedianum*) and largemouth bass (*Micropterus salmoides*). It was not possible to collect the target number of 20 bass from each body of water, so common carp (*Cyprinus carpio*) also were collected to provide a combined total of 20 fish. Carp were selected as a surrogate species for bass because they are widely distributed, are present at both locations, and have been used historically in other monitoring efforts on the ORR for contaminant analyses.

At the K-901-A Holding Pond, mean PCB concentrations in largemouth bass fillets in 2018 were significantly lower (0.50 µg/g) than those in 2017 (1.26 µg/g) and in other recent years, and were below the target level of 1 µg/g for fillet concentrations at the K-1007-P1 Pond (Figure 3.49). The average concentrations of PCBs in carp fillets in this pond were similar in 2018 (1.31 µg/g) to 2017 (1.28 µg/g), as were concentrations in clams deployed in this pond (Figure 3.50).



SE = standard error
Notes:
1. Mean PCBs (± 1 SE) in largemouth bass fillets, 1993–2017 (µg/g).
2. N = 6 fish per year, when possible.
3. The dotted red line shows the advisory level for PCBs in fish fillets (1 µg/g).

Figure 3.49. Mean total polychlorinated biphenyl (PCB) concentrations in largemouth bass from the K-901-A Pond

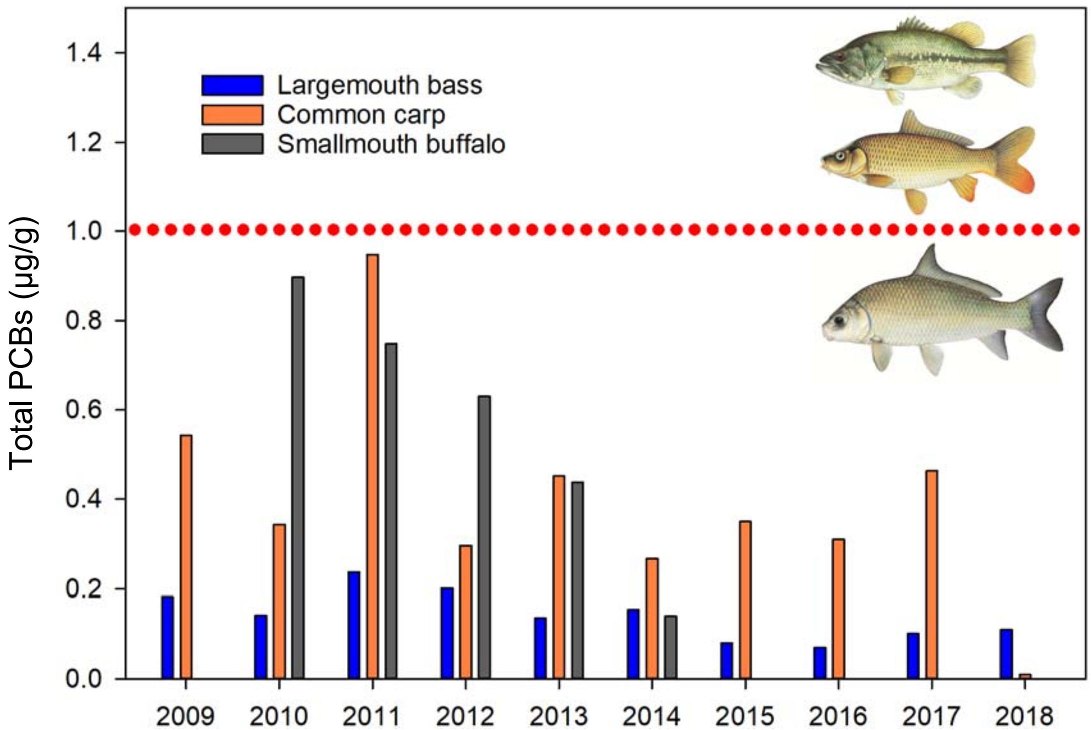


Notes:
1. Total PCBs defined as the sum of Aroclors 1248, 1254, and 1260.
2. N = 2 composites of 10 clams each per year.
3. Shown in green are data for clams collected from the reference site, Little Sewee Creek (Sweetwater, Tennessee).

Figure 3.50. Mean total polychlorinated biphenyl (PCB; µg/g, wet wt; 1993–2018) concentrations in the soft tissues of caged Asiatic clams deployed in the K-901-A Pond for a 4 week period

K-720 Slough

Routine bioaccumulation monitoring in the K-720 Slough began in 2009. Although the target species for fish fillet monitoring in this slough is largemouth bass, as in the K-901-A Pond it has been difficult to collect a full sample of 20 fish of this species; to complete the collection, common carp also are collected for a total of 20 fish. Figure 3.51 shows the temporal trends in fish fillet concentrations in the slough. In 2018, PCB concentrations in both fish species monitored were below the state advisory limit of 1 µg/g. In all cases PCB levels in fish collected from the K-720 Slough were significantly lower than in the K-901-A Holding Pond for the same species (Table 3.23). PCB concentrations in largemouth bass collected from the K-720 Slough were significantly lower than those in the other monitored ponds, averaging 0.11 µg/g in 2018. Concentrations in carp and smallmouth buffalo collected from the slough were higher than concentrations in bass, averaging 0.51 µg/g and 0.28 µg/g, respectively. Total PCBs in whole body gizzard shad from the K-720 Slough were similar to those seen in recent years and were lower than those seen in whole body fish collected from the other monitored ponds, averaging 0.28 µg/g in 2018.



Notes:
1. Total PCBs defined as the sum of Aroclors 1248, 1254, and 1260.
2. The target sample was 20 largemouth bass, but because these fish are not abundant in the slough, carp and smallmouth buffalo were collected to complete the sample size of 20 fish.
3. Dotted red line shows the advisory level for PCBs in fish fillets (1 µg/g).

Figure 3.51. Mean total polychlorinated biphenyl (PCB; µg/g, wet wt; 2009–18) concentrations in the fillets of largemouth bass, common carp, and smallmouth buffalo collected from the K-720 Slough

Table 3.23. Average concentrations (µg/g, wet wt) of total polychlorinated biphenyl (PCBs; Aroclors 1248, 1254, and 1260) and total mercury (µg/g, wet wt) in fillets and whole-body composites of fish collected in 2018 near the East Tennessee Technology Park and Hinds Creek, a reference stream

Site	Species	Sample type	Sample size (n)	Total PCBs (mean ± SE)	Range of PCB values	No. > target[a] (PCBs)/n
K-1007-P1 Pond	Bluegill	Fillets	20	1.21 ± 0.12	0.34 – 2.49	10/20
		Whole body composites	6	4.00 ± 0.47	3.32 – 6.30	6/6
K-901-A Pond	Largemouth bass	Fillets	3	0.50 ± 0.06	0.44 - 0.61	0/3
	Common carp	Fillets	17	1.31 ± 0.20	0.44 - 2.25	11/17
	Bluegill	Fillets	20	0.48 ± 0.09	0.13 - 1.83	3/20
		Whole body composites	6	1.22 ± 0.05	0.98 - 1.43	0/6
	Gizzard shad	Whole body composites	6	2.96 ± 0.11	2.79 - 3.48	6/6
K-720 Slough	Largemouth bass	Fillets	4	0.11 ± 0.01	0.09 - 0.14	0/4
	Smallmouth buffalo	Fillets	6	0.28 ± 0.11	0.03 - 0.60	0/6
	Common carp	Fillets	12	0.51 ± 0.12	0.05 - 1.53	1/12
	Gizzard shad	Whole body composites	6	0.28 ± 0.02	0.23 – 0.33	0/6
CRM 11.0	Bluegill	Whole body composites	6	0.05 ± 0.001	0.04 - 0.05	0/6
	Gizzard shad	Whole body composites	6	0.15 ± 0.02	0.11 - 0.22	0/6
PCM 1.0	Bluegill	Whole body composites	6	0.17 ± 0.01	0.14 - 0.20	0/6
	Gizzard shad	Whole body composites	6	0.41 ± 0.03	0.33 - 0.51	0/6

CRM = Clinch River mile
No. = number
PCB = polychlorinated biphenyl
PCM = Poplar Creek mile
SE = standard error
Notes:
1. Values are mean concentrations (µg/g) ± 1 SE.
2. Each whole body composite sample is composed of 10 individual fish.
3. Also shown are the ranges of values observed for PCBs and the number of fish whose fillet PCB concentrations exceeded 1 ppm out of the total number of fish (or composites) sampled (n).

3.7.3 Task 2: Instream Benthic Macroinvertebrate Communities

Benthic macroinvertebrate communities in Mitchell Branch are sampled using ORNL and TDEC protocols (Figs. 3.52 and 3.53). Evaluation of long-term trends of macroinvertebrate communities in the stream make it possible to document the effectiveness of pollution abatement activities or remediation efforts as well as to assess the potential consequences of unanticipated events as site-wide remediation continues (e.g., chromium release into Mitchell Branch).

Figure 3.52. Emptying an invertebrate sample collected with Tennessee Department of Environment and Conservation protocols

Figure 3.53. Sampling for benthic macroinvertebrates with TDEC protocols

Benthic Macroinvertebrates

The major objectives of the benthic macroinvertebrate task are (1) to help assess the ecological condition of Mitchell Branch and (2) to evaluate changes in stream ecology associated with changes in facilities operations and remedial actions within the Mitchell Branch watershed. To meet these objectives, the condition of the benthic macroinvertebrate community of Mitchell Branch has been monitored routinely since late 1986. This summary includes results of samples collected each April from 1987 to 2018 following ORNL BMAP quantitative sampling protocols and samples collected annually (August/September) with TDEC semi-quantitative sampling protocols for estimating the Tennessee Stream Biotic Index and Habitat Biotic Index (TDEC 2011; TDEC 2017). TDEC protocol guidance was updated in August of 2017 and the most recent 2017 guidance was used for the 2018 invertebrate and habitat surveys. For both sets of protocols, four sites were assessed in Mitchell Branch— MIKs 0.4, 0.7, 0.8, and 1.4. MIK 1.4 serves as the primary reference site, but narrative Biotic Index results for TDEC protocols are based on reference conditions established by TDEC from a suite of reference sites in the same ecoregion as Mitchell Branch. Finally, also included in this summary is a comparison between the macroinvertebrate community structure at the four Mitchell Branch sites and five other reference sites on the ORR. Most of these reference sites - spanning a range of stream sizes both smaller and larger than Mitchell Branch (based on watershed area) - have been monitored using ORNL protocols since the mid-1980s for other biological monitoring projects on the ORR (ORNL BMAP and WRRP/Bear Creek Biological Monitoring Program) (Table 3.24). This summary provides information on how invertebrate community structure at Mitchell Branch sites, including MIK 1.4, compares with the community structure of a range of relatively unaffected reference sites on the ORR.

Table 3.24. Stream sites included in the comparison between Mitchell Branch and other reference sites on the Oak Ridge Reservation (ORR)

Site	Location		Watershed area (km^2)	Program
	Latitude (N)	Longitude (W)		
Mitchell Branch				
MIK 0.4	35.93786	84.38792	1.554	ETTP BMAP
MIK 0.7	35.93786	84.38682	1.347	ETTP BMAP
MIK 0.8	35.93802	84.38560	1.269	ETTP BMAP
MIK 1.4 (reference)	35.93790	84.37662	0.311	ETTP BMAP
Other ORR reference sites				
First Creek (FCK 0.8)	35.92671	84.32327	0.596	ORNL BMAP
Fifth Creek (FFK 1.0)	35.93251	84.31741	0.596	ORNL BMAP
Gum Hollow Branch (GHK 2.9)	35.96385	84.31594	0.777	Bear Creek BMP/WRRP
Walker Branch (WBK 1.0)	35.95805	84.27953	1.010	ORNL BMAP
White Oak Creek (WCK 6.8)	35.94106	84.30145	2.072	ORNL BMAP

BMAP = Biological Monitoring and Abatement Program
BMP = Biological Monitoring Program
ETTP = East Tennessee Technology Park
MIK = Mitchell Branch kilometer
ORNL = Oak Ridge National Laboratory
WRRP = Water Resources Restoration Program

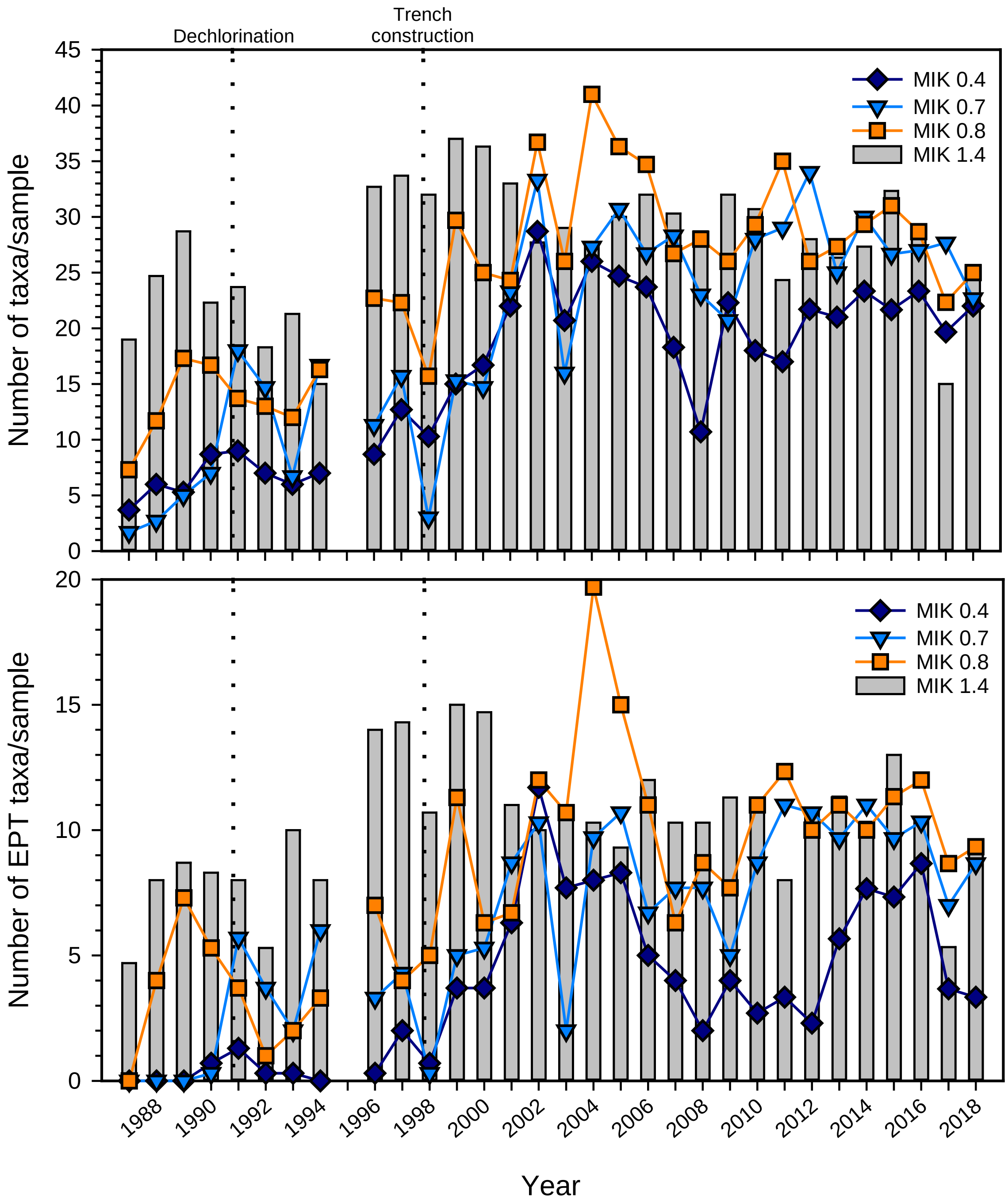
Mitchell Branch—ORNL and TDEC Protocols

Based on ORNL protocols in April 2018, all Mitchell Branch sites, except MIK 1.4, showed similar patterns to those observed in May 2017 for taxa richness (i.e., the total number of taxa per sample) and Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa richness (i.e., the total number of pollution-intolerant EPT taxa per sample). EPT are mayflies, stoneflies, and caddisflies, respectively. At MIK 1.4, both total and EPT taxa richness increased in 2018. EPT richness patterns among sites regained a resemblance of past patterns observed in 2010–2016, where EPT richness was highest upstream at MIK 1.4 and lowest at MIK 0.4 (Figure 3.54).

The percent density of the pollution-intolerant taxa (higher values are indicative of good condition) was highest at MIK 1.4, the reference site, and lowest at MIK 0.4 (Figure 3.55). Similarly, the percent density of pollution-tolerant taxa (lower values are indicative of good conditions) was lowest at MIK 1.4 and highest at MIK 0.4 (Figure 3.55). These results suggest the invertebrate community in Mitchell Branch continues to be mildly to moderately degraded downstream of MIK 1.4.

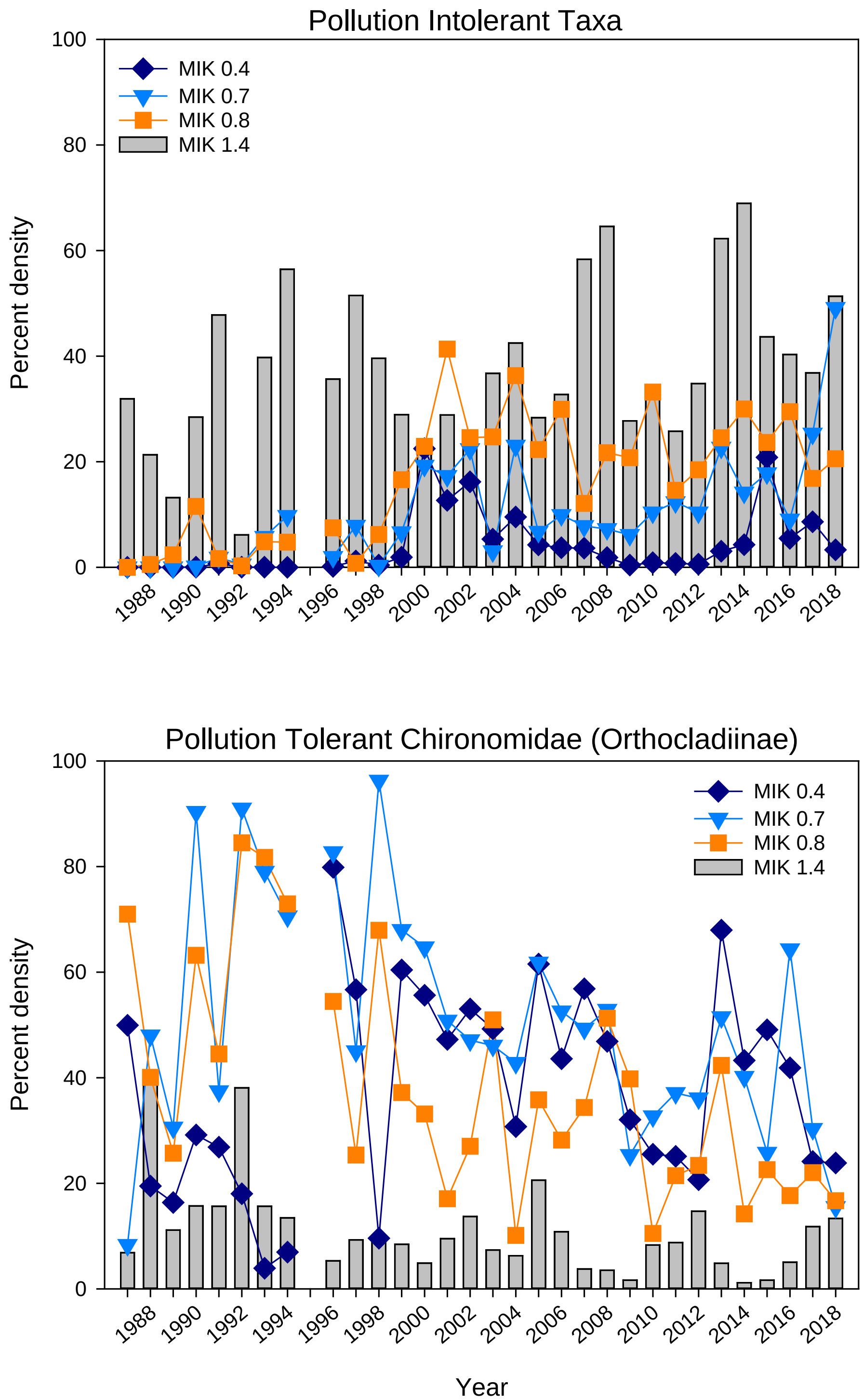
Based on TDEC 2017 protocols, scores for the Tennessee Macroinvertebrate Biotic Index in 2018 rated the invertebrate community as non-impaired at MIK 1.4 and slightly-impaired at MIKs 0.4, 0.7, and 0.8 (Figure 3.56). Scores at MIK 0.4 and 0.7 decreased in 2018 due to the low number of EPT taxa collected using TDEC protocols. MIK 0.8 remained at the same biotic index score as 2017.

Based on TDEC stream habitat protocols, habitat quality was rated as non-impaired at MIK 0.8 and moderately impaired at MIKs 0.4, 0.7, and 1.4 (Figure 3.56). Habitat scores increased at all sites from 2017 to 2018, except at MIK 1.4 where the score dropped slightly due to a decrease in bank stability and increase in non-native vegetation.



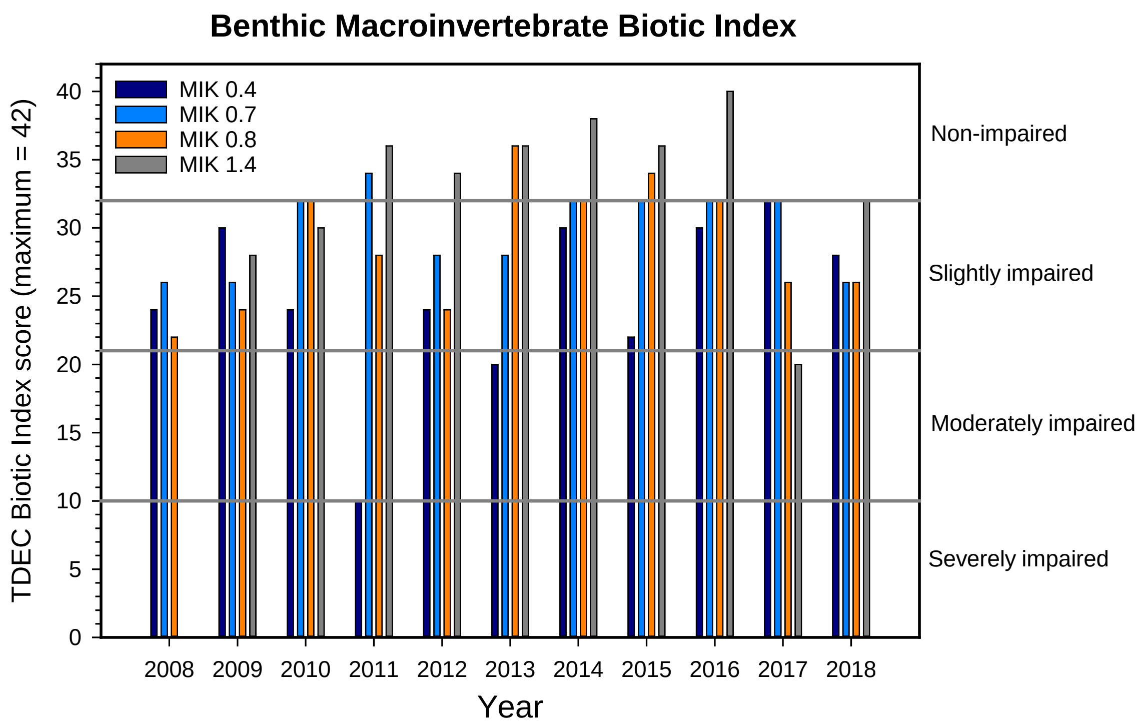
MIK = Mitchell Branch kilometer
Note:
Samples were not collected in April 1995, as indicated by the gap in the lines.

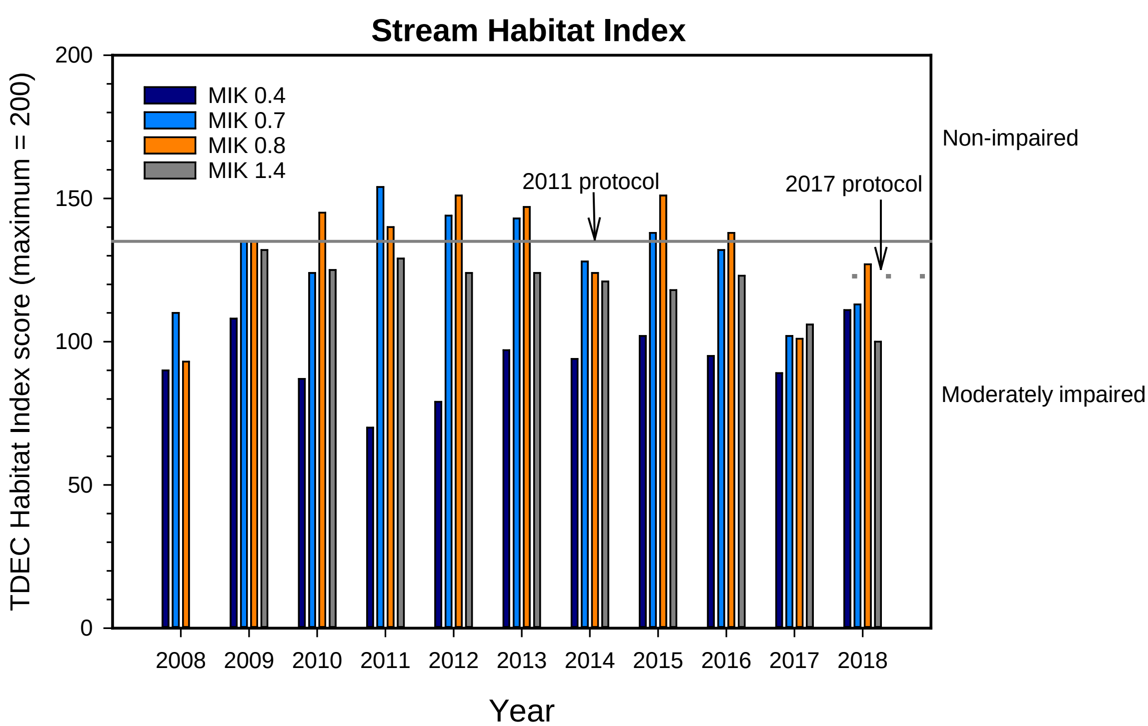
Figure 3.54. Mean total taxonomic richness (top) and taxonomic richness of the pollution-intolerant Ephemeroptera, Plecoptera, and Trichoptera (mayflies, stoneflies, and caddisflies, or EPT) taxa per sample (bottom) for the benthic macroinvertebrate community in Mitchell Branch, 1987–2018



MIK = Mitchell Branch kilometer
Notes:
1. Percentages were based on total densities for each site.
2. Samples were not collected in April 1995, as indicated by the gap in the lines.

Figure 3.55. Mean percent density of the pollution-intolerant Ephemeroptera, Plecoptera, and Trichoptera taxa (i.e., stoneflies, mayflies, and caddisflies), and percent density of the pollution-tolerant Orthocladiinae midge larvae (Chironomidae) in Mitchell Branch, 1987–2018





Notes:
1. Mitchell Branch site MIK 1.4 was not sampled with TDEC protocols in 2008.
2. The horizontal lines on each graph show the rating thresholds for each index; respective narrative ratings for each threshold are shown on the right side of each graph.
3. TDEC 2011 guidance used 2008-2017, TDEC 2017 guidance used in 2018.

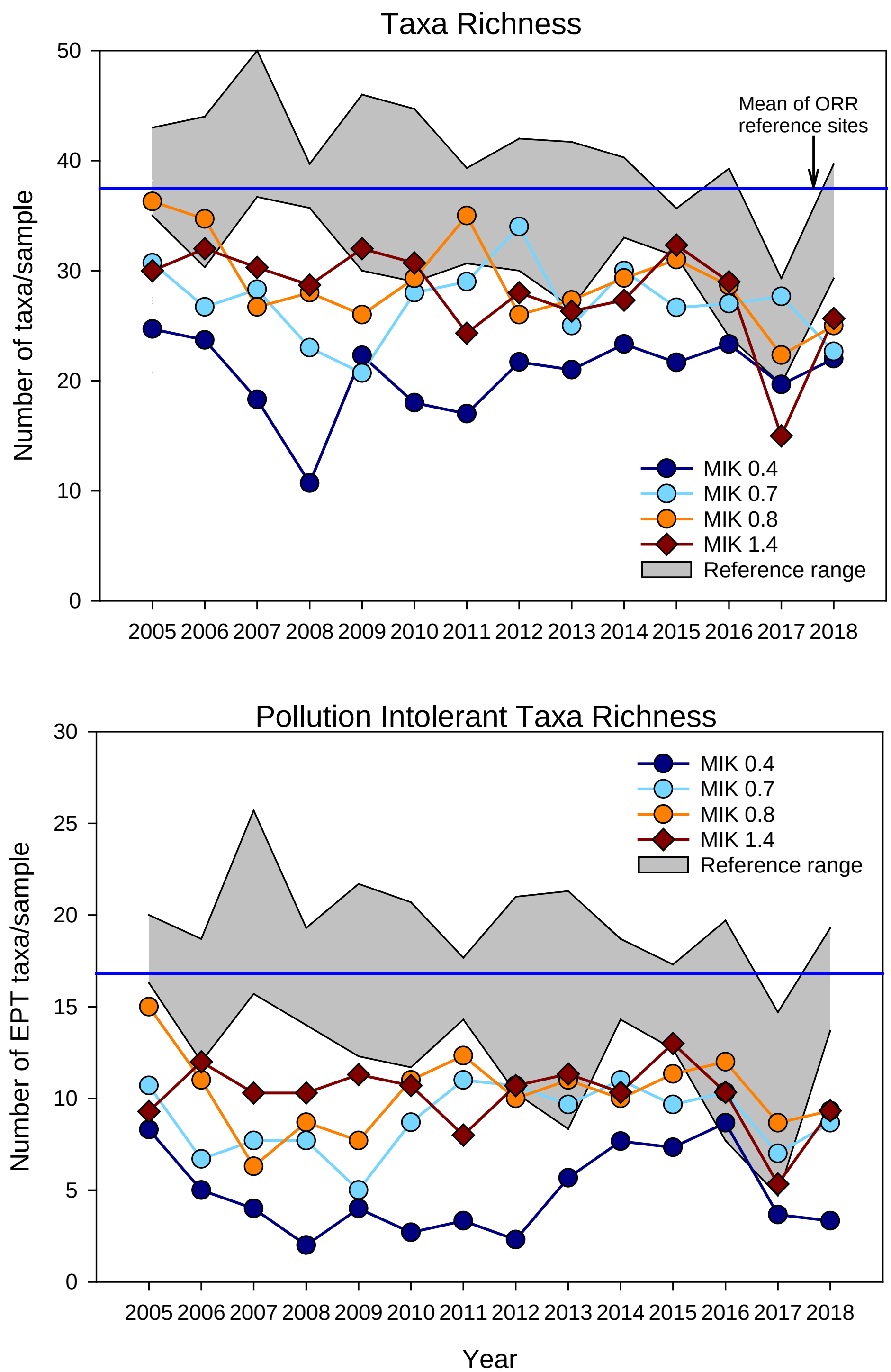
Figure 3.56. Temporal trends in the Tennessee Department of Environment and Conservation (TDEC) Biotic Index (top) and Stream Habitat Index (bottom) scores for Mitchell Branch, August 2008–2018

Comparison Between Mitchell Branch and Other Reference Sites on the Oak Ridge Reservation

Here the benthic macroinvertebrate communities in Mitchell Branch are compared to ORR reference streams over a 14-year period since 2005. Mean values for total and mean taxa richness of pollution-intolerant taxa for Mitchell Branch are shown in Figure 3.57, and percent density of the pollution-intolerant and pollution-tolerant taxa are shown in Figure 3.58. Also shown in Figs. 3.57 and 3.58 is the range of metric means for the five reference sites, First Creek kilometer 0.8, Fifth Creek kilometer 1.0, White Oak Creek kilometer 6.8, Walker Branch kilometer 1.0, and Gum Hollow Branch kilometer 2.9, in gray shading.

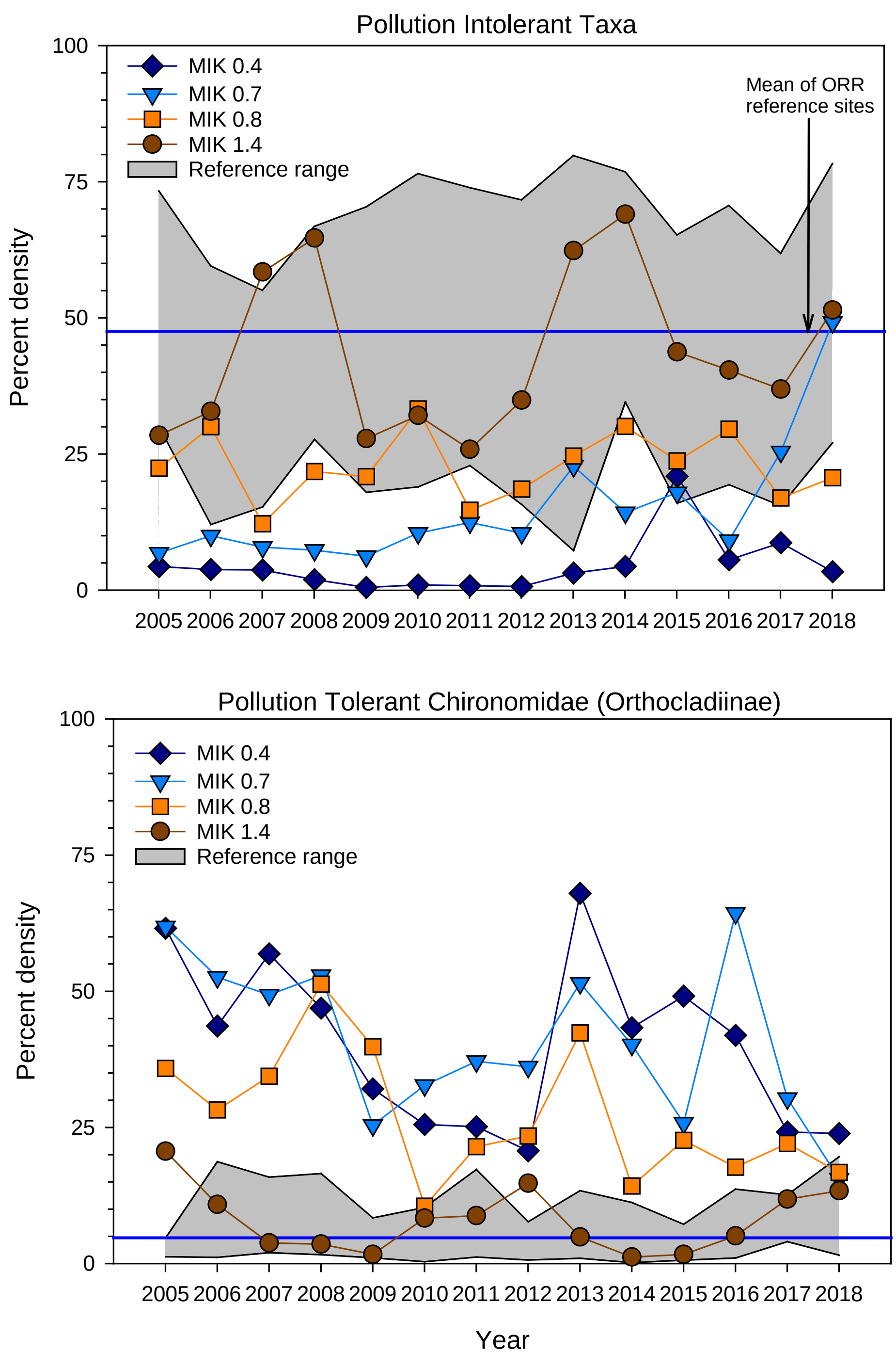
With few exceptions, total taxa richness and taxa richness of pollution-intolerant taxa at Mitchell Branch sites, including MIK 1.4, were less than what was present at the other reference sites from 2005 to 2018. Additionally, means for both richness metrics at all Mitchell Branch sites were less than the 14-year mean for the reference sites (Figure 3.57). In contrast to richness metrics, the mean percent densities of pollution-intolerant and pollution-tolerant taxa at MIK 1.4 were rarely outside of the range for the reference sites. Mean percent density of pollution-intolerant taxa at MIK 0.8 fluctuated in and out of the reference range, while the percent density of pollution-tolerant taxa fell within the reference range. MIK 0.7 showed marked improvement in percent density of both pollution-intolerant and pollution-tolerant taxa in 2018. Except for 2015, percent densities of both groups were outside of the reference range at MIK 0.4 in every year.

These results from the comparison of Mitchell Branch sites with the reference sites, combined with the long-term results for all Mitchell Branch sites discussed above, suggest that from the standpoint of reference sites, MIK 1.4 falls within the lower range of expected reference conditions on the ORR. Factors potentially contributing to frequent excursions of invertebrate community metrics outside of the range of other reference sites include the somewhat smaller size of MIK 1.4 compared with the other reference sites (based on watershed area; Table 3.24), which may limit the range of invertebrate species that can colonize and thrive at the site, as well as habitat characteristics that have typically contributed to the lower quality habitat at the site, such as low flow and poor substrate quality (see results above for the TDEC Habitat Index). These results also support the contention that sites downstream of MIK 1.4 continue to exhibit evidence of mild to moderate degradation.



MIK = Mitchell Branch kilometer
Note:
The gray shading on each graph shows the range of values at five additional reference stream sites on the Oak Ridge Reservation (ORR) from 2005 to 2018, and the solid blue horizontal line on each graph is the mean of the reference sites for the same period.

Figure 3.57. Mean total taxonomic richness (top) and taxonomic richness of the pollution-intolerant Ephemeroptera, Plecoptera, and Trichoptera (mayflies, stoneflies, and caddisflies, or EPT) taxa per sample (bottom) for the benthic macroinvertebrate community at sites in Mitchell Branch, 2005–2018



MIK = Mitchell Branch kilometer

Notes:

1. Percentages were based on total densities for each site.
2. The gray shading on each graph shows the range of values at five additional reference stream sites on the Oak Ridge Reservation (ORR) from 2005 to 2018, and the solid blue horizontal line in each graph is the mean of the reference sites for the same period.

Figure 3.58. Mean percent density of the pollution-intolerant taxa (i.e., stoneflies, mayflies, and caddisflies; top), and percent density of the pollution-tolerant Orthocladiinae midge larvae (Chironomidae; bottom) in Mitchell Branch, 2005–2018

3.7.4 Task 3: Fish Community

Fish population and community studies are used to evaluate the biotic integrity (or general ecological health) of Mitchell Branch. The fish community is sampled quantitatively at two sites in Mitchell Branch, MIK 0.4 (downstream of SD 190) and MIK 0.7 (downstream of SD 170) and at local reference streams.

Historically, the fish community in Mitchell Branch was most severely impacted in the late 1980s and early 1990s. After some recovery in the mid-1990s, Mitchell Branch was impacted negatively again in 1998 in association with a remedial activity that replaced a large section of stream bottom with a liner and interlocking rock substrate (Figure 3.59). In recent years, this reach of stream appears to be developing more natural habitat, including a more robust riparian plant community and some instream riffle/pool sequences as substrate is slowly beginning to accumulate throughout the reach. Since 2000, the fish community has had relatively stable species diversity but rather large variations in fish density and biomass (Figs. 3.60-3.62), which are often reflective of unstable, impaired streams. Streams that experience high density and biomass of tolerant fish species are often indicative of either high nutrient influences on a fish community (i.e., more algal growth means more food at the base of the food chain) or poor instream habitat—and often a combination of both. Of the two sites sampled for fish community, MIK 0.7 has experienced the greatest fluctuations in these community parameters. This is likely due to the modified riparian areas and poor instream habitat associated with the remediation work in this reach. Similar conditions are seen in other area streams on the ORR, including sections of EFPC where tolerant species dominate the concrete- and bedrock-lined channel, which supports little riparian protection. In addition, extremely low precipitation amounts in the summer of 2016 resulted in very low flows in many area streams. Small first and second order streams without springs or groundwater influence were most severely affected by these conditions. This may partially explain the decreased density and biomass numbers observed in spring 2017 samples and the apparent return of higher values in spring 2018.

Figure 3.59. Construction of lined section of Mitchell Branch, MIK 0.7, in 1998 (top) and more recent habitat conditions in 2018 (bottom)

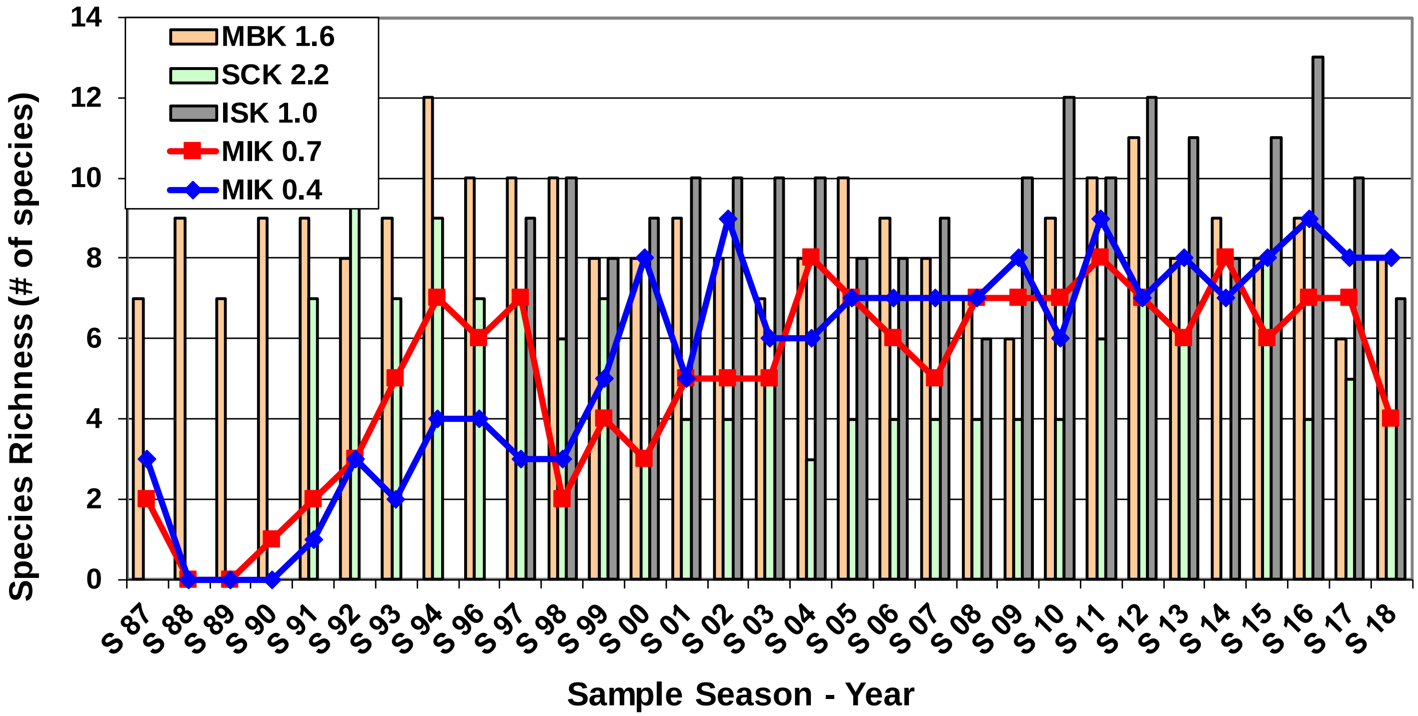


Figure 3.60. Species richness for the fish communities at sites in Mitchell Branch (MIK) and in reference streams Mill Branch (MBK), Scarboro Creek (SCK), and Ish Creek (ISK), 1987–2018

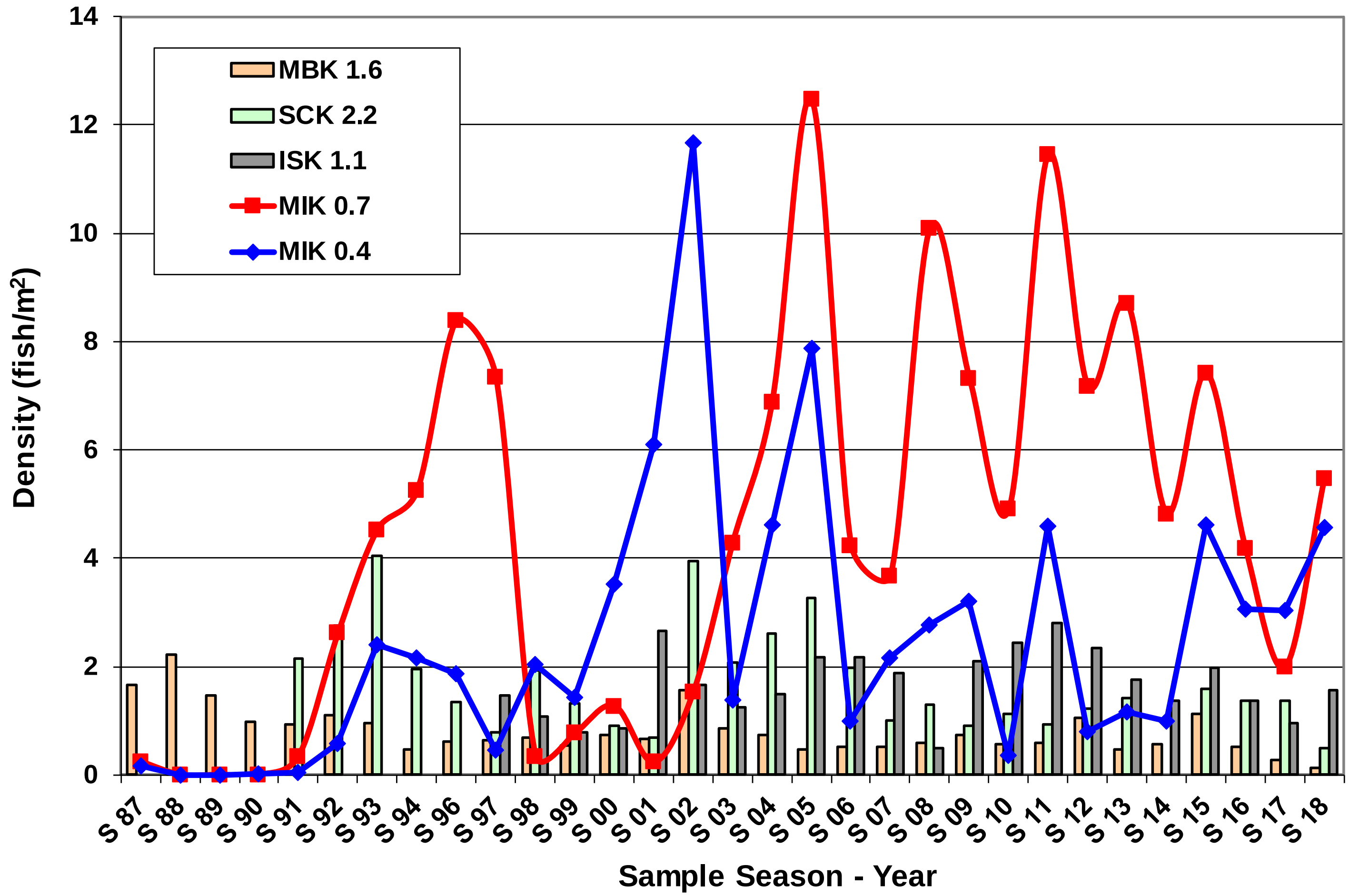


Figure 3.61. Density for the fish communities at sites in Mitchell Branch (MIK) and in reference streams Mill Branch (MBK), Scarboro Creek (SCK), and Ish Creek (ISK), 1987–2018

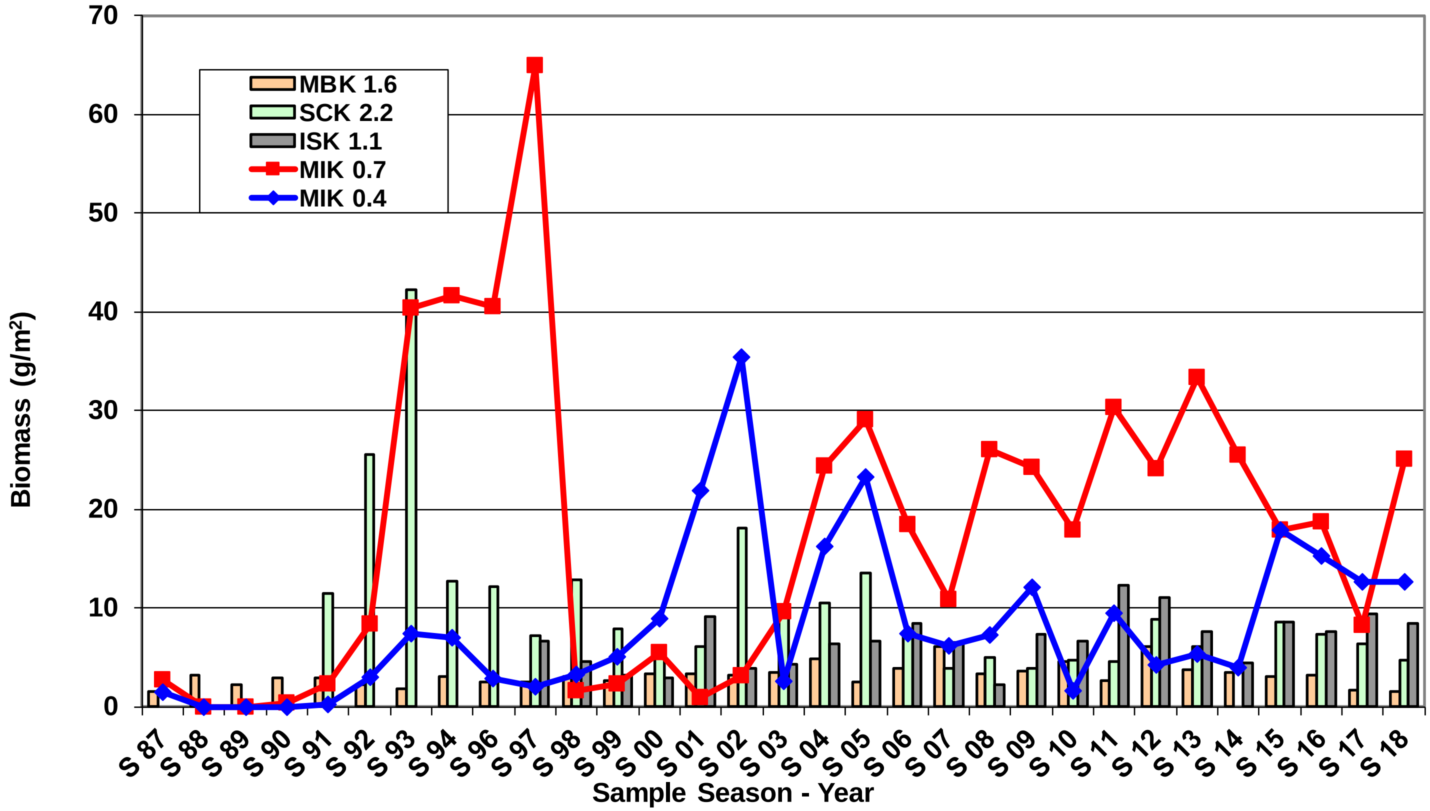


Figure 3.62. Biomass for the fish communities at sites in Mitchell Branch (MIK) and in reference streams Mill Branch (MBK), Scarboro Creek (SCK), and Ish Creek (ISK), 1987–2018

At both MIK 0.4 and MIK 0.7, the 2018 sample of community parameters indicated continued variation. There was a substantial decrease in fish species richness (number of species) at MIK 0.7 from 2017 to 2018 (7 species to 4). In contrast MIK 0.4 species richness remained comparable with reference streams. As mentioned above, density (number of fish) at both sites increased from 2017 and still remains well above reference conditions. Biomass (weight) also increased at the upper site while remaining stable at the lower site. Both the lower Mitchell Branch site and the upper site had reduced diversity of sensitive fish species in 2018, and both sites also experienced a slight decrease in sensitive species density (Figs. 3.63 and 3.64). Overall the last five years, there has been a slight uptick in sensitive species diversity and density at both sampled sites which can be attributed to the presence of fish such as banded sculpin (*Cottus carolinae*), which appear to be a resident species in Mitchell Branch, and also occasional occurrences of other more sensitive fish.

In general, the Mitchell Branch fish communities at MIK 0.4 and MIK 0.7 continue to lack diverse resident species that are sensitive to stress or that have specialized feeding or reproductive requirements, such as darters or suckers that occur consistently at higher frequencies in the reference streams. Like the benthic communities, fish community monitoring provides an integrated response to *all* of the various water chemistry and habitat influences in a stream. Identifying the major stressor influences on the community (i.e., causal analysis) would require additional investigatory strategies coupled with the monitoring data.

During routine bioaccumulation sampling, several species of fish are collected regularly at MIK 0.2 that are almost never observed in the Mitchell Branch fish community monitoring activities at the upstream sites. These included four pollution-sensitive species: snubnose darter (*Etheostoma simoterum*), greenside darter (*Etheostoma blennioides*), black redhorse (*Moxostoma duquesnei*), and northern hogsucker (*Hypentelium nigricans*) (Figure 3.63-3.65). Future monitoring will help determine if these species are becoming established farther upstream in Mitchell Branch or are merely seasonal migrants to the stream's lower section, which is easily accessible from the much larger Poplar Creek.

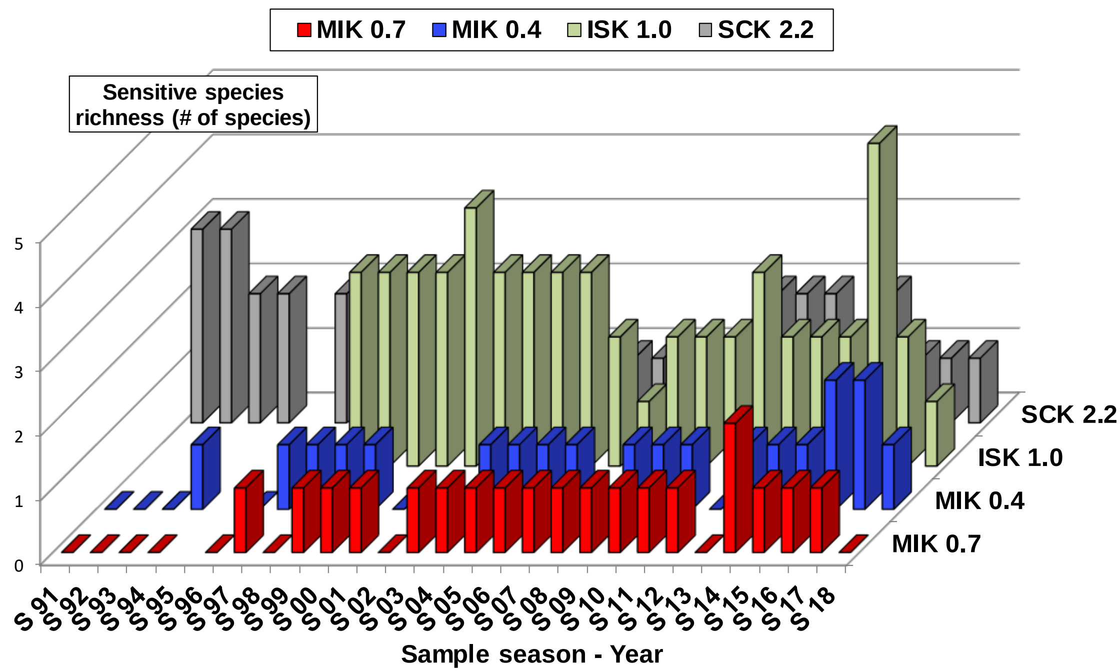


Figure 3.63. Sensitive species (e.g., banded sculpin and snubnose darter) richness of the fish communities at sites in Mitchell Branch (MIK) and in reference streams Scarboro Creek (SCK) and Ish Creek (ISK), 1991–2018

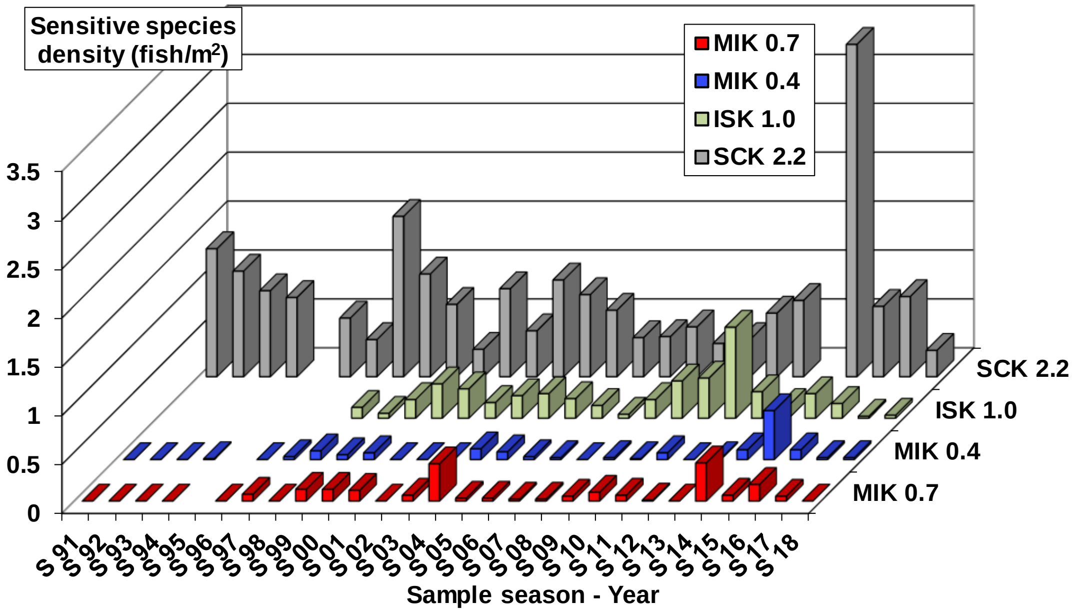
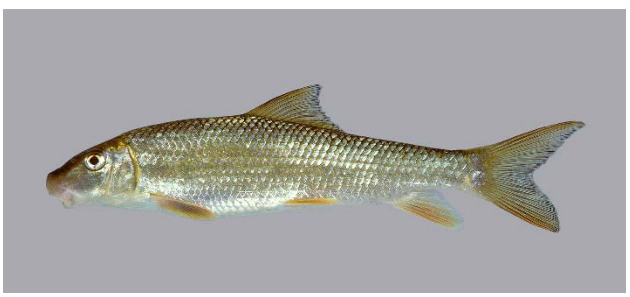


Figure 3.64. Sensitive species (e.g., banded sculpin and snubnose darter) density of the fish communities at sites in Mitchell Branch (MIK) and in reference streams Scarboro Creek (SCK) and Ish Creek (ISK), 1991–2018



Black redhorse (*Moxostoma duquesnei*)

Snubnose darter (*Etheostoma simoterum*)

Northern hogsucker (*Hypentelium nigricans*)

Greenside darter (*Etheostoma blennioides*)

Photos: Chris Bryant

Figure 3.65. Sensitive fish species observed in lower Mitchell Branch

3.7.5 K-1007-P1 Pond Fish Community

The fish communities in the K-1007-P1 pond are assessed annually. This sampling is conducted to evaluate the effectiveness of remediation efforts implemented in 2009 and is aimed at reducing the PCBs available for transfer out of the pond via natural routes (i.e., trophic transfer). The remedial actions included capping contaminated sediment with fill dirt, planting native aquatic vegetation to stabilize sediment, and removing potentially contaminated fish from the pond. Fish initially were removed from the pond using a piscicide (Rotenone), and uncontaminated native fish were stocked in the pond with the goal of establishing a sunfish-dominated community. Sunfish have a shorter lifespan than many other species of fish, especially higher trophic level fish, and they have a prey source that is generally varied but consistently lower on the aquatic food chain compared with species such as largemouth bass, thus reducing the likelihood that contaminants would biomagnify within the system.

Despite efforts to remove all unwanted fish from the pond, an unexpected breach in the weir separating the K-1007-P1 pond from the adjacent Poplar Creek in May 2010 allowed numerous fish to enter the pond during high waters. These unwanted fish constituted several species that were unfavorable to the pond action—including (1) nonnative species and (2) species with life history traits that undermined the remediation efforts, such as being long-lived and having feeding habits that disturb potentially contaminated sediments. Continued work to remove these unwanted fish has been productive, and only limited numbers of the most long-lived species, such as common carp (*Cyprinus carpio*) and smallmouth buffalo (*Ictiobus bubalus*), are encountered in annual monitoring.

Two additional species that returned to the pond after the weir breach were gizzard shad (*Dorosoma cepedianum*) and largemouth bass (*Micropterus salmoides*). Gizzard shad feed on phytoplankton and zooplankton in natural environments such as larger reservoirs, but in smaller ponds such as P1, they often turn to feeding on algal growth at the surface of the pond sediment, which can disturb soils and potentially resuspend contaminants in the pond substrate. Largemouth bass tend to be a long-lived species and are a top predator in aquatic environments, making them particularly susceptible to bioaccumulation. They also are a game fish highly prized by many anglers as well as a common table fare. These two species also have been targeted for removal during continued remediation efforts and fish surveys.

Overall, the K-1007-P1 Pond fish community surveys conducted in February 2018 revealed the presence of 12 species of fish (Figure 3.66). An observation of particular importance from previous surveys is the abundance of sunfish species (bluegill, redear sunfish, and warmouth), which constitute approximately 80 percent of the total fish population. Bluegill, the most prevalent of these species, were historically the dominant sunfish species in the pond, and they are the desired bioindicator fish species to have in the remediated pond. Although largemouth bass continue to persist in the pond, their abundance remains relatively low. Despite removal efforts, their presence is expected to continue, given the habitat conditions currently in the pond (i.e., abundant prey sources and open water). Gizzard shad continue to be present in the pond and are suspected of reproducing; however, they constitute only approximately 13 percent of the fish population at present.

A few additional strategies were utilized in 2017-2018 in an effort to further manipulate the fish population and overall pond ecosystem to better reflect the desired end state. These included: more strategic and targeted fish removal efforts, stocking of 41,000 juvenile bluegill over two years, and aquatic and terrestrial plantings of native plants in various areas around the pond. These efforts were designed to reduce nuisance fish presence through removal, adjust the fish community through inundation of specific fish age classes, and increase vegetative cover in areas of the pond that currently lack vegetation. Future monitoring will provide insight on the effectiveness of these efforts and provide guidance for future management techniques.

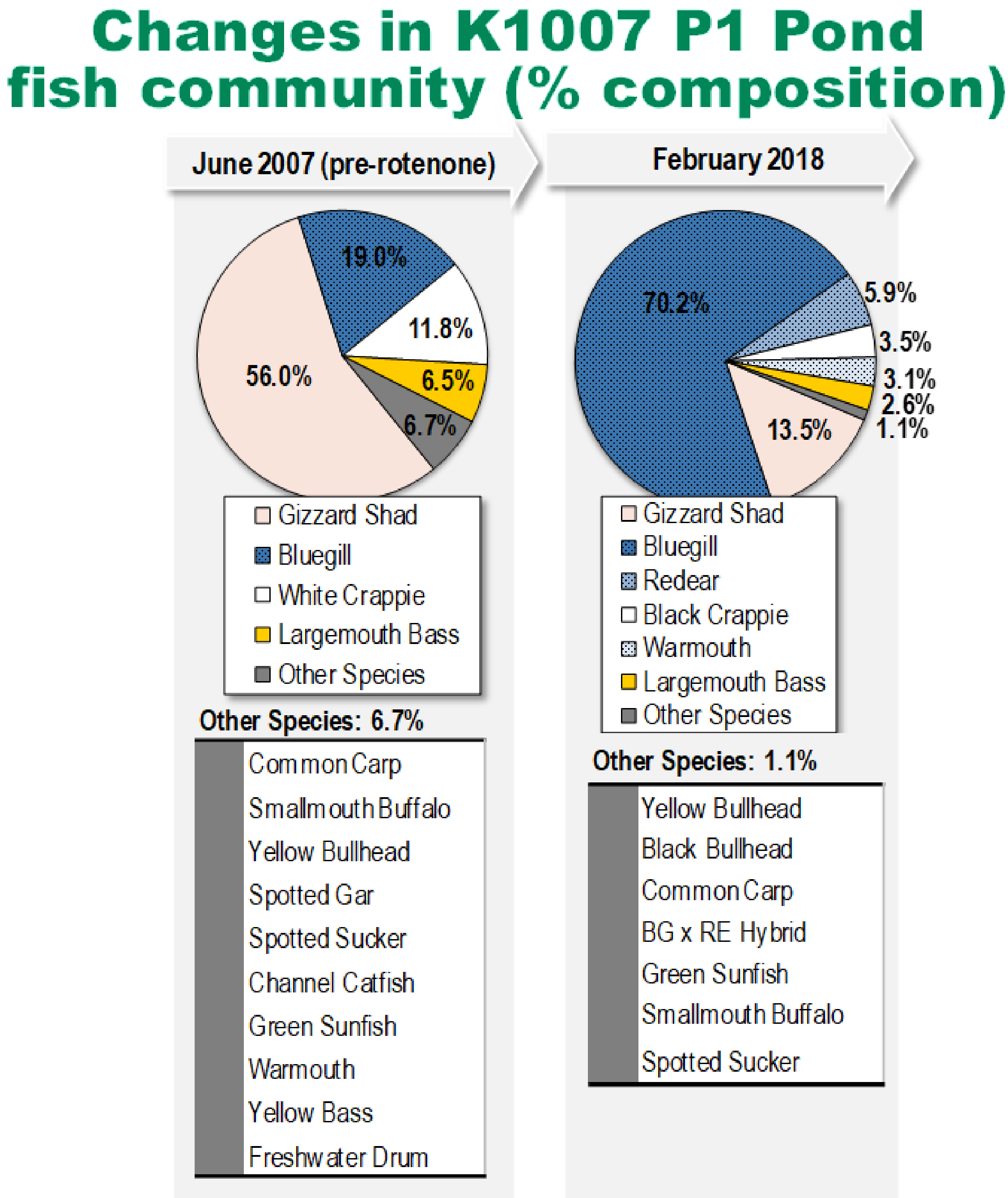


Figure 3.66. Changes in the K-1007-P1 Pond fish community (% composition) from 2007 to 2018

3.8 Environmental Management and Waste Management Activities

3.8.1 Waste Management Activities

Restoration of the environment, D&D of facilities, and management of legacy wastes constitute the major operations at ETTP.

CWTS is a small water treatment unit for chromium-contaminated groundwater that sits within the existing CNF footprint. CWTS came online in late 2012, and handles purge water from groundwater monitoring, as well as the chromium collection system water. Effluent from CWTS discharges into the Clinch River through an existing CNF discharge line. Section 3.6.12 provides a more detailed discussion of CWTS operations.

3.8.2 Environmental Remediation Activities

UCOR's soil remediation efforts at ETTP are helping to prepare the site for future commercial industrial use. The site is divided into two cleanup regions: Zone 1, a 1,400-acre area outside the main plant area, and Zone 2, the 800-acre area that comprises the main plant area. The areas in these zones are divided into exposure units (EUs) that vary in size.

3.8.2.1 Zone 1

The Interim ROD, which documents the cleanup method for Zone 1 (DOE 2002a, DOE/OR/01-1997&D2), requires the DOE Oak Ridge Office of Environmental Management (OREM) to remediate soil for the protection of groundwater and a future industrial workforce, and to maintain land use controls (LUCs). In FY 2018, remediation of the duct bank was completed. The duct bank, constructed in 1944, was an underground power transmission system that provided power from the former K-704 Switchhouse to the gaseous diffusion plant uranium enrichment facilities. The duct bank was abandoned in the early 1970s.

Also in FY 2018, remediation of two areas on Duct Island was completed to ensure there were no ecological risks to wildlife. Duct Island, which is actually a peninsula, is a stretch of land located between the old Powerhouse area and the main plant site. Its name is derived from the numerous underground electrical ducts that crossed the peninsula to deliver power to the site.

3.8.2.2 Zone 2

The Zone 2 ROD (DOE 2005b) requires OREM to remediate soil for the protection of an industrial workforce and groundwater and divides the zone into 44 EUs that range in size from 6 to 38 acres. In FY 2018, OREM and UCOR completed characterization of EUs Z2-19 and remediation of EUs Z2-11, 12, 14, and 17. Three separate RAs were completed in EU-22 (two were associated with removing soil contaminated with concentrations of ^{234}U exceeding the groundwater soil screening level, and the third was associated with removing PCB-contaminated soil with concentrations exceeding the Zone 2 ROD maximum remediation level for PCBs). Also within EU-22 (K-25 Building Footprint), a major RA was initiated to excavate soil contaminated with concentrations of ^{99}Tc exceeding the Zone 2 groundwater soil screening level criterion. The soil contaminated with ^{99}Tc poses a threat to groundwater, but crews are working to address and remove those risks.

Alternatives were evaluated for the remediation of TCE-contaminated soil within the footprint of the former K-25 building because the soil could pose a threat to groundwater. The remedy in the Zone 2 ROD is soil excavation, but due to several factors, including the volume of soil to be excavated and the structural integrity of surrounding buildings, other alternatives were considered. The recommendation was to excavate the soil as required by the Zone 2 ROD.

3.8.2.3 K-1200 Centrifuge Complex Demolition

The buildings of the K-1200 Centrifuge complex have been undergoing deactivation to prepare them for safe demolition. Demolition will take place in the next few years.

The deactivation process includes asbestos abatement, utility disconnection, equipment and waste removal, and other necessary steps to ensure demolition can be performed safely. Deactivation in the Centrifuge complex began in FY 2018. The facility was used to gauge the reliability of test centrifuges.

3.8.2.4 TSCA Incinerator Demolition

Demolition of the TSCA Incinerator was completed in 2018 ahead of schedule and under budget. The incinerator began operating in 1991, treating radioactive and hazardous wastes (mixed wastes) contaminated with PCBs. As the only US facility permitted to incinerate these types of waste, it accepted material from ORR and other facilities across the nationwide DOE complex.

The incinerator was shut down in December 2009 after treating 35.6 million pounds of waste. Workers then began preparing the facility for demolition, which included cleaning, rinsing, and filling sumps; encapsulating PCB and radioactive contamination; disconnecting pipes; and removing and disposing of carbon vessels, which were part of the water management system.

3.8.2.5 Building K-1037 Deactivation Continues

UCOR continued deactivation work in Building K-1037 in FY 2018. Deactivation is the initial step that prepares the facility for eventual demolition. The facility manufactured all of the barrier material used in the gaseous diffusion process since 1947. This material was a key component of the gaseous diffusion process when workers separated the ^{235}U and ^{238}U isotopes.

K-1037 was once a warehouse, which was later converted into a facility that produced the porous barrier material used in the separation process.

Crews completed asbestos-abatement activities identified in the original scope; however, as items such as loose equipment were removed throughout the building, additional asbestos was uncovered, so abatement work and loose equipment removal activities continued into 2018. In addition, a tremendous amount of effort was dedicated to the removal of excess chemicals throughout the facility. Over 1400 chemicals have been collected, sampled, and prepared for disposal. Demolition is scheduled to begin in 2019.

3.8.2.6 K-633 Test Loop Facility Demolition Completed

Demolition of ETTP's K-633 Test Loop Facility, one of several radiologically contaminated facilities in ETTP's Poplar Creek area, has been completed. The building consisted of four separate and independent testing loops that have common auxiliary systems and utilities. The first three loops were built to test and evaluate gaseous diffusion plant stage equipment performance under production conditions. In 1981, a fourth test loop was installed, which evaluated prototype equipment designed for withdrawal of depleted uranium hexafluoride tails from the gas centrifuge enrichment plant. The 18,100-square-foot facility was shut down in 1984. The radiological contaminants in the building were affixed inside piping and equipment using fixatives and foam, allowing for safe demolition of the structure.

3.8.2.7 Central Neutralization Facility Deactivation Continues

The CNF was a wastewater treatment facility for industrial wastewater generated at ETTP. CNF was constructed in stages from 1945 to 2000. In 2013, CNF was decommissioned and the NPDES-permitted facility water treatment equipment was cleaned of all hazardous waste contamination. All operations at CNF ceased in 2013.

In 2018, demolition was completed ahead of schedule and under budget.

3.8.2.8 Commemoration of the K-25 Site

National historic preservation initiatives at ETTP reached a milestone in FY 2018 with the procurement of the services of construction and exhibit fabrication and installation support subcontractors for the History Center work. Construction of the K-25 Site commemorative facilities have begun.

The K-25 History Center will be located on the second floor of the COR-owned Fire Station # 4 at ETTP. The K-25 History Center is expected to open in 2019. Visitors to the K-25 History Center will be invited to explore the rich history of this Manhattan Project site. This facility will feature a theatre experience, period artifacts, equipment replicas, and workers' oral histories, placing K-25 in its proper historical context in World War II and the Cold War. An in-depth look at gaseous diffusion, the thousands of equipment stages housed in K-25, and the people who sacrificed to make it a reality, will be highlighted. The Equipment Building and Viewing Tower design replicates the exterior appearance of the K-25 building, and will house a representative cross-section of gaseous diffusion technology. An enclosed observation deck will provide a 360-degree view of the site.

3.8.3 Reindustrialization

As cleanup has progressed extensively at ETTP, more large parcels are becoming available for transfer to the private and commercial industrial sectors. In 2018, DOE completed transfer of Duct Island, a 207-acre parcel on the western portion of ETTP, to CROET. This transfer is the second largest transfer in the history of the program, and the largest at ETTP Heritage Center. This brings the total acreage of land transferred to 1,280 acres, with 789 of those acres at the Heritage Center. Additionally, a large area of 170 acres at the southeast corner of ETTP has been approved for transfer to Metropolitan Knoxville Airport Authority for a potential regional airport project. The general aviation airport runway would accommodate small corporate jets, private airplanes, and EMS aircraft. A final decision from the Federal Aviation Administration (FAA) on this project is anticipated in 2019.

DOE completed an Environmental Assessment to support the property transfer and potential construction and operation of the airport. DOE has also received EPA and TDEC approval for future property transfer of the former Powerhouse area, which is over 400 acres. The transfer of large parcels, as more of the site cleanup is completed, provides the best opportunities to date for industrial and commercial development of ETTP.

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4. The Y-12 National Security Complex

Y-12 National Security Complex (Y-12), a premier manufacturing facility operated by Consolidated Nuclear Security, LLC (CNS) for the National Nuclear Security Administration (NNSA), plays a vital role in the DOE Nuclear Security Enterprise. Drawing on more than 70 years of manufacturing excellence, Y-12 helps ensure a safe and reliable United States nuclear weapons deterrent.

Y-12 also retrieves and stores nuclear materials, fuels the nation's naval reactors, and performs complementary work for other government and private-sector entities.

Today's environment requires that Y-12 has a new level of flexibility and versatility; therefore, while continuing its key role, Y-12 has evolved to become the resource that the nation looks to for support in protecting America's future by developing innovative solutions in manufacturing technologies, prototyping, safeguards and security, technical computing, and environmental stewardship.

Due to different permit reporting requirements and instrument capabilities, this report uses various units of measurement. The lists of units of measure and conversion factors on pages xxvii and xxviii are included to help readers convert numeric values presented herein as needed for specific calculations and comparisons.

4.1 Description of Site and Operations

4.1.1 Mission

Charged with maintaining the safety, security, and effectiveness of the United States' nuclear weapons stockpile, Y-12 is a one-of-a-kind manufacturing facility that plays an important role in United States national security. Y-12's core mission is to ensure a safe, secure, and reliable United States nuclear deterrent, which is essential to national security. Every weapon in the United States nuclear stockpile has components manufactured, maintained, or ultimately dismantled by Y-12. Through life extension program activities, Y-12 produces refurbished, replaced, and/or upgraded weapons components to modernize the enduring stockpile. As the nation reduces the size of its arsenal, Y-12 has a central role in decommissioning weapons systems and providing weapons material for non-explosive, peaceful uses. Y-12 provides the expertise to secure highly enriched uranium (HEU), store it with the highest security, and make material available for non-weapons uses (e.g., in research reactors that produce cancer-fighting medical isotopes and in commercial power reactors). Y-12 also processes HEU from weapons removed from the nation's nuclear weapons stockpile for use by the Naval Reactors program to fuel nuclear-powered submarines and aircraft carriers.

Located within the city limits of Oak Ridge, Tennessee, Y-12 covers more than 328 ha (810 acres) in the Bear Creek Valley, stretching 4.0 km (2.5 mi) in length down the valley and nearly 2.4 km (1.5 mi) in width across it. NNSA-related facilities located offsite from Y-12 include the Central Training Facility, Uranium Processing Facility (UPF) project offices, Y-12 Material Acquisition and Control, and the Union Valley Sample Preparation Facility.

4.1.2 Modernization

Government-owned facilities and operations are becoming smaller, more efficient, and more responsive to changing national and global challenges. NNSA's vision for a smaller, safer, more-secure, and less-expensive nuclear weapons complex must leverage the scientific and technical capabilities of its workforce while continuing to meet national security requirements. Nowhere in the National Security Enterprise is this more important than at Y-12.

More than 60 percent of Y-12 mission-critical facilities are over 70 years old (Figure 4.1). To address this situation, Y-12 has been consolidating operations, modernizing facilities and infrastructure, and reducing the legacy footprint for more than a decade. These actions are consistent with and supportive of NNSA enterprise transformation planning. Through continued infrastructure projects, new construction, and the disposition of excess facilities, Y-12 will continue to strive toward becoming a more responsive, sustainable enterprise.

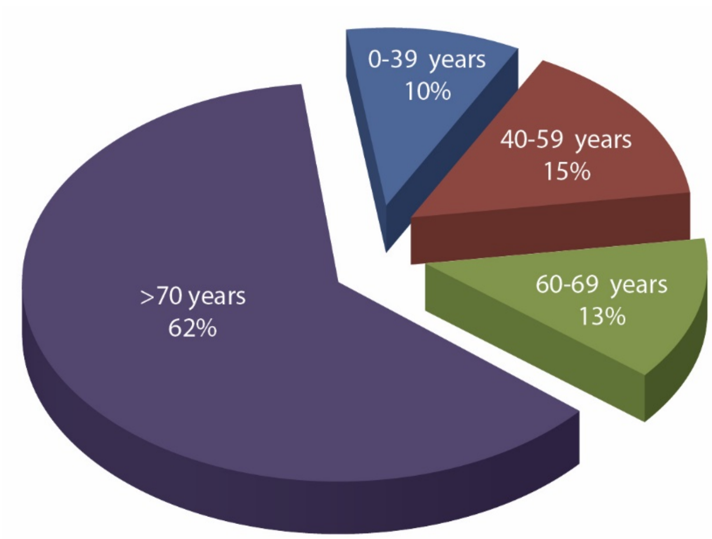


Figure 4.1. Age of mission-critical facilities at the Y-12 National Security Complex

Replacement and revitalization are key elements of the modernization strategy at Y-12. A significant number of facilities at Y-12 are at or beyond design life. Construction at UPF continues to make good progress, and replacement projects for several additional facilities are in the critical design process.

4.1.3 Enriched Uranium Operations

Y-12's core manufacturing and processing operations are housed in decades-old buildings that are near or past the end of their expected life spans.

UPF will be an integral part of Y-12 transformation efforts and a key component of the NNSA Uranium Center of Excellence. UPF will be a modern manufacturing facility designed and constructed for health, safety, security, and operations efficiency. In Fiscal Year (FY) 2014, NNSA commissioned a Project Peer Review Team to assess the progress and opportunities for the UPF project. This evaluation produced a number of recommendations to refocus the project to a smaller footprint and to relocate various processes to existing facilities.

When the current UPF construction is complete, it will replace a portion of HEU production functions. The remaining HEU production capability will be transitioned to Buildings 9215 and 9204-02E, which must be sustained to achieve the HEU mission strategy. The strategy includes the following:

- Accelerating transition out of Building 9212 by 2025 to reduce nuclear safety and operational risk while maintaining enriched uranium capabilities.
- Integrating evaluation of alternatives for delivery of UPF that prioritizes replacement capabilities according to risk to nuclear safety, security, and mission continuity.
- Substantially improving the needed Y-12 infrastructure over the next decade at a risk-based annual funding level that supports safe and secure operations.
- Prioritizing replacement capabilities by risk-to-mission continuity, nuclear safety, and security.

4.1.4 Lithium Processing Facility

The lithium production equipment and facilities at Y-12 have degraded to the point that repair is no longer an option. Thus, to ensure continued mission availability and to reduce annual operating costs, the lithium capability must be replaced. Production work for lithium and related non-nuclear special material vital to production of canned subassemblies is performed in Building 9204-2, built in 1944. The facility (at approximately 325,000 ft^2) is oversized for today's mission, and for decades, concrete on the inside and outside of the building has deteriorated. The roof, walls, and ceilings have been exposed to corrosive liquids and processing fumes, which have caused significant deterioration to the concrete. Separation of the concrete and rebar poses a realized risk of falling concrete, which requires administrative controls, including restricted access and protective equipment in many areas. The facility, currently carrying approximately $33 million in deferred maintenance, could be replaced by a new facility less than one-third its size. Site production risk assessments rate two of the lithium processes as the highest equipment risks at Y-12. Critical process equipment (hydraulic press) failures caused "code blue," or immediate, repair efforts to minimize the negative impact on delivery schedules of directed stockpile work (DSW) components. The inability to control humidity due to aged and inoperable heating, ventilating, and air conditioning (HVAC) equipment has caused recurrent lost work days, negatively affecting DSW costs and life extension program schedules. Construction and replacement activities are underway for the HVAC equipment.

4.1.5 Support Facilities

Emergency response capabilities at Y-12 reside in five primary facilities—four located onsite (Buildings 9706-2, 9105, 2005, and 9710-2), and one (Building K-1650) located at ETTP. Building 9706-2 houses the Plant Shift Superintendent (PSS) and the Emergency Control Center. The Technical Support Center (TSC) was relocated to Building 9105 due to a flood event in Building 9706-02 in 2014. Building 9710-2 is the principal facility housing Fire Protection Operations, with a back-up facility (2005) located on the west end. Building K-1650 houses the Command Center/alternate Emergency Operations Center (EOC). A line-item project for construction of a new EOC, scheduled to begin in 2020, includes the replacement of the PSS, TSC, and Emergency Response Center. The proposed EOC will more effectively and efficiently support Y-12 missions by consolidating emergency-response capabilities into a habitable, survivable facility that also provides space for a technical support team.

Built in 1948, Building 9710-2 houses the Fire Station and the Fire Department Alarm Room. The overflow station for the fire department is located in Building 2005, at the far west end of the plant.

Building 9710-02 is located within the most highly protected area of the plant and close to Y-12's most hazardous operations. Seismic, tornado, hazardous material release, and security events could render the fire station inaccessible. Off-duty personnel augment the duty staff, and thus, their access to the facility is critical. Although upgrades have been performed over the years, the Fire Protection Operations facility has exceeded its useful life and needs to be replaced.

Building 2005 was constructed in 1980 and was originally occupied by ORR roads and grounds crew. The fire department assumed occupancy of the facility in 2014 and renovated portions for crew support and vehicle staging. Relocation of the fire station away from Y-12 hazardous material facilities is necessary to ensure that the fire department can respond safely and effectively to all emergencies at Y-12. A proposed new fire station is planned for construction beginning in 2020. The new facility will be located on the east end of the plant and is designed to meet current codes and functional requirements.

Over the next 25-year horizon, Y-12 will continue to consolidate personnel and processes in support of the vision for long-range footprint reduction and modernization. The planned construction at Y-12 would eliminate many of the World War II-vintage buildings that currently house the nuclear operations. The following projects are under construction or are being initiated during the Future Year Nuclear Security Plan period:

- UPF
- new 13.8kV substation and plant electrical distribution
- EOC
- West End Protected Area reduction
- Fire Station
- Lithium Processing Facility
- extended life strategy for Buildings 9215, 9204-02E, and 9995
- West End Production Support Change House

The following projects are planned for construction beyond the Future Year Nuclear Security Plan period:

- Applied Technologies Laboratory
- Security Support Complex
- Consolidated Depleted Uranium Manufacturing Capability
- Maintenance Complex
- Non-Special Nuclear Material Storage and Staging Facility
- Waste Management Complex
- Enriched Uranium Manufacturing Center (9215 replacement capability)
- Assembly and Disassembly Center (9204-02E replacement capability)

4.1.6 Excess Facility Disposition

Since 2002, Y-12 has demolished more than 1.6 million gross square footage of excess facilities. Currently, more than 102 excess DOE facilities are located on the Y-12 site, with a total of 2.8 million gross square footage. The excess facilities are owned by NNSA and the DOE Office of Environmental Management (EM), Office of Science, and Office of Nuclear Energy. Process-contaminated excess facilities contain radiological or chemical contamination resulting from their mission operations during the Manhattan Project or the Cold War.

EM, through its contractors, is responsible for decommissioning and demolishing the legacy contaminated facilities.

Non-process-contaminated excess facilities generally do not contain radiological or chemical contamination from mission operations but may contain hazardous industrial materials associated with their construction materials (e.g., asbestos insulation, paint containing lead, or oil contaminated with polychlorinated biphenyls [PCBs]). The non-process-contaminated excess facilities will be deactivated by NNSA and decommissioned by NNSA or EM, depending on the cost and complexity.

The NNSA Facilities Disposition Program will continue to evaluate facilities, prioritize their disposition, develop cost and schedule, and communicate requirements for disposal of excess facilities. In 2016, Y-12 established the Excess Facility Disposition Program to stabilize and de-inventory the three major high-risk process-contaminated facilities and to safely dispose of other excess facilities around the site.

4.2 Environmental Management System

As part of CNS's commitment to environmentally responsible operations, Y-12 has implemented an Environmental Management System (EMS) based on the requirements of the globally recognized International Organization of Standardization (ISO) 14001:2004 standard to plan, implement, control, and continually improve environmental performance at Y-12 (ISO 2004).

DOE Order (O) 436.1, *Departmental Sustainability* (DOE 2011a), provides requirements and responsibilities for managing sustainability within DOE in accordance with applicable Executive Orders (EOs). DOE O 436.1 further requires implementation of an EMS that is either registered to the requirements of ISO 14001:2004 by an accredited ISO 14001 registrar or self-declared to be in conformance to the standard in accordance with instructions issued by the Office of the Federal Environmental Executive, a chartered task force under the White House Council on Environmental Quality. Y-12 has maintained an EMS with self-declared conformance to ISO 14001 since 2006.

The EMS requirements taken from DOE O 436.1 have been incorporated into the Environmental Protection functional area of Y-12's Contractor Assurance System.

4.2.1 Integration with Integrated Safety Management System

Y-12's Integrated Safety Management System (ISMS) is the basis for planning and implementing environment, safety, and health (ES&H) programs and systems that provide the necessary structure for any work activity that could affect the public, a worker, or the environment. At Y-12, the elements of the ISO 14001 EMS are incorporated in and are consistent with the ISMS to achieve environmental compliance, pollution prevention, waste minimization, resource conservation, and sustainability. Both the ISMS and EMS are based on an internationally recognized cycle of continual improvement commonly known as the "plan-do-check-act" cycle, as depicted in Figure 4.2, which shows the relationship between the ISMS and the integrated EMS.

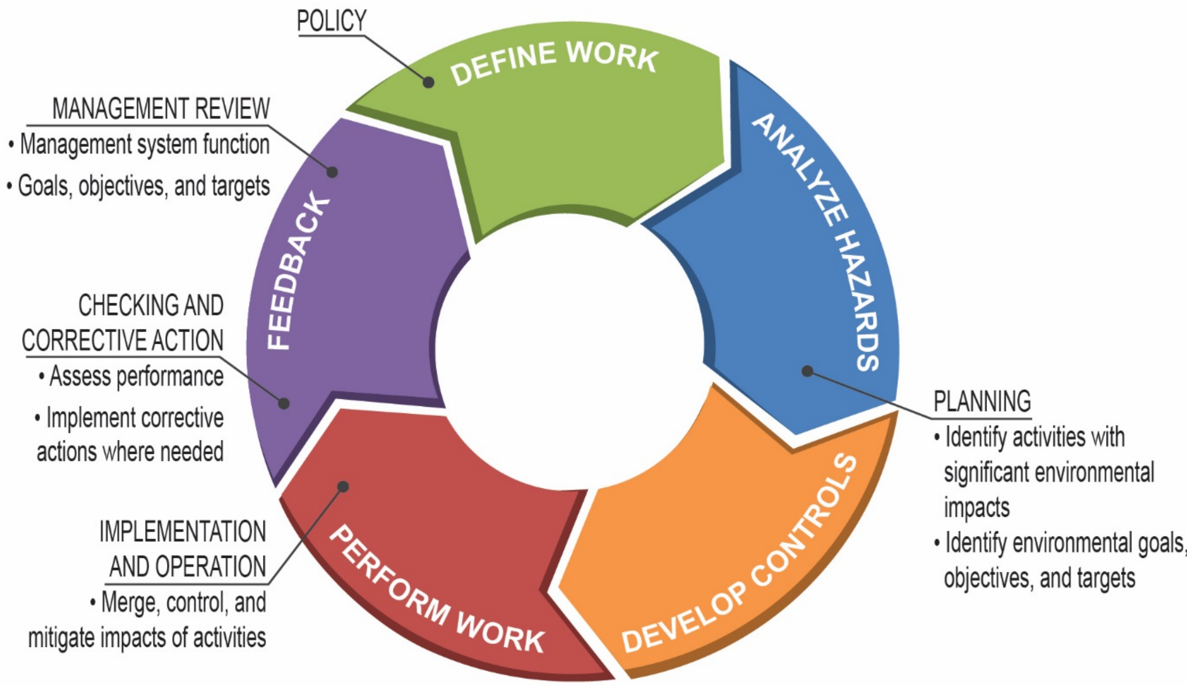


Figure 4.2. Relationship between the Y-12 National Security Complex Environmental Management System and the Integrated Safety Management System depicted in a "plan-do-check-act" cycle

4.2.2 Policy

Y-12's environmental policy and commitment to providing sound environmental stewardship practices through the implementation of an EMS have been defined, are endorsed by top management, and have been made available to the public via company-sponsored forums and public documents such as this one. Y-12's ES&H policy is presented in Figure 4.3.

Y12 Environment, Safety, and Health Policy Statement

As we work to achieve the Y-12 mission and our vision of a modernized Y-12 Complex, we will do so by ensuring the safety and health of every worker, the public, and the environment. Every employee, contractor, and visitor is expected to take personal responsibility for their actions.

- Environmental Policy Statement: We protect the environment, prevent pollution, comply with applicable requirements, and continually improve our environment.
- Safety and Health Policy Statement: The safety and health of our workers and the protection of public health and safety are paramount in all that we do. We maintain a safe work place, and plan and conduct our work to ensure hazard prevention and control methods are in place and effective.

In support of these policies, we are committed to:

- Integrating Environment, Safety and Health into our business processes
- Continuously improving our processes and systems
- Directly, openly, and truthfully communicating this policy and our ES&H performance
- Striving to minimize the impact of our operations on the environment in a safe, compliant, and cost-effective manner using sustainable practices
- Incorporating sustainable design principles into the design and construction of facility upgrades, new facilities, and infrastructure considering life-cycle costs and savings
- Incorporating the use of engineering controls to reduce or eliminate hazards whenever possible into the design and construction of facility upgrades, new facilities, and infrastructure
- Striving to provide a clean and efficient workplace free of occupational injuries and illnesses (Target Zero)
- Fostering and maintaining a work environment of mutual respect and teamwork that encourages free and open expression of ES&H concerns

Figure 4.3. Y-12 National Security Complex's environment, safety, and health policy

In addition to Y-12's ES&H policy, CNS has issued an environmental policy that is a significant component of the CNS ISMS and contributes to sustaining the Pantex and Y-12 imperatives of safe and secure operations. The Y-12 ES&H policy and the CNS environmental policy are communicated to all employees and are incorporated into mandatory training for every employee. The policies are available for viewing on both Y-12's external and internal websites. Y-12 personnel are made aware of the commitments stated in the policies and how the commitments relate to Y-12 work activities.

4.2.3 Planning

4.2.3.1 Y-12 National Security Complex Environmental Aspects

Environmental aspects may be thought of as potential environmental hazards associated with a facility operation, maintenance job, or work activity. The environmental aspects and their impacts (potential effects on the environment) are evaluated to ensure that the significant aspects of Y-12 activities that are identified continue to reflect stakeholder concerns and changes in regulatory requirements. The EMS provides the system to ensure that environmental aspects are systematically identified, monitored, and controlled to mitigate or eliminate potential impacts to the environment.

The analysis identified the following as significant environmental aspects in 2018:

- wastewater
- excess facilities and unneeded materials and chemicals
- surface water
- aging infrastructure and equipment
- legacy contamination and disturbance

4.2.3.2 Legal and Other Requirements

To implement the compliance commitments of the ES&H policy and to meet legal requirements, systems are in place to review changes in federal, state, or local environmental regulations and to communicate those changes to affected staff. The environmental compliance status is documented each year in this report (see Section 4.3).

4.2.3.3 Objectives, Targets, and Environmental Action Plans

CNS responds to change and pursues sustainability initiatives at Y-12 by establishing and maintaining environmental objectives, targets (goals), and action plans. Goals and commitments are established annually considering Y-12’s significant environmental aspects. They are consistent with Y-12’s mission, budget guidance, ES&H work scope, and DOE sustainability goals. Targets and action plans are established for broad objectives to pursue improvement in environmental performance in five areas: clean air; energy efficiency; hazardous materials; stewardship of land and water resources; and waste reduction, recycling, and buying green. Highlights of the 2018 environmental targets achieved at Y-12 are presented in Section 4.2.6.1.

4.2.3.4 Programs

NNSA has developed and funded several important programs to integrate environmental stewardship into all facets of Y-12 missions. The programs also address the requirements in DOE Orders for protecting various environmental media, reducing pollution, conserving resources, and helping to promote compliance with all applicable environmental regulatory requirements and permits.

Environmental Compliance

Y-12’s Environmental Compliance Department (ECD) provides environmental technical support services and oversight for Y-12 line organizations to ensure that site operations are conducted in a manner that is protective of workers, the public, and the environment; in compliance with applicable standards, DOE Os, environmental laws, and regulations; and consistent with CNS environmental policy and Y-12 site procedures. ECD serves as Y-12’s interpretive authority for environmental compliance requirements and as the primary point of contact between Y-12 and external environmental compliance regulatory agencies such as the City of Oak Ridge, the Tennessee Department of Environment and Conservation (TDEC), and EPA. ECD administers compliance programs aligned with the major environmental legislation that affects Y-12 activities. Compliance status and results of monitoring and measurements conducted for these compliance programs are presented in this document.

ECD also maintains and ensures implementation of Y-12’s EMS and spearheads initiatives to proactively address environmental concerns, to continually improve environmental performance, and to exceed compliance requirements.

Waste Management

The Y-12 Waste Management Program supports the full life cycle of all waste streams within Y-12. While ensuring compliance with federal and state regulations, DOE Os, waste acceptance criteria, and Y-12 procedures and policies, the Waste Management Program provides services for day-to-day solid and liquid waste operations, including collection and transport, storage, on-site treatment operations, and shipment to off-site treatment/disposal. The program also provides technical support to Y-12 operations for waste planning, characterizing, packaging, tracking, reporting, and managing waste treatment/disposal subcontracts.

Sustainability and Stewardship

The Sustainability and Stewardship Program has two major missions. The first is to establish and maintain company-wide programs and services to support sustainable material management operations. These sustainable operations include pollution prevention and recycling programs, excess materials programs, the PrYde program, generator services programs, sanitary waste/landfill coordination, and destruction and recycle facility operations. Y-12 has implemented continuous improvement activities, such as an "Items Available for Re-use" section on the Property Accountability Tracking System website and a central telephone number (574-JUNK), to provide employees easy access to information and assistance related to the proper methods for disposing of excess materials.

The second mission is stewardship practices, the programs that manage legacy issues and assist in preventing the development of new problematic issues. Stewardship programs include Clean Sweep, Unneeded Materials and Chemicals (UMC), and Targeted Excess Materials. The Clean Sweep Program provides turnkey services to material generators, including segregation, staging, and pickup of materials for excess, recycle, and disposal. "Sustain" areas have been established across the site to improve housekeeping through efficient material disposition. Customers place unneeded items into the transition portion of each Sustain area and Clean Sweep Program personnel take care of the rest. Additionally, at Y-12, unneeded materials are not automatically assumed to be wastes requiring disposal. Y-12 uses a systematic disposition evaluation process. The first step in the disposition process is to determine if the items can be reused at Y-12. Items that cannot be used at Y-12 are evaluated for use at other DOE facilities or government agencies. Items are then evaluated for potential sale, recycle, or, as a last resort, disposal as waste.

Combining these programs under a single umbrella improves overall compliance with EOs, DOE Os, federal and state regulations, and NNSA expectations and eliminates duplication of efforts while providing an overall improved appearance at Y-12.

Additionally, the implementation of these programs directly supports EMS objectives and targets to disposition UMC, continually improve recycle programs by adding new recycle streams as applicable, improve sustainable acquisition (i.e., promote the purchase of products made with recycled content and bio-based products), meet sustainable design requirements, and adhere to pollution prevention reporting requirements.

Energy Management

The mission of Y-12 Energy Management Program is to incorporate energy-efficient technologies sitewide and to position Y-12 to meet NNSA energy requirement needs. The program identifies improvements in energy efficiency in facilities, coordinates energy-related efforts across the site, and promotes employee awareness of energy conservation programs and opportunities. Y-12 continues to status sustainability goals established under EO 13693, "Planning for Federal Sustainability in the next Decade" until DOE establishes new goals in concurrence with the execution of EO 13834, "Efficient Federal Operations," issued in May 2018.

4.2.4 Implementation and Operation

4.2.4.1 Roles, Responsibility, and Authority

The safe, secure, efficient, and environmentally responsible operation of Y-12 requires the commitment of all personnel. All personnel share the responsibility for successful day-to-day accomplishment of work and the environmentally responsible operation of Y-12.

Environmental and Waste Management technical support personnel assist the line organizations with identifying and carrying out their environmental responsibilities. Additionally, the Environmental Officer Program is in place to facilitate communication of environmental regulatory requirements and to promote EMS as a tool to drive continual environmental improvement at Y-12. Environmental officers coordinate their organizations' efforts to maintain environmental regulatory compliance and to promote other proactive improvement activities.

4.2.4.2 Communication and Community Involvement

Y-12 is committed to keeping the community informed on operations, environmental concerns, safety, and emergency preparedness. The Community Relations Council, composed of more than 20 members from a cross-section of the community, including environmental advocates, neighborhood residents, Y-12 retirees, and business and government leaders, serves to facilitate communication between Y-12 and the community. The council provides feedback to Y-12 regarding its operations and ways to enhance community and public communications. Y 12 sponsored the Great Smoky Mountains National Park and the East Tennessee Foundation, and supported the expansion of a Girls, Inc., program that promotes science, technology, engineering, and mathematics. Additionally, an Introduce a Girl Engineering Event was held at Y-12's New Hope Center on February 22, 2018.

As part of Y-12 Earth Day and America Recycles Day activities, eight local charities received $200 donations from funds raised by Y-12 employee aluminum beverage can recycling efforts. Since the program began in 1994, more than $90,400 raised by the collection of aluminum beverage cans has been donated to various local charities.

Y-12 continues to promote sustainable behaviors for environmental improvements at the site and within the community. As a part of Earth Day activities, LiveWise personnel again collected gently used athletic shoes to support the Modular Organic Regenerative Environments Foundation Group. Personal eye glasses were also collected for donation. A United Way Coat and Toiletries Drive is conducted annually to provide coats and other needed items for the Volunteer Ministry Center for the Homeless. These activities reflect Y-12 employees' commitment to reduce landfill waste and to support community outreach.

4.2.4.3 Emergency Preparedness and Response

Local, state, and federal emergency response organizations are fully involved in Y-12's emergency drill and exercise program. The annual drill and exercise schedule is coordinated with all organizations to ensure maximum possible participation. At a minimum, the Tennessee Emergency Management Agency (TEMA) Operations Office and the DOE Headquarters Watch Office participate in all Y-12 emergency response exercises.

Exercises, performance drills, and training drills were conducted at Y-12 during FY 2018. The drills and exercises focused on topics such as responding to a hazardous chemical release, natural disaster, radiological fire and release, active shooter event, and a criticality event. Building evacuation and accountability drills were also conducted.

4.2.5 Checking

4.2.5.1 Monitoring and Measurement

Y-12 maintains procedures to monitor overall environmental performance and to monitor and measure key characteristics of its operations and activities that can have a significant environmental impact. Environmental effluent and surveillance monitoring programs are well established, and results of 2018 program activities are described throughout this chapter. Progress in achieving environmental goals is reported as a monthly metric on Performance Track, the senior management web portal that consolidates and maintains Y-12 site-level performance. Progress is reviewed in periodic meetings with senior management and the NNSA Production Office (NPO).

4.2.5.2 Environmental Management System Assessments

To periodically verify that EMS is operating as intended, assessments are conducted as part of the Y-12 internal assessment program. The assessments are designed to ensure that nonconformities with ISO 14001 are identified and addressed.

The Environmental Assessment Program comprises several types of assessments, each type serving a distinct but complementary purpose. Assessments range from informal observations of specific activities to rigorous audits of site-level programs.

To self-declare conformance to ISO 14001 in accordance with instructions issued by the Federal Environmental Executive and adhere to DOE O 436.1 (DOE 2011a) requirements, EMS must be audited at least every 3 years by a qualified party outside of the control or scope of EMS. To fulfill this requirement, a four-person audit team from The University of Tennessee Center for Industrial Services evaluated Y-12's EMS during June 2018. The Y-12 EMS was found to fully conform, and no issues were identified. The next external verification audit is scheduled for spring 2021.

4.2.6 Performance

The EMS objectives and targets and other plans, initiatives, and successes that work together to accomplish DOE goals and reduce environmental impacts are discussed in this section. Y-12 used a number of DOE reporting systems, including the following, to report performance:

- The Federal Automotive Statistical Tool, which collects fleet inventory and fuel use.
- The DOE Sustainability Dashboard, which collects data on metering requirements, water use, renewable energy generation and purchases, greenhouse gas (GHG) generation, and sustainable buildings. Pollution prevention waste reduction and recycling data, sustainable acquisition product purchases, electronic stewardship, and best practices data are also collected in this Dashboard system.

The DOE Office of Health, Safety, and Security annual environmental progress reports on implementation of EMS requirements and sustainability goals driven by EOs and the Office of Management and Budget's (OMB's) Environmental Stewardship Scorecard gave Y-12 an EMS scorecard rating for FY 2018 of green, indicating full implementation of EMS requirements.

4.2.6.1 Environmental Management System Objectives and Targets

At the end of FY 2017, Y-12 had achieved 5 of 10 targets that had been established; the remaining targets were carried into future years. Highlights include the following, with additional details and successes presented in other sections of this report:

- Clean Air—Y-12 finalized implementation of a new Title V air operating permit.

- Energy Efficiency—Implementation of five Energy Savings Performance Contract (ESPC) energy conservation measures began in FY 2014 for projects to improve lighting, chilled water, air compressors, and the Y-12 steam system. The five projects were completed in 2017. Significant progress was made on the effort to obtain Leadership in Energy and Environmental Design (LEED) certification on the UPF Construction Support Building. LEED awarded a Silver Certification, with the additional credit points required for obtaining a Gold Certification pending occupancy.
- Hazardous Materials—A project to disposition and ship more than 60 items of legacy mixed waste per Site Treatment Plan milestones was completed in 2018, and UMC FY 2018 priorities were completed to disposition UMCs in the Development High Head Area.
- Land/Water/Natural Resources—Projects to reduce compliance risks associated with aboveground inactive tanks, dikes, and containment areas were completed, which resulted in draining/dispositioning and/or closing more than 25 tanks in FY 2018.
- Reduce/Reuse/Recycle/Buy Green—Y-12 completed a project to improve the Destruction and Recycling Facility and a project to install a drum crusher in one facility to greatly reduce the quantity of empty drum waste.

4.2.6.2 Sustainability and Stewardship

Numerous efforts at Y-12 have reduced its impact on the environment. Efforts include increased use of environmentally friendly products and processes and reductions in waste and emissions. During the past few years, these efforts have been recognized by our customers, our community, and other stakeholders (see Section 4.2.7). Pollution prevention efforts at Y-12 have not only benefited the environment but have also resulted in cost efficiencies (Figure 4.4).

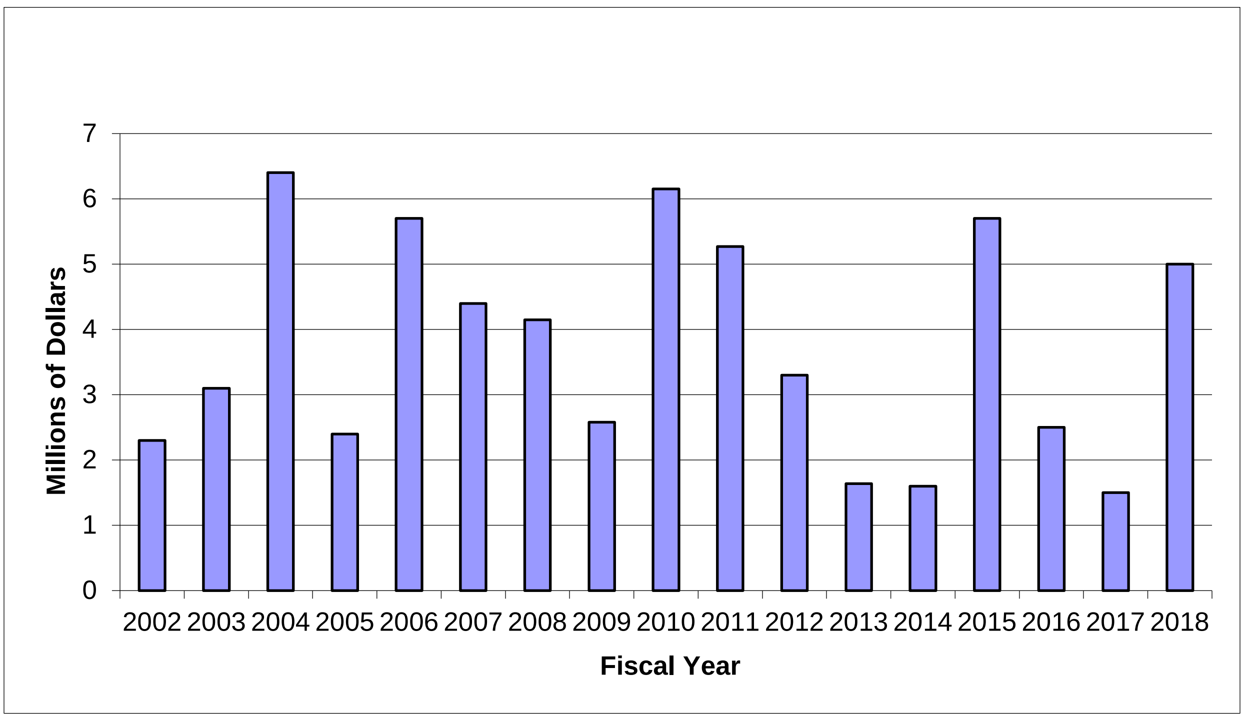


Figure 4.4. Cost efficiencies from Y-12 National Security Complex pollution prevention activities

In FY 2018, Y-12 implemented 96 pollution prevention initiatives (Figure 4.5), with a reduction of more than 62.7 million lb of waste and cost efficiencies of more than $5 million. The completed projects include the activities described below.

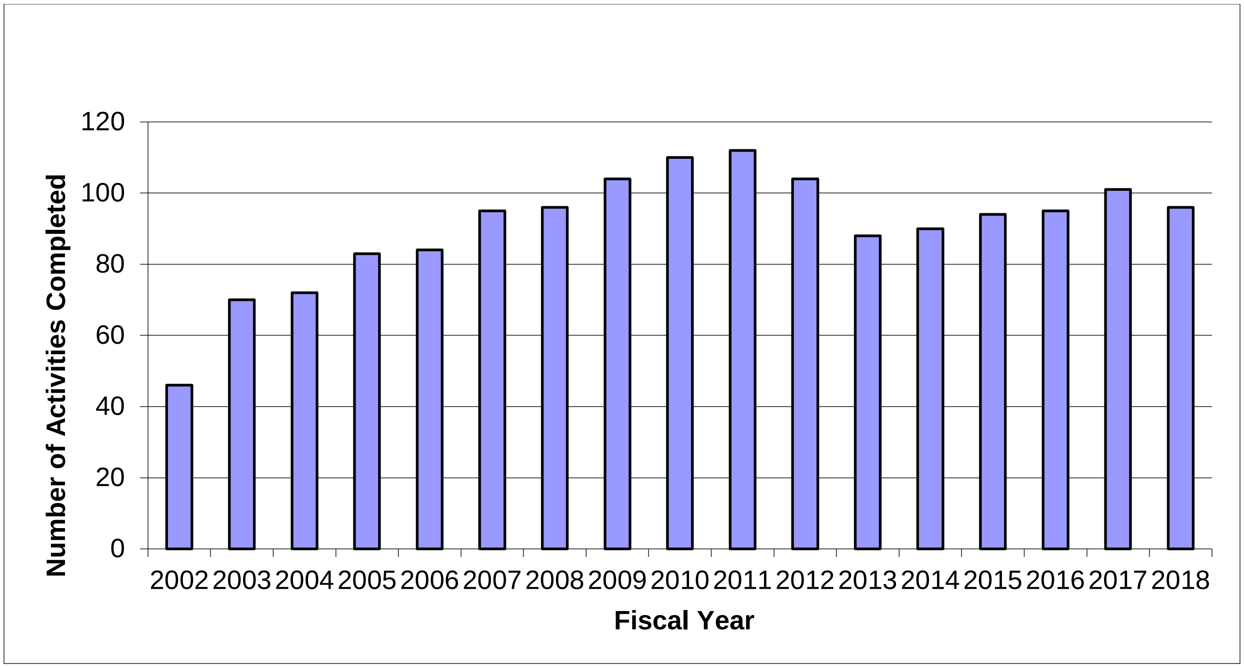


Figure 4.5. Y-12 National Security Complex pollution prevention initiatives

Pollution Prevention/Source Reduction

Sustainable initiatives have been embraced across Y-12 to reduce the impact of pollution on the environment and to increase operational efficiency. Many of Y-12's sustainable initiatives have pollution prevention benefits or targets eliminating the source of pollution, including the 2018 activities highlighted in this section.

Sustainable Acquisition—Environmentally Preferable Purchasing

Sustainable products, including recycled-content materials, are procured for use across Y-12. In 2018, Y-12 procured recycled-content materials valued at more than $14.2 million for use at the site.

Solid Waste Reduction

At Y-12, unneeded materials are not automatically assumed to be wastes requiring disposal. Y-12 uses a systematic disposition evaluation process. The first step in the disposition process is to determine if the items can be reused at Y-12. Items that cannot be reused at Y-12 are evaluated for use at other DOE facilities or government agencies. Items are then evaluated for potential sale; recycle; or, as a last resort, disposal as waste. There is not a waste-to-energy facility for non-hazardous solid municipal or construction and demolition waste in Tennessee.

In 2018, Y-12 diverted 51.6 percent of municipal and 91.5 percent of construction and demolition waste from landfill disposal through reuse and recycle. Y-12 diverted more than 2.3 million lb of municipal materials from landfill disposal through source reduction, reuse, and recycling in FY 2018. More than 60.1 million lb of construction and demolition materials were diverted from landfill disposal in FY 2018.

Hazardous Chemical Minimization

The Generator Services Group provides a material disposition management service for generators at Y-12, which includes the technical support aspect to assist generators with a determination of whether or not the materials can be recycled, excessed, or reused rather than determining that all materials received must be declared as a waste. Generator Services Group can be used by any department or generator at Y-12. During FY 2018, Generator Services Group personnel, rather than declaring materials as waste, reused or disseminated to other Y-12 organizations for reuse, various excess materials and chemicals. In FY 2018, Generator Services Group prevented the generation of more than 3,200 lb of waste by transferring materials for on-site reuse.

Recycling

Y-12 has a well-established recycling program and continues to identify new material streams and expand the types of materials that can be recycled by finding new markets and outlets for the materials. As shown in Figure 4.6, more than 2.78 million lb of materials was diverted from landfills and into viable recycle processes during 2018. Currently, recycled materials range from office-related materials to operations-related materials, such as scrap metal, tires, and batteries. Y-12 adds at least one new recycle stream to the Recycle Program each year to continue to increase the waste diversion rate. The plastics recycling program was expanded in FY 2018 to broaden waste diversion efforts.

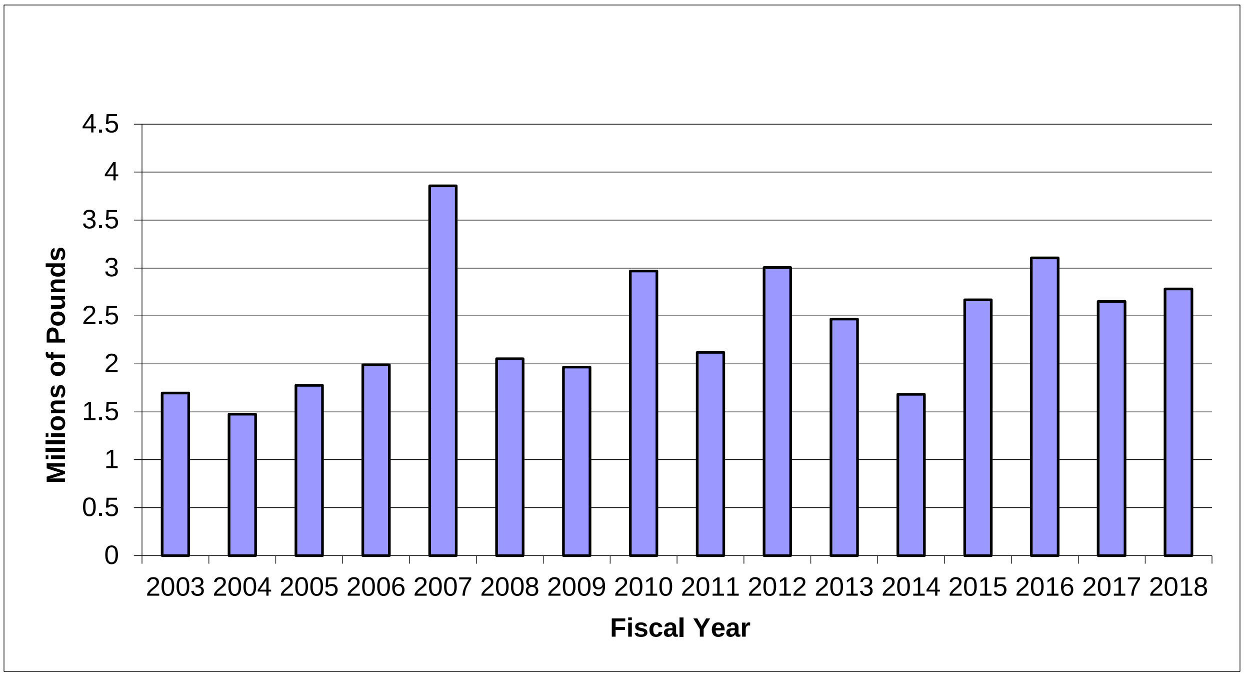


Figure 4.6. Y-12 National Security Complex recycling results

4.2.6.3 Energy Management

The mission of Y-12's Energy Management Program is to incorporate energy-efficient technologies sitewide and to position Y-12 to meet NNSA energy requirement needs. The program identifies improvements in energy efficiency in facilities, coordinates energy-related efforts across the site, and promotes employee awareness of energy conservation programs and opportunities.

EO 13693 established a 25-percent energy intensity reduction goal by 2025 from a FY 2015 baseline. In 2018, Y-12 achieved a 9-percent reduction in energy intensity. Significant reductions have been noted with the implementation of ESPCs at Y-12. Specific ESPC initiatives that aided in the reduction of energy consumption at Y-12 include:

- Completion of a new, more-efficient Air Compressor Plant at the end of FY 2016.

- Continuing to upgrade light fixtures.
- Replacing steam with natural gas.
- Upgrading chillers with new high-efficiency variable speed modes; retrofitting existing chillers with efficient controls; replacing constant-speed chilled water pumps with a variable-speed type; and replacing tower pumps, steam controls, and control valves.
- Replacing Cooling Towers.

Additional energy reductions will be required in numerous areas to fully reduce energy use across the plant. Both facility management and utilities management are focusing on improvements to achieve the goal. Efforts that are incorporated into planning activities for facilities are listed below:

- Energy Independence and Securities Act (EISA) assessments are included in annual reporting.
- Energy conservation measures from both EISA and the ESPC process are included in budgeting reviews.
- Low-cost/no-cost efforts, including component replacements, are incorporated into routine activities. These include upgrades such as new control valves, leak repairs, and new faucets.
- Future reductions may be challenging due to a projected increase in the site's energy intensity. Current projections indicate increases once UPF goes on-line, but they may be partially offset by an accelerated demolition program.

The following efforts are planned to ensure continued site success for energy reduction:

- Consolidating data centers.
- Continuing installation of advanced metering as funding becomes available.
- Continuing facility upgrades for high-performance sustainable building (HPSB) compliance and implement building retro-commissioning.
- Continuing implementation of cool roof applications.
- Encouraging energy reduction through tenant awareness, including training and monthly meter reporting.

Energy Monitoring

Comprehensive water and energy audits at Y-12 are performed to meet EISA Section 432 requirements. The audits evaluate energy and water use and identify opportunities to reduce use. Energy projects are included in out-year planning for the site and, with adequate return on investment, will be funded. Specific examples include HVAC replacements and lighting upgrades in HPSB candidate facilities.

The actual electricity costs for Y-12 are based on total energy consumption, as defined by the Tennessee Valley Authority (TVA) revenue meters in the ELZA 1 substation. Monitoring of the ELZA 1 substation electricity usage is used to ensure accurate billing from TVA and to develop the annual utilities budget.

Efforts to read meters and monitor commodity information have been hindered during FY 2018 by communication issues with the Utilities Management System. Where meter data are available, they are entered into the Portfolio Manager for benchmarking and reporting purposes. At present, 135 facilities have been entered and are being tracked for compliance.

Energy Savings Performance Contracts

Dedicated funding for large-scale energy and water projects is provided via the ESPC mechanism. ESPC Delivery Order 2 is in the seventh period of performance at Y-12. This contract included chiller plant improvements, steam condensate return system modifications, steam trap improvements, and demineralized water production facility replacement. Efforts from Delivery Order 2 have greatly contributed toward both energy reduction and efficiency gains for the projects implemented.

In 2013, NNSA issued an ESPC to Johnson Controls and subsequently added additional scope through Modification 2 in 2014 and Modification 3 in 2015. The task order, Delivery Order 3, and modifications included the following:

- steam system decentralization
- chiller plant upgrades
- energy efficient lighting upgrades
- steam and condensate system improvements
- compressed air system upgrades

4.2.6.4 Dashboard Reporting and the Y-12 National Security Complex Site Sustainability Plan

DOE is required to meet sustainability goals mandated by statute and related EOs, including goals for GHG emissions, energy and water use, fleet optimization, green buildings, and renewable energy. Each year, DOE tracks performance and reports progress towards these goals by providing the annual GHG Inventory, Annual Energy Report, Strategic Sustainability Performance Plan, and related reports to OMB, the White House Council for Environmental Quality, and Congress (EPA 2010). In 2018, the Sustainability Performance Office utilized the web-based DOE Sustainability Dashboard to collect DOE site-level sustainability data and consolidate these data sets on behalf of the Department. CNS has completed required sustainability reporting through the DOE Sustainability Dashboard, the Department's official sustainability reporting tool.

The Sustainability Dashboard focuses on specific sustainability goals, and Site Sustainability Plans are completed within the Dashboard. These goals are based on the prior DOE EO (EO 13693) and are found in Table 4.1, along with the current Y-12 performance ratings.

Table 4.1. FY 2018 sustainability goals and performance

Prior DOE goal	Current performance status
Multiple categories	
50% Scope 1 and 2 GHG emissions reduction by FY 2025 from a FY 2008 baseline	Goal met: Site Scope 1 and 2 GHG emissions have been reduced by 55%. Contributing energy reduction efforts can be attributed to major initiatives involving infrastructure improvements completed through ESPC projects
25% Scope 3 GHG emissions reduction by FY 2025 from a FY 2008 baseline	Goal at risk: Site Scope 3 emissions have decreased by 5.6% (-1,779.5 MtCO2e/31,894.5 MtCO2e). Increasing site population and business travel negatively impact this goal
Energy management	
25% energy intensity (Btu per gross square foot) reduction in goal-subject buildings by FY 2025 from a FY 2015 baseline	Goal on track: Y-12 achieved a 9% energy intensity reduction from the 2015 baseline for FY 2018

Table 4.1. FY 2018 sustainability goals and performance (continued)

Prior DOE goal	Current performance status
EISA Section 432 continuous (4-year cycle) energy and water evaluations	Goal met: Y-12 conducts EISA evaluations on a continuous 4-year cycle
Meter all individual buildings for electricity, natural gas, steam, and water, where cost-effective and appropriate	Goal not met: Y-12 meters all utilities; however, not all appropriate buildings are currently metered
Water management	
36% potable water intensity (gal per gross square foot) reduction by FY 2025 from a FY 2007 baseline	Goal met: A 66% reduction from the 2007 baseline was achieved
30% water consumption (gal) reduction of industrial, landscaping, and agricultural water by FY 2025 from a FY 2010 baseline	Goal not applicable: Y-12 does not use industrial, landscaping, and agricultural water
Waste management	
Divert at least 50% of non-hazardous solid waste, excluding construction and demolition debris	Goal met: 51.6% (1,066.6 metric tons/2,065.6 metric tons) of non-hazardous waste diverted from the landfill
Divert at least 50% of construction and demolition materials and debris	Goal met: 91.5% (27,301.1 metric tons/29,849.8 tons) of construction and demolition materials diverted from the landfill
Fleet management	
20% reduction in annual petroleum consumption by FY 2015 relative to a FY 2005 baseline; maintain 20% reduction thereafter	Goal not met: Alternative fuel (E85) was not available onsite in FY 2018. Y-12 currently operates under an exemption
10% increase in annual alternative fuel consumption by FY 2015 relative to a FY 2005 baseline; maintain 10% increase thereafter	Goal not met: Alternative fuel (E-85) was not available onsite in FY 2018. Y-12 currently operates under an exemption
Clean and renewable energy	
Clean energy requires that the percentage of an agency's total electric and thermal energy accounted for by renewable and alternative energy shall be not less than 25% by FY 2025 and each year thereafter	Goal on track: Y-12 receives RECs from Pantex under the shared contract structure. This allows both sites to meet this goal
Renewable electric energy requires that renewable electric energy account for not less than 30% of a total agency electric consumption by FY 2025 and each year thereafter	Goal on track: Y-12 receives RECs from Pantex under the shared contract structure. This allows both sites to meet this goal
Green buildings	
At least 17% (by building count) of existing buildings greater than 5,000 gross ft^2 to be compliant with the revised Guiding Principles for HPSB by FY 2025, with progress to 100% thereafter	Goal at risk: Y-12 had one DOE-owned building compliant with the HPSB goals, the LEED Gold Construction Support Building for FY 2018
Acquisition and procurement	
Promote sustainable acquisition and procurement to the maximum extent practicable, ensuring bio-preferred and bio-based provisions and clauses are included in 95% of applicable contracts	Goal met: All contracts issued after October 1, 2013, contain the sustainable acquisition clauses

Table 4.1. FY 2018 sustainability goals and performance (continued)

Prior DOE goal	Current performance status
Measures, funding, and training	
Annual targets for performance contracting to be implemented in FY 2017 and annually thereafter as part of the planning of Section 14 of EO 13693	Goal met: Y-12 has supported performance contracts issued by NNSA. These contracts have been instrumental in achieving energy, water, building modernization, and infrastructure goals at Y-12
Electronic stewardship	
Purchases – 95% of eligible acquisitions each year are EPEAT-registered products	Goal met: More than 95% (6,395/6,717) of all eligible electronic acquisitions during FY 2018 were EPEAT-registered. More than 96% (6,456/6,717) were either EPEAT-registered or Energy Star-qualified products and 95.5% (4,901/5,131) of all computers (desktops and laptops), tablets, workstations, monitors, scanners, and printers were either EPEAT Gold- or Silver-registered
Power management – 100% of eligible personal computers, laptops, and monitors have power management enabled	Goal not met: Y-12 has implemented power management to feasible CPUs and laptops; power management features are enabled on all monitors not deemed mission-critical
Automatic duplexing – 100% of eligible computers and imaging equipment have automatic duplexing enabled	Goal not met: During FY 2018, more than 75.4% (4,275/5,670) of the imaging devices were set to automatically duplex. The majority of these devices that are set to non-duplex or are changed to non-duplex are used to support production and other initiatives that require simpler printed materials
End of Life – 100% of used electronics are reused or recycled using environmentally sound disposition options each year	Goal met: All FY 2018 shipments were made to a R2-certified recycler. Electronics that were not recycled were electronics that could not be radiologically cleared for release. Therefore, 100% of eligible electronics were recycled to a R2-certified recycler
Data Center Efficiency – establish a power usage effectiveness target in the range of 1.2-1.4 for new data centers and less than 1.5 for existing data centers	Goal not met: Y-12 data centers are not currently metered, and the current PUE is estimated to be <2.4. During FY 2018, initial steps were made to vacate the 9117 data center allowing refurbishment of the space
Organizational resilience	
Discuss overall integration of climate resilience in emergency response, workforce, and operations procedures and protocols	Goal met: The Y-12 Severe Event Emergency Response Plan addresses severe natural phenomena events, extended loss of power events, and events that result in the loss of mutual aid. The site is monitoring the increased number of events as related to Grand Solar Minimum of Activity

Btu = British thermal unit
CPU = central processing unit
DOE = US Department of Energy
EISA = Energy Independence and Securities Act
EO = Executive Order
EPEAT = Electronic Product Environmental Assessment Tool
ESPC = Energy Savings Performance Contract
FY = fiscal year
GHG = greenhouse gas
HPSB = high-performance sustainable building
LEED = Leadership in Energy and Environmental Design
MtCO2e = metric tons of carbon dioxide equivalent
NNSA = National Nuclear Security Administration
PUE = power usage effectiveness
R2 = reused or recycled
REC = renewable energy credit
Y-12 = Y-12 National Security

4.2.6.5 Water Conservation

In FY 2018, Y-12 achieved a 66 percent water intensity reduction from the baseline, surpassing the 2025 goal of 36 percent. Y-12 is currently meeting the water intensity reduction goals and storm water initiatives. All potable water consumed at Y-12 originates from Melton Hill Lake as raw water and is pumped across the ridge to the City of Oak Ridge water treatment plant, which is located within the Y-12 boundary. Y-12 purchases potable water from the city for all domestic and industrial applications. Actions that have contributed to the overall reduction in potable water use include:

- steam trap repairs and improvements
- condensate return installations, repairs, and reroutes
- replacement of once-through air handling units
- low-flow fixture installation
- chiller replacements
- cooling tower replacements
- replacing steam with natural gas in buildings

Most potable water is not metered at the point of use at Y-12, but an evaluation based on known data, facility usage, and other factors provides an estimated assessment of the usage by type. Cooling towers, production facilities, and maintenance-related activities comprise the largest consumers on the Y-12 site. Through ESPC and utility efficiency improvement initiatives, the site is seeing significant improvement in water consumption. As future projects are implemented, additional savings will be realized.Internal EISA audits are conducted on covered facilities on a 4-year rotating schedule. Additionally, in FY 2016, Pacific Northwest National Laboratory conducted a water assessment of the Y-12 site through the Federal Energy Management Program. These assessments have identified a number of water conservation projects that could be implemented should funding be allocated. These projects include domestic plumbing retrofits, kitchen equipment upgrades, process system upgrades, cooling tower upgrades, and steam plant upgrades. Continued reductions in water usage will be incorporated into ongoing facility repairs and renovations as funding becomes available. These efforts will include the following:

- Upgrading toilets and urinals to low-flow, hands-free units.
- Installing flow restrictors on faucets and shower heads.
- Repairing condenser loop connections so all condenser water is returned to the cooling towers.
- Replacing existing once-through, water-cooled air conditioning systems with air-cooled equivalents.
- Installing advanced potable water meters.

Many of the domestic upgrades are identified in the Balance of Plant Facilities Plan for implementation on a building-by-building basis as funding allows. Similarly, many of the cooling tower upgrades are prioritized in the Utilities Migration Plan and will be evaluated accordingly for implementation as funding permits. Specific goals include the following:

- There are several HVAC units in Building 9201-3 that require once-through cooling water to cool the condenser. These units are old, and the controls do not work properly. These were submitted as a project to the Asset Management Program. Goal one is to replace these units.
- Replacement of very old, underground laterals that go from the water main to buildings. Because these are very old, they are suspected to leak water.
- Replacement of several vacuum pumps in Y-12 that require once-through cooling water.

4.2.6.6 Fleet Management

The Y-12 fleet is comprised of Agency and Government Services Administration (GSA)-owned sedans, light-duty trucks/vans, medium-duty trucks/vans, and heavy-duty trucks. During the last quarter of FY 2015, 240 sedans and light- and medium-duty vehicles from Y-12’s agency-owned fleet were transferred to GSA. Throughout FY 2016, GSA replaced 240 of those vehicles, with 177 of the replacements being alternative fuel (E85) vehicles. Y-12 additionally acquired 31 Flex Fuel vehicles during FY 2017 and completed an assessment of the heavy-duty vehicle inventory. As a result of the assessment, multiple heavy-duty vehicle reassignments were made to better utilize the heavy-duty fleet. This revitalization of the existing fleet has decreased the average age of Y-12's vehicles from 15 years to 2 years of age for light- and medium-duty vehicles. By replacing the older, less fuel efficient vehicles with newer, alternative fuel vehicles, Y-12 will reduce its consumption of petroleum fuels and its GHG emissions and increase its potential capacity for the use of alternative fuels. Y-12 continues to operate a taxi service as one of the strategies for fleet optimization.

Y-12 currently does not utilize alternative fuel and continues to operate under an exception from DOE. The only available on-site fuel station was placed out of service in 2015 after the rupture of an on-site fuel tank. In FY 2018, Y-12 continued to implement an interim refueling process using mobile tanker trucks to perform all vehicle and equipment refueling operations until a new fueling capability can be established. The mobile tanker trucks have only enough capacity to provide diesel and gasoline.

4.2.6.7 Electronic Stewardship

Y-12 has implemented a variety of electronic stewardship activities, including server virtualization, virtual desktop infrastructure, procurement of energy-efficient computing equipment, reuse and recycle of computing equipment, replacement of aging computing equipment with more energy-efficient equipment, and reconfiguration of data centers to achieve more energy-efficient operations. More than 95 percent of desktop computers, laptops, monitors, and thin clients purchased or leased during FY 2018 were registered Electronic Product Environmental Assessment Tool (EPEAT) products. Y-12's standard desktop configuration specifies the procurement of EPEAT-registered and Energy Star-qualified products.

4.2.6.8 Greenhouse Gases

Y-12 reduced Scope 1 and Scope 2 GHG emissions by 55 percent in FY 2018 compared to the FY 2008 baseline, meeting the 50 percent reduction goal for 2025. Emission reduction can be attributed primarily to decreased Scope 1 (on-site fuel burning) emissions from more efficient steam generation and decreased Scope 2 (purchased electricity) emissions from energy efficiency projects.

Purchased electricity is by far the biggest contributor to Y-12's GHG footprint, accounting for nearly 97 percent of Scope 1 and 2 GHG emissions. Energy reduction efforts include major initiatives involving production facilities and utility infrastructure completed through ESPC projects.

4.2.6.9 Storm Water Management and the Energy Independence and Security Act of 2007

EISA Section 438 requires federal agencies to reduce storm water runoff from development and redevelopment projects to protect water resources. Y-12 complies with these requirements using a variety of storm water management practices, often referred to as "green infrastructure" or "low-impact development" practices. During the last few years, several green infrastructure initiatives have been implemented to reduce the size and number of impervious surfaces through the use of sustainable vegetative practices and porous pavements. Actions that have contributed to the overall prevention of storm water runoff during Calendar Year (CY) 2018 include the demolition of Buildings 9111 and 9112. The area was returned to a grass area once the buildings and footings were removed. The two demolitions added about 0.5 acres of green space within Y-12.

4.2.7 Awards and Recognition

Since November 2000, the commitment to environmentally responsible operations at Y-12 has been recognized with more than 146 external environmental awards from local, state, and national agencies. The awards received in 2018 are summarized in the following sections.

4.2.7.1 Electronic Product Environmental Assessment Tool Award

Y-12 received an EPEAT Purchaser 4 Star Level Award for Excellence in Green Procurement of Electronics in a ceremony in Minneapolis, Minnesota, on May 14, 2018. Y-12 was recognized by the Green Electronics Council at the 4 Star Level for purchasing EPEAT electronics in the following categories during Fiscal Year 2017: Personal Computers and Displays, Imaging Equipment (e.g., copiers, scanners, and multi-function devices), Televisions, and Mobile Phones.

4.2.7.2 US Department of Energy and National Nuclear Security Administration Sustainability Awards

Y-12 received the following 2018 DOE Sustainability Awards:

- The Strategic Partnerships for Sustainability Award was presented to the UPF Project Office Site Infrastructure and Services Integrated Project Team for building strategic partnerships for sustainability. The award recognizes the team, and the partnership between the US Army Corps of Engineers Nashville District, UPF Project Office, and CNS, that resulted in the successful on-time and under-budget completion of the LEED Gold certification for the UPF's Construction Support Building (CSB). The innovative CSB design will support the site's sustainability efforts throughout the lifetime of the facility.
- The Sustainability Champion Award was presented to Y-12's Frank McHenry for his role in Y-12's ESPC. The activities completed under these contracts contributed to achieving or surpassing sustainability goals for GHG emissions and water and energy intensities. McHenry successfully coordinated Y-12's managing and operating contractor, CNS, and ESPC contractor personnel.

Both of these activities were also awarded a corresponding NNSA Sustainability Award.

4.3 Compliance Status

4.3.1 Environmental Permits

Table 4.2 lists environmental permits in force at Y-12 during 2018. More-detailed information can be found in the following sections.

4.3.2 National Environmental Policy Act/National Historic Preservation Act

As federal agencies, DOE and NNSA comply with National Environmental Policy Act (NEPA) requirements (procedural provisions, 40 Code of Federal Regulations [CFR] 1500 through 1508), as outlined in DOE's Implementing Procedures for NEPA (Title 10 CFR 1021). CNS fully supports NNSA's commitment to NEPA through evaluating the potential impacts of proposed federal actions that affect the quality of the environment at Y-12. CNS ensures that reasonable alternatives for implementing such actions have been considered in the decision-making process and that such decisions are documented in accordance with DOE/NNSA and the Council on Environmental Quality regulations. Such a prescribed evaluation process ensures that the proper level of environmental review is performed before an irreversible commitment of resources is made.

Table 4.2. Y-12 environmental permits, CY 2018

Regulatory driver	Title/description	Permit number	Issue date	Expiration date	Owner	Operator	Responsible contractor
CAA	Title V Major Source Operating Permit	571832	12/01/2017	11/30/2022	DOE	DOE	CNS
CAA	Permit to Construct or Modify an Air Contaminant Source	974225	09/14/2018	09/13/2020	DOE	DOE	CNS
CWA	Industrial & Commercial User Wastewater Discharge (Sanitary Sewer) Permit	1-91	07/01/2017	03/31/2021	DOE	DOE	CNS
CWA	NPDES Permit	TN0002968	10/31/2011	11/30/2016[a]	DOE	DOE	CNS
CWA	UPF 401 Water Quality Certification/ ARAP Access/Haul Road	NRS10.083	06/10/2010	06/09/2015[c]	DOE	DOE	CNS
CWA	UPF Department of Army Section 404 Clean Water Act Permit	2010-00366	09/02/2010	09/02/2020	DOE	DOE	CNS
CWA	UPF General Storm Water Permit Y-12 (41.7 hectares/103 acres)	TNR 134022	10/27/2011	09/30/2021	DOE	CNS	CNS
CWA	No Discharge Portal 20 Pump and Haul Permit	SOP-170-14	07/08/2017	07/01/2022	DOE	DOE	CNS
CWA	No Discharge Portal 23 Pump and Haul Permit	SOP-170-15	07/08/2017	07/01/2022	DOE	DOE	CNS
CWA	No Discharge Portal 19 Pump and Haul Permit	SOP-130-31	06/26/2018	06/30/2023	DOE	DOE	CNS
CWA	No Discharge EMWMF Pump and Haul Permit	SOP-01043	09/01/2017	09/31/2022	DOE	UCOR	UCOR
RCRA	Hazardous Waste Transporter Permit	TN3890090001	12/17/2018	01/31/2020	DOE	DOE	CNS
RCRA	Hazardous Waste Corrective Action Permit	TNHW-164	09/15/2015	09/15/2025	DOE	DOE, NNSA, and all ORR co-operators of hazardous waste permits	UCOR

Table 4.2. Y-12 environmental permits, CY 2018 (continued)

Regulatory driver	Title/description	Permit number	Issue date	Expiration date	Owner	Operator	Responsible contractor
RCRA	Hazardous Waste Container Storage Units	TNHW-122	08/31/2005	08/31/2015 [a]	DOE	DOE/CNS	CNS/ Navarro co-operator
RCRA	Hazardous Waste Container Storage and Treatment Units	TNHW-127	10/06/2005	10/06/2015 [a]	DOE	DOE/CNS	CNS co-operator
RCRA	RCRA Post-closure Permit for the Chestnut Ridge Hydrogeologic Regime	TNHW-128	09/29/2006 Permit reapplication was denied and the permit closed on 02/23/2018	02/23/2018 [b]	DOE	DOE/UCOR	UCOR
RCRA	RCRA Post-closure Permit for the Bear Creek Hydrogeologic Regime	TNHW-116	12/10/2003 Permit reapplication was denied and the permit closed on 02/23/2018	02/23/2018 [b]	DOE	DOE/UCOR	UCOR
RCRA	RCRA Post-closure Permit for the Upper East Fork Poplar Creek Hydrogeologic Regime	TNHW-113	09/23/2003 Permit reapplication was denied and the permit closed on 02/23/2018	02/23/2018 [b]	DOE	DOE/UCOR	UCOR
Solid Waste	Industrial Landfill IV (operating, Class II)	IDL-01-103-0075	Permitted in 1988—most recent modification approved 12/18/2018	N/A	DOE	DOE/UCOR	UCOR
Solid Waste	Industrial Landfill V (operating, Class II)	IDL-01-103-0083	Initial permit, most recent modification approved 12/18/2018	N/A	DOE	DOE/UCOR	UCOR
Solid Waste	Construction and Demolition Landfill (overfilled, Class IV subject to CERCLA ROD)	DML-01-103-0012	Initial permit 01/15/1986	N/A	DOE	DOE/UCOR	UCOR

Table 4.2. Y-12 environmental permits, CY 2018 (continued)

Regulatory driver	Title/description	Permit number	Issue date	Expiration date	Owner	Operator	Responsible contractor
Solid Waste	Construction and Demolition Landfill VI (post-closure care and maintenance)	DML-01-103-0036	Permit terminated by TDEC 03/15/2007	N/A	DOE	DOE/UCOR	UCOR
Solid Waste	Centralized Industrial Landfill II (post-closure care and maintenance)	IDL-01-103-0189	Most recent modification approved 05/08/1992	N/A	DOE	DOE/UCOR	UCOR
SDWA	Underground Injection Control Class V Injection Well Permit	Permit by Rule TDEC Rule 0400-45-06	03/12/2002	None	DOE	DOE	CNS

[a] Continue to operate in compliance pending TDEC action on renewal and reissuance.

[b] A public notice to deny the renewal of the three post-closure permits and provide post-closure care under CERCLA was published on December 27, 2017, and issued final with an effective date of February 23, 2018.

[c] Monitoring and maintenance phase.

ARAP = Aquatic Resource Alteration Permit
CAA = Clean Air Act
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
CNS = Consolidated Nuclear Security LLC
CWA = Clean Water Act
CY = calendar year
DOE = US Department of Energy
EMWMF = Environmental Management Waste Management Facility
N/A = not applicable
Navarro = Navarro Research and Engineering, Inc.
NNSA = National Nuclear Security Administration
NPDES = National Pollutant Discharge Elimination System
ORR = Oak Ridge Reservation
RCRA = Resource Conservation and Recovery Act
ROD = record of decision
SDWA = Safe Drinking Water Act
TDEC = Tennessee Department of Environment and Conservation
UCOR = URS | CH2M Oak Ridge LLC
UPF = Uranium Processing Facility
Y-12 = Y-12 National Security Complex

The *Final Site-Wide Environmental Impact Statement for the Y-12 National Security Complex* (DOE 2011b) was issued in March 2011. The Site-Wide Environmental Impact Statement (SWEIS) and the Notice of Availability were published on March 4, 2011 (EIS-0387). NNSA issued a Record of Decision (ROD) in July 2011 (EIS-0387 ROD) (DOE 2011c) for the continued operation of Y-12, based on the SWEIS. Since the ROD, NNSA has updated the strategy and design approach for the UPF. NNSA would use a hybrid approach of upgrading existing Y-12 facilities and building multiple UPF facilities, which was consistent with recommendations from a project peer review of the UPF, *Final Report of the Committee to Recommend Alternatives to the Uranium Processing Facility Plan in Meeting the Nation's Enriched Uranium Strategy* (ORNL 2014). The updated UPF strategy was addressed in detail in a Supplement Analysis (SA) for the Final SWEIS (DOE 2016a; EIS-0387-SA-01), and NNSA amended the ROD (DOE 2016b, 81 FR 45138) on July 22, 2017.

In accordance with 10 CFR 1021.330, DOE/NNSA shall evaluate sitewide environmental impact statements (EISs) by means of an SA at least every 5 years. The SA determines if there are substantial changes to the SWEIS, if there are significant new circumstances at the site, or if there is information that is relevant to environmental concerns as discussed in 40 CFR 1502.9(c)(1). The SA determines whether: (1) the SWEIS is sufficient, (2) a supplement EIS is required, or (3) if a new SWEIS document is required. The SA discussed above (EIS-0387-SA-01) addressed UPF's change in strategy and did not address or evaluate the remainder of operations and activities at Y-12 since the 2011 document. Therefore, in 2016, a second SA was initiated to address the continual operations and activities at Y-12. The draft of this document was issued for public comment in June 2018 with over 70 comments received. The existing ROD was not amended, and the final SA (EIS-0387-SA-03) was issued in August 2018 (DOE 2018a).

During 2018, CNS completed environmental evaluations for 50 proposed actions at Y-12, and 47 such actions were categorically excluded, as allowed by Y/TS-2312, *National Environmental Policy Act General Categorical Exclusion, Appendix B to Subpart D of Part 1021* (B&W Y-12 2012a). The majority of the proposed actions involved the sustainment of enduring facilities, bridging strategies for facilities identified with an out-year replacement, and the deactivation and demolition of facilities deemed excess to Y-12's needs. As many facilities have, or are, approaching the end of design life, substantial investment is required to ensure that they remain viable for the near future. The following projects were evaluated for the Extended Life Program (for existing enriched uranium facilities): the Nuclear Facility Electrical Maintenance Project (electrical improvements and transformer upgrades), the Fire Suppression Upgrade Project (wet pipe sprinkler head replacements), high energy computed tomography, design of new chip melt furnaces, new chip dollies, and multiple machining tool and controller equipment upgrades. In addition, the following projects were also evaluated during 2018: (1) the West End Protection Area Reduction (WEPAR) project (including utility re-routes and disconnects); (2) the bridging and sustainment of current lithium production capabilities (equipment and facilities), including the replacement and refurbishment of the humidity control system (Kathabar), upgrades to Wet Chemistry operations, upgrades to Lithium Purification, and upgrades/changes to the Lithium Salvage Reclamation; (3) the replacement of an elevator hydraulic jack for one building; (4) the demolition and deactivation projects for multiple excess facilities (including equipment draining and removal); (5) the design and installation of three new 13-kV transmission lines inside Y-12; (6) the installation and activation of a New Brunswick Laboratory trailer for the Analytical Chemistry Organization; (7) environmental control upgrades (HVAC) to Y-12's computing data center; (8) the assessment and placement of excess stationary tanks into permanently out-of-service status; and (9) the re-surfacing and paving of Y-12 roads, with the creation of new parking lots for the UPF project. The Roof Asset Management Project, along with the planning and design of the Y-12 EOC and the Y-12 Fire Station, continued this year.

During 2018, the following categorically excluded determination forms were approved by NPO and posted on the public website:

- Property Transfer of the Y-12 West End Fuel Station, CX-ORR-18-001
- NEPA 4728, revision 1, Demolition of Building 9720-24
- NEPA 4840, Demolition of Groups #2 and #3 trailers
- NEPA 4834, revision 2, WEPAR Project

An environmental assessment determination (EAD) was sent to NNSA for review and approval for the Lithium Production Capability (LPC; NEPA #4810). NNSA concurred that an environment assessment was required to evaluate an alternative (and potential environmental impacts) for the construction of a replacement facility for the manufacturing and production capability for lithium components. In March 2018, NNSA approved the EAD and renamed the new facility as the Lithium Processing Facility (LPF). A new LPF will provide administrative and manufacturing space for the production of lithium components. The new facility will ensure Y-12 maintains the required lithium production capabilities, reduces the annual operating cost, and increases processing efficiencies—using safer, more-modern, more-agile, and more-responsive processes. The construction footprint is located within the Biology Complex, located on the east end of Y-12. DOE Office of Real Estate Management (OREM) has committed to the demolition of several of the Biology Complex buildings, removing slabs and/or footings, and the remediation of any contaminated soil. DOE OREM will need to gain regulatory concurrence that no further action will be required to address soil contamination (within the defined construction footprint) for NNSA to proceed. The LPF is anticipated to be a non-nuclear, hazardous material facility.

In accordance with the National Historic Preservation Act of 1966, NNSA is committed to identifying, preserving, enhancing, and protecting its cultural resources. The prescribed evaluation process ensures that the proper level of environmental review is performed before an irreversible commitment of resources is made. Compliance activities in 2018 included completing Section 106 reviews of ongoing and new projects, collecting and storing historic artifacts, conducting tours, maintaining the Y-12 History Center, and participating in various outreach projects with local organizations and schools.

Fifty proposed projects were evaluated to determine whether any historic properties eligible for inclusion in the National Register of Historic Places would be adversely impacted. It was determined that none of the 50 projects would have an adverse effect on historic properties eligible for listing in the National Register and that no further Section 106 documentation was required. The Y-12 Oral History Program continues efforts to identify leads to conduct oral interviews and to document the knowledge and experience of those who worked at Y-12 during World War II and the Cold War era. The interviews also provide information on day-to-day operations of Y-12, the use and operation of significant components and machinery, and how technological innovations occurred over time. Some of the information collected from past interviews is available in various media, including DVDs shown in the Y-12 History Center.

The Y-12 History Center, located in The New Hope Center, continues to be a work in progress. The Y-12 History Center features many historical photographs and artifacts, a history library, and a video viewing area. More interactive and video-based exhibits are planned for the future. The Y-12 History Center is open to the public Monday through Thursday from 8:00 a.m. to 5:00 p.m. and on Fridays by special request. A selection of materials, including brochures, books, pamphlets, postcards, and fact sheets, is available free to the public.

Y-12 partnered with the National Park Service during the annual Earth Day events on April 19, 2018. These events were held in Y-12's Jack Case Center cafeteria lobby area. The DOE Earth Day Theme was "Earth Day—There is No Planet B." Information was made available to help individuals take action on behalf of the environment.

Congress passed the National Defense Authorization Act of 2015, which included provisions authorizing a park to be located at three sites: Oak Ridge, Tennessee; Hanford, Washington; and Los Alamos, New Mexico. A foundational document has been completed. This document will establish a baseline for park planning and interpretive activities and provide basic guidance for planning and management decisions. President Obama signed the National Defense Authorization Act into law on December 19, 2014.

On November 10, 2015, the Secretary of the Interior and the Secretary of Energy signed a Memorandum of Agreement between the two agencies defining the respective roles in creating and managing the park. The agreement included provisions for enhanced public access, management, interpretation, and historic preservation. With the signing, the Manhattan Project National Historical Park officially was established.

Outreach activities in 2018 consisted of partnering with the City of Oak Ridge, the Oak Ridge Convention and Visitor's Bureau, and the Arts Council of Oak Ridge, which sponsor the annual Secret City Festival.

In June 2018, the Secret City Festival promoted the history of the Manhattan Project by providing information to visitors regarding the history of Y-12 and directions for them to visit the Y-12 History Center. Y-12 provided visitors with windshield tours of the perimeter of Y-12 and a more in-depth tour inside Building 9731, also known as the "Pilot Plant."

Y-12 also continues to partner with the American Museum of Science and Energy by providing guided public tours of the Y-12 History Center from March through November. Other outreach activities to local and visiting schools, agencies, and organizations included tours and presentations on the rich and significant history of Y-12 and Oak Ridge.

4.3.3 Clean Air Act Compliance Status

Permits issued by the State of Tennessee are the primary vehicle used to convey the clean air requirements that are applicable to Y-12. New projects are governed by construction permits and modifications to the Title V operating air permit, and eventually the requirements are incorporated into the sitewide Title V operating permit. Y-12 is currently governed by Title V Major Source Operating Permit 571832.

The permit requires annual and semiannual reports. More than 2,000 data points are obtained and reported each year. All reporting requirements were met during CY 2018, and there were no permit violations or exceedances during the report period.

Ambient air monitoring, while not specifically required by any permit condition, is conducted at Y-12 to satisfy DOE O 458.1, *Radiation Protection of the Public and the Environment* (DOE 2011e), requirements as a best management practice and/or to provide evidence of sufficient programmatic control of certain emissions. Ambient air monitoring conducted specifically for Y-12 (i.e., mercury monitoring) is supplemented by additional monitoring conducted for ORR and by both on- and off-site monitoring conducted by TDEC.

Section 4.4 provides detailed information on 2018 activities conducted at Y-12 in support of the Clean Air Act (CAA).

4.3.4 Clean Water Act Compliance Status

During 2018, Y-12 continued its excellent record for compliance with the National Pollutant Discharge Elimination System (NPDES) water discharge permit. Data obtained as part of the NPDES program are provided in a monthly report to TDEC. The percentage of compliance with permit discharge limits for 2018 was 100 percent.

Approximately 2,300 data points were obtained from sampling required by the NPDES permit; no non-compliances were reported. Y-12's NPDES permit in effect during 2015 (TN0002968) was issued on October 31, 2011, and became effective on December 1, 2011. A modification was effective in May 2014. It expired on November 30, 2016.

An application for a new permit was prepared and submitted to TDEC in May 2016. The currently expired NPDES permit continues in effect until the new permit is issued by the State of Tennessee.

4.3.5 Safe Drinking Water Act Compliance Status

The City of Oak Ridge supplies potable water to Y-12 and meets all federal, state, and local standards for drinking water. The water treatment plant, located north of Y-12, is operated by the City of Oak Ridge. Y-12 potable water distribution is operated by a State-certified distribution system operator. The distribution system is regulated by TDEC as a public water system, with public water distribution system identification number 0001068.

Tennessee Regulations for Public Water Systems and Drinking Water Quality, Chapter 0400-45-01, sets limits for biological contaminants, chemical activities, and chemical contaminants. Sampling for total coliform, chlorine residuals, lead, copper, and disinfectant byproducts is conducted by Y-12's ECD, with oversite by a State-certified operator.

In 2018, Y-12's potable water system received a sanitary survey score of 100 out of a possible 100 points and, thus, retained its approved status as a public water system in good standing with TDEC. The next sanitary survey is scheduled for 2020. All total coliform samples collected during 2018 were analyzed by the State of Tennessee laboratory, and all results were negative. Analytical results for disinfectant byproducts (total trihalomethanes and haloacetic acids) for Y-12's water distribution system were within allowable TDEC and Safe Drinking Water Act (SDWA) limits for the yearly average. Y-12's potable water system is currently sampled triennially for lead and copper. The system sampling was last completed in 2017. These results were below TDEC and SDWA limits and met the established requirements.

4.3.6 Resource Conservation and Recovery Act Compliance Status

The Resource Conservation and Recovery Act (RCRA) regulates hazardous wastes that, if mismanaged, could present risks to human health or the environment. The regulations are designed to ensure that hazardous wastes are managed from the point of generation to final disposal. In Tennessee, EPA delegates the RCRA program to TDEC, but EPA retains an oversight role. Y-12 is considered a large-quantity generator because it may generate more than 1,000 kg of hazardous waste in a month and because it has RCRA permits to store hazardous wastes for up to 1 year before shipping offsite to licensed treatment and disposal facilities. Y-12 also has a number of satellite accumulation areas and 90-day waste storage areas.

Mixed wastes are materials that are both hazardous (under RCRA guidelines) and radioactive. The Federal Facilities Compliance Act of 1992 requires that DOE work with local regulators to develop a Site Treatment Plan to manage mixed waste. Development of the plan has two purposes: to identify available treatment technologies and disposal facilities (federal or commercial) that can manage mixed waste produced at federal facilities, and to develop a schedule for treating and disposing of the waste streams.

The ORR Site Treatment Plan is updated annually and submitted to TDEC for review. The current plan (TDEC 2017) documents the mixed-waste inventory and describes efforts undertaken to seek new commercial treatment and disposal outlets for various waste streams. NNSA has developed a disposition schedule for the mixed waste in storage and will continue to maintain and update the plan as a reporting mechanism as progress is made. Y-12 has developed disposition milestones to address its remaining inventory of legacy mixed waste. Disposition milestones for the final inventory are FYs from 2016 through 2026 (see Figure 4.7). In FY 2018, Y-12 staff completed disposition of 51 percent of the inventory of legacy mixed waste listed on the ORR Site Treatment Plan.

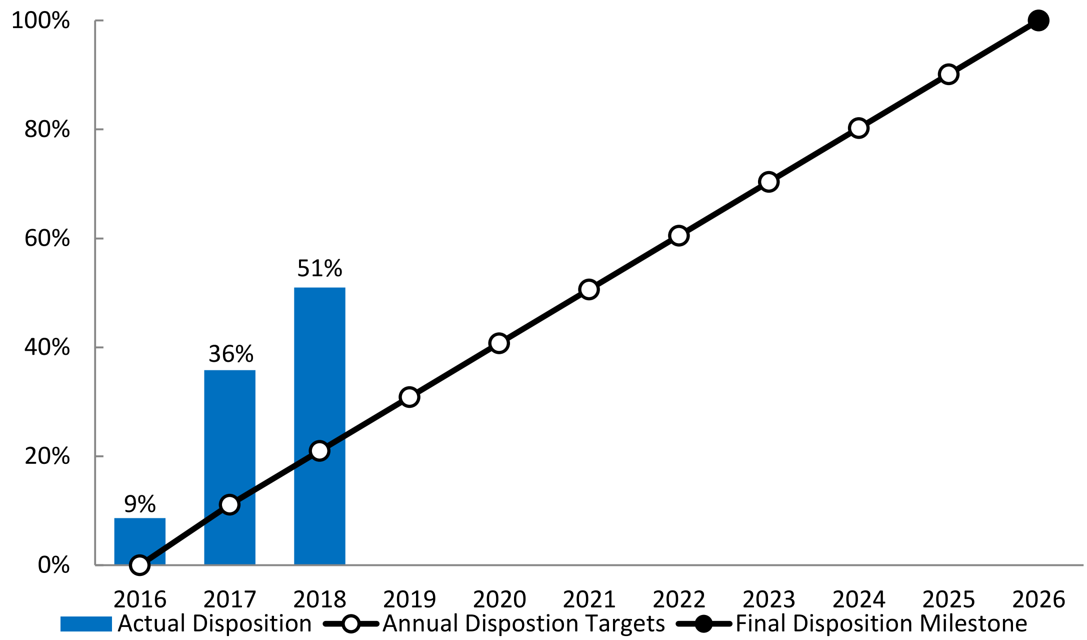


Figure 4.7. Y-12 National Security Complex's path to elimination of its inventory of legacy mixed waste as part of the Oak Ridge Reservation Site Treatment Plan by Fiscal Year

The quantity of hazardous and mixed wastes generated by Y-12 increased in 2018 (Figure 4.8). The increase was primarily due to an increase in remediation activities compared to 2017. Y-12 currently reports waste on 74 active waste streams. Y-12 is a State-permitted treatment, storage, and disposal facility. Under its permits, Y-12 received 1,539 kg of hazardous and mixed waste from the off-site Union Valley analytical chemistry laboratory and ETTP in 2018.

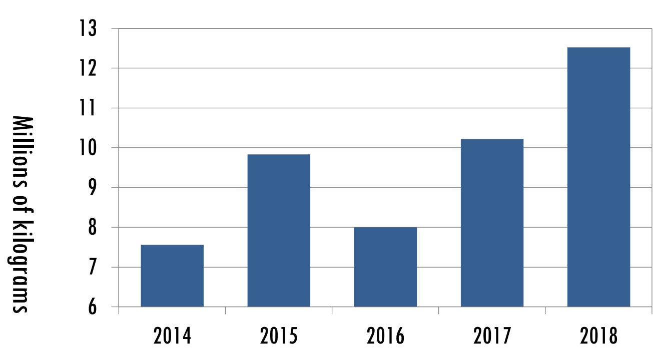


Figure 4.8. Hazardous waste generation, 2014–2018

In addition, 2,033,162 kg of hazardous and mixed waste was shipped to DOE-owned and commercial treatment, storage, and disposal facilities. More than 10 million kg of hazardous and mixed wastewater was treated at on-site wastewater treatment facilities.

4.3.6.1 Resource Conservation and Recovery Act Underground Storage Tanks

TDEC regulates active petroleum underground storage tanks (USTs). Existing UST systems that remain in service must comply with performance requirements described in TDEC UST regulations (TN 0400-18-01).

Closure and removal of the last two petroleum USTs at the East End Fuel Station were completed in August 2012. There are no petroleum USTs remaining at Y-12.

4.3.6.2 Resource Conservation and Recovery Act Subtitle D Solid Waste

The ORR landfills operated by the DOE EM Program are located within the boundary of Y-12. The facilities include two Class II operating industrial solid waste disposal landfills and one operating Class IV construction demolition landfill. The facilities are permitted by TDEC and accept solid waste from DOE operations on ORR. In addition, one Class IV facility (Spoil Area 1) is overfilled by 8,945 m^3 and has been the subject of a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) remedial investigation (RI)/feasibility study. A CERCLA ROD for Spoil Area 1 was signed in 1997 (DOE 1997). One Class II facility (Landfill II) has been closed and is subject to post-closure care and maintenance. Associated TDEC permit numbers are noted in Table 4.2. Additional information about the operation of these landfills is addressed in Section 4.8.4, “Waste Management.”

4.3.7 Resource Conservation and Recovery Act–Comprehensive Environmental Response, Compensation, and Liability Act Coordination

The ORR Federal Facility Agreement (FFA) (DOE 2017) is intended to coordinate the corrective action processes of RCRA required under the Hazardous Waste Corrective Action document (formerly known as the Hazardous and Solid Waste Amendments permit) with CERCLA response actions.

During CY 2015, the renewal of ORR Corrective Action document TNHW-164 was issued for the 10-year period from September 15, 2015, through September 15, 2025. As required in TNHW-164, the annual update of solid waste management units and areas of concern was submitted to TDEC in January 2018 as an update of the previous CY 2017 activities.

Three RCRA post-closure permits, one for each of the three hydrogeologic regimes at Y-12, had been issued to address the eight major closed waste disposal areas at Y-12. Because it falls under the jurisdiction of two post-closure permits, the S-3 Pond site was described as having two parts, eastern and former S-3 (Table 4.3). RCRA groundwater monitoring data were reported to TDEC and EPA in the Annual Groundwater Monitoring Report for Y-12 (UCOR 2018a).

Permit renewal applications had been previously submitted to TDEC, Division of Solid Waste Management for the three RCRA post-closure permits. On December 27, 2017, TDEC issued a Public Notice of their intent to deny the renewal of the three permits. The proposed denial was initiated by DOE’s request to withdraw the permit renewal applications in coordination in advance with TDEC. Pursuant to the ORR FFA, this denial allows DOE to provide post-closure care for the permitted hazardous waste management units under the existing CERCLA remedial program. The public comment period for this notice ended on February 12, 2018, and was issued as a final action with an effective date of February 23, 2018. This CY 2018 ASER concludes the annual reporting actions for the three RCRA post-closure permits and all future reporting will occur through the CERCLA FFA process.

Table 4.3. Y-12 National Security Complex Resource Conservation and Recovery Act post-closure status for former treatment, storage, and disposal units on the Oak Ridge Reservation

Unit	Major components of closure	Major post-closure requirements
	Upper EFPC Hydrogeologic Regime (RCRA Post-closure Permit TNHW-113)	
New Hope Pond	Engineered cap, upper EFPC distribution channel	Cap inspection and maintenance. No current groundwater monitoring requirements in lieu of ongoing CERCLA actions in the eastern portion of Y-12
Eastern S-3 Ponds groundwater plume	None for groundwater plume; see former S-3 Ponds (S-3 Site) for source area closure	Post-closure corrective action monitoring. Inspection and maintenance of monitoring network
	Chestnut Ridge Hydrogeologic Regime (RCRA Post-closure Permit TNHW-128)	
Chestnut Ridge security pits	Engineered cap	Cap inspection and maintenance. Post-closure corrective action monitoring. Inspection and maintenance of monitoring network and survey benchmarks
Kerr Hollow Quarry	Waste removal, access controls	Access controls inspection and maintenance. Post- closure detection monitoring. Inspection and maintenance of monitoring network and survey benchmarks
Chestnut Ridge sediment disposal basin	Engineered cap	Cap inspection and maintenance. Post-closure detection monitoring. Inspection and maintenance of monitoring network and survey benchmarks
East Chestnut Ridge Waste Pile	Engineered cap	Cap inspection and maintenance. Post-closure detection monitoring. Inspection and maintenance of monitoring network, leachate collection sump, and survey benchmarks. Management of leachate
	Chestnut Ridge Hydrogeologic Regime (RCRA Post-closure Permit TNHW-128)	
Former S-3 Ponds (S-3 pond site)	Neutralization and stabilization of wastes, engineered cap, asphalt cover	Cap inspection and maintenance. Post-closure corrective action monitoring. Inspection and maintenance of monitoring network and survey benchmarks
Oil landfarm	Engineered cap	Cap inspection and maintenance. Post-closure corrective action monitoring. Inspection and maintenance of monitoring network and survey benchmarks
Bear Creek Burial Grounds: A-North, A-South, and C-West and the walk-in pits	Engineered cap, seep collection system specific to the burial grounds	Cap inspection and maintenance. Post-closure corrective action monitoring. Inspection and maintenance of monitoring network and survey benchmarks

CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
RCRA = Resource Conservation and Recovery Act
EFPC = East Fork Poplar Creek
Y-12 = Y-12 National Security Complex

4.3.8 Toxic Substances Control Act Compliance Status

The storage, handling, and use of PCBs are regulated under the Toxic Substances Control Act (TSCA). Capacitors manufactured before 1970 that are believed to be oil-filled are handled as though they contain PCBs, even when that cannot be verified from manufacturer records. Certain equipment containing PCBs and PCB waste containers must be inventoried and labeled. The inventory is updated by July 1 of each year and was last submitted on June 7, 2017.

Given the widespread historical uses of PCBs at Y-12 and fissionable material requirements that must be met, an agreement between EPA and DOE was negotiated to assist ORR facilities in becoming compliant with TSCA regulations. This agreement, the ORR PCB Federal Facility Compliance Agreement (FFCA), which became effective in 1996, provides a forum with which to address PCB compliance issues that are truly unique to these facilities. Y-12 operations involving TSCA-regulated materials were conducted in accordance with TSCA regulations and the ORR PCB FFCA.

The removal of legacy PCB waste, some of which had been stored since 1997, in accordance with the terms of the ORR PCB FFCA, was completed in 2011.

4.3.9 Emergency Planning and Community Right-to-Know Act Compliance Status

The Emergency Planning and Community Right-to-Know Act (EPCRA) requires that facilities report inventories (i.e., Tier II report sent to state and local emergency responders) and releases (i.e., toxic release inventory report submitted to state and federal environmental agencies) of certain chemicals that exceed specified thresholds. Y-12 submitted reports for reporting year 2018 in accordance with requirements under EPCRA Sections 302, 303, 311, 312, and 313.

Y-12 had no unplanned release of a hazardous substance that required notification of the regulatory agencies (see Section 4.3.11 for more information). There were no new Section 311 notifications sent to TEMA and local emergency responders in 2018. Inventories, locations, and associated hazards of over-threshold hazardous and extremely hazardous chemicals were submitted to TEMA and local emergency responders in the annual Tier II Report required by Section 312. Data submittal was through the E-Plan web-based reporting system, as requested by TEMA. Some local emergency responders also accepted data through the E-Plan system, but others require that electronic copies of the Tier II Reports be submitted via email. Y-12 reported 40 chemicals that were over Section 312 inventory thresholds in 2018.

Y-12 operations are evaluated annually to determine the applicability for submittal of a toxic release inventory report to TEMA and EPA in accordance with EPCRA Section 313 requirements. The amounts of certain chemicals manufactured, processed, or otherwise used are calculated to identify those that exceed reporting thresholds. After threshold determinations are made, releases and off-site transfers are calculated for each chemical that exceeds a threshold. Submittal of the data to TEMA and EPA is made through the Toxics Release Inventory-Made Easy (abbreviated as TRI-ME) web-based reporting system operated by EPA. Total 2018 reportable toxic releases to air, water, and land and waste transferred off-site for treatment, disposal, and recycling were 54,977 kg (121,203 lb). Table 4.4 lists the reported chemicals for Y-12 for 2017 and 2018 and summarizes releases and off-site waste transfers for those chemicals.

Table 4.4. Emergency Planning and Community Right-to-Know Act Section 313 toxic chemical release and off-site transfer summary for the Y-12 National Security Complex, 2017 and 2018

Chemical	Year	Quantity[a] (lb)[b]
Chromium	2017	5,853
	2018	10,513
Copper	2017	2,809
	2018	4,635
Lead compounds	2017	9,948
	2018	32,472
Manganese	2017	Form A[d]
	2018	5,245

Table 4.4. Emergency Planning and Community Right-to-Know Act Section 313 toxic chemical release and off-site transfer summary for the Y-12 National Security Complex, 2017 and 2018 (continued)

Chemical	Year	Quantity[a] (lb)[b]
Mercury	2017	5,263
	2018	7,466
Methanol	2017	29,207
	2018	49,191
Nickel	2017	7,914
	2018	11,501
Total	2017	60,994
	2018	121,203

[a] Represents total releases to air, land, and water and includes off-site waste transfers. Also includes quantities released to the environment as a result of remedial actions, catastrophic events, or one-time events not associated with production processes.
[b] 1 lb = 0.4536 kg.
[c] Not reported in previous year.
[d] Form A is less than 500 lb released.

4.3.10 Spill Prevention, Control, and Countermeasures

The Clean Water Act, Section 311, regulates the discharge of oils or petroleum products to waters of the United States and requires the development and implementation of spill prevention, control, and countermeasures (SPCC) plans to minimize the potential for oil discharges. The major requirements for SPCC plans are contained in Title 40 CFR Part 112. These regulations require that SPCC plans be reviewed, evaluated, and amended at least once every 5 years or earlier if significant changes occur. The SPCC rule includes requirements for oil spill prevention, preparedness, and response to prevent oil discharges to navigable waters and adjoining shorelines. The rule requires specific facilities to prepare, amend, and implement SPCC plans.

Y-12's SPCC Plan (CNS 2015) was revised in September 2015 to update general Y-12 changing site infrastructure. This plan presents the SPCC to be implemented by Y-12 to prevent spills of oil and hazardous constituents and the countermeasures to be invoked should a spill occur. In general, the first response of an individual discovering a spill is to call the PSS. Spill response materials and equipment are stored near tanks and drum storage areas and other strategic areas of Y-12 to facilitate spill response. All Y-12 personnel and subcontractors are required to have initial spill and emergency response training before they can work on the site.

4.3.11 Unplanned Releases

Y-12 has procedures for notifying off-site authorities for categorized events at Y-12. Off-site notifications are required for specified events according to federal statutes, DOE Orders, and the Tennessee Oversight Agreement. As an example, any observable oil sheen on East Fork Poplar Creek (EFPC) and any release impacting surface water must be reported to the EPA National Response Center in addition to other reporting requirements. Spills of CERCLA reportable quantity limits must be reported to the EPA National Response Center, DOE, TEMA, and the Anderson County Local Emergency Planning Committee.

In addition, Y-12's occurrence reporting program provides timely notification to the DOE community of Y-12 events and site conditions that could adversely affect the public or worker health and safety, the environment, national security, DOE safeguards and security interests, functioning of DOE facilities, or the reputation of DOE.

Y-12 occurrences are categorized and reported through the Occurrence Reporting and Processing System, which provides NNSA and the DOE community with a readily accessible database of information about occurrences at DOE facilities, causes of those occurrences, and corrective actions to prevent recurrence of the events. DOE analyzes aggregate occurrence information for generic implications and operational improvements.

There were no reportable releases to the environment in 2018. During 2018, there were no unplanned radiological air emission releases for Y-12.

4.3.12 Audits and Oversight

A number of federal, state, and local agencies oversee Y-12 activities. In 2018, Y-12 was inspected by federal, state, or local regulators on four occasions. Table 4.5 summarizes the results, and additional details follow.

Table 4.5. Summary of external regulatory audits and reviews, 2018

Date	Reviewer	Subject	Issues
March 6	City of Oak Ridge	Semiannual Industrial Pretreatment Compliance Inspection	0
April 24	TDEC	Sanitary Survey of Non-Community Water System	0
August 28-29	TDEC	Annual RCRA Hazardous Waste Compliance Inspection	1
September 5	City of Oak Ridge	Semiannual Industrial Pretreatment Compliance Inspection	0

RCRA = Resource Conservation and Recovery Act
TDEC = Tennessee Department of Environment and Conservation

As part of the City of Oak Ridge's pretreatment program, City personnel collect samples from the Y-12 monitoring station to conduct compliance monitoring, as required by the pretreatment regulations. City personnel also conduct compliance inspections twice yearly. No issues were identified in 2018.

Personnel from the TDEC Division of Water Resources (DWR) performed an on-site inspection of the distribution system as part of the Sanitary Survey on April 24, 2018. The inspections covered monitoring records, data verification and compliance with requirements. The Y-12 Plant water System earned 421 points out of a possible 421 points and remains in the State's "Approved" category.

Personnel from the TDEC–Knoxville Office conducted a RCRA hazardous waste compliance inspection on August 28-29, 2018. The inspections covered 38 waste storage areas and records reviews. The report identified one finding involving two weekly inspection records that did not include the inspection time, as required.

4.3.13 Radiological Release of Property

Clearance of property from Y-12 is conducted in accordance with approved procedures that comply with DOE O 458.1, *Radiation Protection of the Public and the Environment* (DOE 2011e). Property consists of real property (i.e., land and structures), personal property, and material and equipment (M&E). At Y-12, there are three paths for releasing property to the public based on the potential for radiological contamination:

- Survey and release of property potentially contaminated on the surface (using pre-approved authorized limits for releasing property).

- Evaluation of materials with a potential to be contaminated in volume (volumetric contamination) to ensure that no radioactivity has been added.
- Evaluation using process knowledge (surface and volumetric).

These three release paths are discussed in the following sections. Table 4.6 summarizes some examples of the quantities of property released in 2018. During FY 2018, Y-12 recycled more than 2.78 million lb of materials offsite for reuse, including but not limited to computers, electronic office equipment, used oil, scrap metal, tires, batteries, lamps, and pallets.

Table 4.6. Summary of materials released in 2018

Category	Amount released
Real property (land and structures)	None
Computer equipment recycle	106,023 lb
–Computers, monitors, printers, and mainframes	
Recycling examples	
–Used oils	5,840 gal
–Used tires	8,800 lb
–Scrap metal	1,488,040 lb
–Lead acid batteries	32,557 lb
Public/negotiated sales[a]	
–Brass	8,680 lb
–Miscellaneous furniture	75,262 lb
–Vehicles and miscellaneous equipment	382,246 lb
External transfers[b]	172,250 lb

[a] Sales during Fiscal Year 2018.

[b] Vehicles; miscellaneous equipment; and materials transferred to various federal, state, and local agencies for reuse during Fiscal Year 2018.

4.3.13.1 Property Potentially Contaminated on the Surface

Property that is potentially contaminated on the surface is subject to a complete survey, unless it can be released based on process knowledge or via a survey plan that provides survey instructions along with technical justification (process knowledge) for the survey plan based on the *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM) (NRC 2000) and the *Multi-Agency Radiation Survey and Assessment of Materials and Equipment Manual* (MARSAME) (NRC 2009)[1]. The surface contamination limits used at Y-12 to determine whether M&E are suitable for release to the public are provided in Table 4.7.

Y-12 uses an administrative limit for total activity of 240 dpm/100 cm^2 for radionuclides in Group 3 and 2,400 dpm/100 cm^2 for radionuclides in Group 4 (see Table 4.7). The use of the more-restrictive administrative limits ensures that M&E do not enter into commerce exceeding the definition of contamination for high toxicity alpha emitters and for beta and gamma emitters, respectively, found in 49 CFR 173, "Shippers—General Requirements for Shipments and Packagings."

[1] The *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM) provides guidance on how to demonstrate that a site is in compliance with a radiation dose or risk-based regulation, otherwise known as a release criterion. The *Multi-Agency Radiation Survey and Assessment of Materials and Equipment* annual is a supplement to MARSSIM that provides technical information on approaches for determining proper disposition of materials and equipment.
Source: Vázquez 2011.

Table 4.7. US Department of Energy Order 458.1 pre-approved authorized limits[a,b]

Radionuclide[c]	Average[d,e]	Maximum[d,e]	Removable[f]
Group 1—Transuranics, ^{125}I, ^{129}I, ^{227}Ac, ^{226}Ra, ^{228}Ra, ^{228}Th, ^{230}Th, ^{231}Pa	100	300	20
Group 2—Th-natural, ^{90}Sr, ^{126}I, ^{131}I, ^{133}I, ^{223}Ra, ^{224}Ra, ^{232}U, ^{232}Th	1,000	3,000	200
Group 3—U-Natural, ^{235}U, ^{238}U, associated decay products, alpha emitters	5,000	15,000	1,000
Group 4—Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except ^{90}Sr and others noted above[g]	5,000	15,000	1,000
Tritium (applicable to surface and subsurface)[h]	N/A	N/A	10,000

[a] The values in this table (except for tritium) apply to radioactive material deposited on but not incorporated into the interior or matrix of the property. No generic concentration guidelines have been approved for release of material that has been contaminated in depth, such as activated material or smelted contaminated metals (e.g., radioactivity per unit volume or per unit mass). Authorized limits for residual radioactive material in volume must be approved separately.
[b] As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by counts per minute measured by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.
[c] Where surface contamination by both alpha- and beta-gamma-emitting radionuclides exists, the limits established for alpha- and beta-gamma-emitting radionuclides should apply independently.
[d] Measurements of average contamination should not be averaged over an area of more than 1 m^2. Where scanning surveys are not sufficient to detect levels in the table, static counting must be used to measure surface activity. Representative sampling (static counts on the areas) may be used to demonstrate by analyses of the static counting data. The maximum contamination level applies to an area of not more than 100 cm^2.
[e] The average and maximum dose rates associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 millirad per hour (mrad/h) and 1.0 mrad/h, respectively, at 1 cm.
[f] The amount of removable material per 100 cm^2 of surface area should be determined by wiping an area of that size with dry filter or soft absorbent paper, applying moderate pressure, and measuring the amount of radioactive material on the wiping with an appropriate instrument of known efficiency. When removable contamination of objects on surfaces of less than 100 cm^2 is determined, the activity per unit area should be based on the actual area, and the entire surface should be wiped. It is not necessary to use wiping techniques to measure removable contamination levels if direct scan surveys indicate the total residual surface contamination levels are within the limits for removable contamination.
[g] This category of radionuclides includes mixed fission products, including the ^{90}Sr that is present in them. It does not apply to ^{90}Sr that has been separated from the other fission products or mixtures where the ^{90}Sr has been enriched.
[h] Measurement should be conducted by a standard smear measurement but using a damp swipe or material that will readily absorb tritium, such as polystyrene foam. Property recently exposed or decontaminated should have measurements (smears) at regular time intervals to prevent a buildup of contamination over time. Because tritium typically penetrates material it contacts, the surface guidelines in Group 4 do not apply to tritium. Measurements demonstrating compliance of the removable fraction of tritium on surfaces with this guideline are acceptable to ensure non-removable fractions and residual tritium in mass will not cause exposures that exceed US Department of Energy dose limits and constraints.

N/A = not applicable

4.3.13.2 Property Potentially Contaminated in Volume (Volumetric Contamination)

Materials, such as activated materials smelted-contaminated metals, liquids, and powders, are subject to volumetric contamination (e.g., radioactivity per unit volume or per unit mass) and are treated separately from surface-contaminated objects. No authorized volumetric contamination limits have been approved for material released from Y-12. Materials that are subject to volumetric contamination are evaluated for release by the following three methods:

1. Unopened, Sealed Containers—Material is still in an original commercial manufacturer's sealed, unopened container. A seal can be a visible manufacturer's seal (i.e., lock tabs, heat shrink) or a manufacturer's seal that cannot be seen (e.g., unbroken fluorescent bulbs, sealed capacitors) as long as the container remains unopened once received from the manufacturer.

2. Process Knowledge—If it can be determined that there is no likelihood of contamination being able to enter a system, then this is documented and used to justify release; then the basis for release is documented. Often this is accompanied by confirmatory surveys.
3. Analytical—The material is sampled, and the analytical results are evaluated against measurement-method critical levels or background levels from materials that have not been impacted by Y-12 activities. If the results meet defined criteria, then they are documented and the material is released.

4.3.13.3 Process Knowledge

Process knowledge is used to release property from Y-12 without monitoring or analytical data and to implement a graded approach (less than 100 percent monitoring) for monitoring of some M&E (MARSAME Classes II and III) (NRC 2009). A conservative approach (nearly 100 percent monitoring) is used to release older M&E for which a complete and accurate history is difficult to compile and verify (MARSAME Class I). The process knowledge evaluation processes are described in Y-12 procedures.

The following M&E are released without monitoring based on process knowledge; this does not preclude conducting verification monitoring, for example, before sale:

- All M&E from buildings evaluated and designated as "RAD-Free Zones."
- Pallets generated from administrative buildings.
- Pallets that are returned to shipping during the same delivery trip.
- Lamps from administrative buildings.
- Drinking water filters.
- M&E approved for release by Radiological Engineering Technical Review.
- Portable restrooms used in non-radiological areas.
- Documents, mail, diskettes, compact disks, and other office media; personal M&E; paper, plastic products, water bottles, aluminum beverage cans, and toner cartridges; office trash, house-keeping materials, and associated waste; breakroom, cafeteria, and medical wastes; and medical and bioassay samples generated in non-radiological areas.
- Subcontractor/vendor/privately owned vehicles, tools, and equipment used in non-radiological areas.
- M&E that are administratively released.
- M&E that were delivered to stores in error and that have not been distributed to other Y-12 locations.
- New computer equipment distributed from Building 9103.
- Subcontractor/vendor/privately owned vehicles, tools, and equipment that have not been used in contaminated areas or for excavation activities. Subcontractor/vendor/privately owned vehicles, tools, and equipment that have not been used in contaminated areas or for excavation activities.
- New cardboard.
- Consumer glass containers.

4.4 Air Quality Program

Sections of Y-12's Title V Permit 571832 contain requirements that are generally applicable to most industrial sites. Examples include requirements associated with asbestos controls, control of stratospheric ozone-depleting chemicals, control of fugitive emissions, and general administration of the permit. The Title V permit also contains a section of specific requirements directly applicable to individual sources of air emissions at Y-12. Major requirements in that section include the Radiological National Emission Standards for Hazardous Air Pollutants (Rad-NESHAPs) (40 CFR 61) requirements and the numerous requirements associated with emissions of criteria pollutants and other, non-radiological hazardous air pollutants (HAPs). In addition, a number of sources that are exempt from permitting requirements under State rules but subject to listing on the Title V Permit application are documented and information about them is available upon request from the State of Tennessee.

4.4.1 Construction and Operating Permits

The following Title V permitting actions were submitted and approved in 2018: an administrative permit amendment to remove a redundant recordkeeping requirement from the emergency generators conditions, a significant modification to update UPF changes, declaration of insignificant activity for a new gasoline dispensing facility, a minor permit modification request to remove Stack 44 process equipment, a minor permit modification to add a calciner process, and an operational flexibility request for lithium chloride operations (wet chemistry).A construction air permit application for an electrorefining process operation was also submitted and approved.

Demonstrating compliance with the conditions of air permits is a significant effort at Y-12. Key elements of maintaining compliance are maintenance and operation of control devices, monitoring, record keeping, and reporting. High-efficiency particulate air (HEPA) filters and scrubbers are control devices used at Y-12. HEPA filters are found throughout the complex, and in-place testing of HEPA filters to verify the integrity of the filters is routinely performed. Scrubbers are operated and maintained in accordance with source-specific procedures. Monitoring tasks consist of continuous stack sampling, one-time stack sampling, and monitoring the operation of control devices. Examples of continuous stack sampling are the radiological stack monitoring systems on numerous sources throughout Y-12.

The Y-12 site wide permit requires annual and semiannual reports. One report is the overall Annual ORR Rad-NESHAPs Report, which includes specific information regarding Y-12 radiological emissions; another is an Annual Title V Compliance Certification Report, which indicates compliance status with all conditions of the permit. A third is a Title V Semiannual Report, which covers a 6-month period for some specific emission sources and consists of monitoring and record-keeping requirements for the sources. Another annual report is the Boiler Maximum Available Control Technology Report for the Y-12 Steam Plant, which requires the boilers to be tuned-up on an annual basis. Table 4.8 gives the actual emissions versus allowable emissions for the Y-12 steam plant.

Table 4.8. Actual versus allowable air emissions from the Y-12 National Security Complex steam plant, 2018

	Emissions (tons/year)[a]		
Pollutant	**Actual**	**Allowable**	**Percentage of allowable**
Particulate	3.43	41	8.4
Sulfur dioxide	0.27	39	0.7
Nitrogen oxides[b]	14.27	81	17.6
VOCs[b]	2.39	9.4	25.4
Carbon monoxide[b]	36.57	139	26.3

NOTE: The emissions are based on fuel usage data for January through December 2018. The volatile organic compound (VOC) emissions include VOC hazard air pollutant emissions.

[a] 1 ton = 907.2 kg.

[b] When there is no applicable standard or enforceable permit condition for a pollutant, the allowable emissions are based on the maximum actual emissions calculation, as defined in Tennessee Department of Environment and Conservation Rule 1200-3-26-.02(2)(d)3 (maximum design capacity for 8,760 hr/year). Both actual and allowable emissions were calculated based on the latest US Environmental Protection Agency compilation of air pollutant emission factors (EPA 1995 and 1998).

4.4.1.1 Generally Applicable Permit Requirements

Y-12, like many industrial sites, has a number of generally applicable requirements that require management and control. Asbestos, ozone-depleting substances (ODSs), and fugitive particulate emissions are notable examples.

Control of Asbestos

Y-12 has numerous buildings and equipment that contain asbestos-containing materials (ACMs). The compliance program for management of removal and disposal of ACMs includes demolition and renovation notifications to TDEC and inspections, monitoring, and prescribed work practices for abatement and disposal of asbestos materials. There was no reportable release of asbestos in 2018. There were four notifications of asbestos demolition or renovation, one revision of notification of asbestos demolition or renovation, and one annual estimate for CY 2018. There was one notification revised three times (May 9, April 17, and March 15). The 2018 annual estimates of friable asbestos were also submitted to TDEC on November 8, 2018, for their records. A revised annual estimate of friable asbestos submitted to TDEC on December 11, 2018.

Stratospheric Ozone Protection

As required by the CAA Title VI Amendments of 1990 and in accordance with 40 CFR Part 82, actions have been implemented to comply with the prohibition against intentionally releasing ODSs during maintenance activities performed on refrigeration equipment. During 2017, EPA enacted major revisions to the Stratospheric Ozone rules to include the regulation of non-ODS substitutes as part of 40 CFR 82 Subpart F. These revisions were effective January 1, 2018, for disposal of small appliances and January 1, 2019, for the leak rate provisions for large appliances. An assessment was conducted in 2018 to identify necessary changes to the Stratospheric Ozone Protection compliance program to comply with the requirements of the new rule.

Fugitive Particulate Emissions

As modernization reduction efforts increase at Y-12, the need also increases for good work practices and controls to minimize fugitive dust emissions from construction and demolition activities. Y-12 personnel continue to use a mature project-planning process to review, recommend, and implement appropriate work practices and controls to minimize fugitive dust emissions. Precautions used to prevent particulate matter from becoming airborne include, but are not limited to: (1) use, where possible, of water or chemicals for control of dust in demolition of existing buildings or structures, construction operations, grading of roads, or the clearing of land; (2) application of asphalt, water, or suitable chemicals on dirt roads, material stockpiles, and other surfaces that can create airborne dusts; and (3) installation and use of hoods, fans, and fabric filters to enclose and vent dusty materials.

4.4.1.2 National Emission Standards for Hazardous Air Pollutants for Radionuclides

The release of radiological contaminants, primarily uranium, into the atmosphere at Y-12 occurs almost exclusively as a result of plant production, maintenance, and waste management activities. The major radionuclide emissions contributing to the dose from Y-12 are ^{234}U, ^{235}U, ^{236}U, and ^{238}U, which are emitted as particulates (Figure 4.9). The particle size and solubility class of the emissions are determined based on review of the operations and processes served by the exhaust systems to determine the quantity of uranium handled in the operation or process, the physical form of the uranium, and the nature of the operation or process. The four categories of processes or operations that are considered when calculating the total uranium emissions are:

- Those that exhaust through monitored stacks.
- Unmonitored processes for which calculations are performed per Appendix D of 40 CFR 61.
- Processes or operations exhausting through laboratory hoods, also involving 40 CFR 61 Appendix D calculations.
- Emissions from room ventilation exhausts (calculated using radiological control monitoring data from the work area).

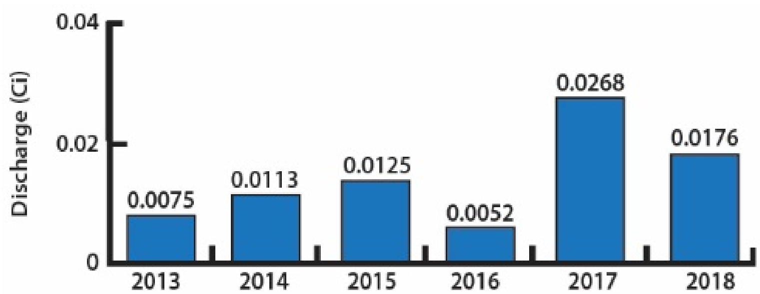


Figure 4.9. Total curies of uranium discharged from the Y-12 National Security Complex to the atmosphere, 2014–2018

Continuous sampling systems are used to monitor emissions from a number of process exhaust stacks at Y-12. In addition, a probe-cleaning program is in place, and the results from the probe cleaning at each source are incorporated into the respective emission point source terms. In 2018, 33 process exhaust stacks were continuously monitored, 25 of which were major sources; the remaining 8 were minor sources. The sampling systems on the stacks have been approved by EPA Region 4.

During 2018, unmonitored uranium emissions at Y-12 occurred from 37 emission points associated with on-site, unmonitored processes and laboratories operated by CNS. Emission estimates for the processes and laboratory stacks were made using inventory data with emission factors provided in 40 CFR Part 61, Appendix D. The Y-12 source term includes an estimate of these emissions.

Y-12's Analytical Chemistry Organization (ACO) operates out of two main laboratories. One is located onsite in Building 9995. The other is located in a leased facility on Union Valley Road, about 0.3 miles east of Y-12, and is not within the ORR boundary. In 2018, there were no radionuclide emission points (or sources) in the off-site laboratory facility.

Additionally, estimates from room ventilation systems are considered using radiological control data on airborne radioactivity concentrations in the work areas. Where applicable, exhausts from any area where the monthly concentration average exceeds 10 percent of the derived air concentration, as defined in the ORR Radionuclide Compliance Plan (DOE 2013), are included in the annual source term. Annual average concentrations and design ventilation rates are used to arrive at the annual emission estimate for those areas. Four emission points from room ventilation exhausts were identified in 2018 where emissions exceeded 10 percent of the derived air concentration. These emission points feed to monitored stacks, and any radionuclide emissions are accounted for as noted for monitored emission points.

Y-12 Title V (Major Source) Operating Permits contain a sitewide, streamlined alternate emission limit for enriched and depleted uranium process emission units. A limit of 907 kg/year of particulate was set for the sources for the purposes of paying fees. The compliance method requires the annual actual mass emission particulate emissions to be generated using the same monitoring methods required for Rad-NESHAPs compliance. An estimated 0.0176 Ci (3.4 kg) of uranium was released into the atmosphere in 2018 as a result of Y-12 process and operational activities.

The calculated radiation dose to the maximally exposed off-site individual from airborne radiological release points at Y-12 during 2018 was 0.15 mrem. This dose is well below the National Emission Standards for Hazardous Air Pollutant (NESHAP) standard of 10 mrem and is less than 0.05 percent of the roughly 300 mrem that the average individual receives from natural sources of radiation. See Chapter 7 for an explanation of how the airborne radionuclide dose was determined.

Lastly, a UPF is presently being designed and constructed. It is intended that this facility house some of the processes that are currently in existing production buildings. The UPF project was issued a Construction Air Permit (No. 967550P) in March 2014. With concurrence from TDEC Air Division, the UPF was included in the 2018 update of Y-12's Site Title V Operating Permit. The facility will be maintained on the Permit as inactive until operations commence in approximately 2025.

4.4.1.3 Quality Assurance

Quality assurance (QA) activities for the Rad-NESHAPs program are documented in the *Y-12 National Security Complex Quality Assurance Project Plan for National Emission Standards for Hazardous Air Pollutants for Radionuclide Emission Measurements* (B&W Y-12 2010). The plan satisfies the QA requirements in 40 CFR Part 61, Method 114, for ensuring that the radionuclide air emission measurements from Y-12 are representative to known levels of precision and accuracy and that administrative controls are in place to ensure prompt response when emission measurements indicate an increase over normal radionuclide emissions. The requirements are also referenced in TDEC Regulation 1200-3-11-.08. The plan ensures the quality of Y-12 radionuclide emission measurements data from the continuous samplers, breakthrough monitors, and minor radionuclide release points. It specifies the procedures for managing activities affecting the quality of data. QA objectives for completeness, sensitivity, accuracy, and precision are discussed. Major programmatic elements addressed in the QA plan are the sampling and monitoring program, emissions characterization, analytical program, and minor source emission estimates.

4.4.1.4 Source-Specific Criteria Pollutants

Proper maintenance and operation of a number of control devices (e.g., HEPA filters and scrubbers) are key to controlling emissions of criteria pollutants. The primary source of criteria pollutants at Y-12 is the steam plant, where only natural gas and Number 2 fuel oil are permitted to be burned. Information regarding actual versus allowable emissions from the steam plant is provided in Table 4.8.

Particulate emissions from point sources result from many operations throughout Y-12. Compliance demonstration is achieved via several activities, including monitoring the operations of control devices, limiting process input materials, and using certified readers to conduct stack-visible emission evaluations.

Use of solvent 140/142 and methanol throughout Y-12 and use of acetonitrile at a single source are primary sources of volatile organic compound (VOC) emissions. Material mass balances and engineering calculations are used to determine annual emissions. The calculated amounts of solvent 140/142 and methanol emitted for CY 2018 are 67.993 lb (0.034 tons) and 49,005 lb (24.50 tons), respectively. The highest calculated amount of acetonitrile and isopropyl alcohol (VOCs) emitted to the atmosphere during any period of 12 consecutive months in CY 2018 was 2.685 tons, which was less than the permitted value of 9 tons/year.

4.4.1.5 Mandatory Reporting of Greenhouse Gas Emissions under 40 Code of Federal Regulations 98

Title 40 of CFR Part 98, *Mandatory Greenhouse Gas Reporting* (EPA 2010), establishes mandatory GHG reporting requirements for owners and operators of certain facilities that directly emit GHGs and for certain fossil fuel suppliers and industrial GHG suppliers. The purpose of the rule is to collect accurate and timely data on GHG emissions that can be used to inform future policy decisions.

The mandatory reporting of GHGs rule requires reporting of annual emissions of carbon dioxide, methane, nitrous oxide, sulfur hexafluoride, hydrofluorocarbons, perfluorochemicals, and other fluorinated gases (e.g., nitrogen trifluoride and hydrofluorinated ethers). These gases are often expressed in metric tons of carbon dioxide equivalent (CO_2e).

Y-12 is subject only to the Subpart A general provisions and reporting from stationary fuel combustion sources covered in 40 CFR 98, Subpart C, *General Stationary Fuel Combustion*. Currently, the rule does not require control of GHGs; rather, it requires only that sources emitting above the 25,000-CO_2e threshold level monitor and report emissions.

The Y-12 steam plant is subjected to this rule. The steam plant consists of four boilers. The maximum heat input capacity of each boiler shall not exceed 99 MM Btu/hr. Natural gas is the primary fuel source for the boilers; Number 2 fuel oil is a backup source of fuel. Other limited, stationary combustion sources are metal-forming operations and production furnaces that use natural gas. In Building 9212, a gas-fired furnace used for drying wet residues and burning solids in a recovery process has a maximum heat input of 700,000 Btu/hr. In Building 9215, 10 natural gas torches, each at 300 standard ft^3/hr, are used to preheat tooling associated with a forging and forming press. In Building 9204-2, natural gas is used to heat two electrolytic cells. The maximum rated heat input to the burners on each cell is 550,000 Btu/hr.

All of the combustion units burning natural gas are served through the fuel supply and distribution system and are reported as combined emissions consistent with the provisions of 40 CFR 98.36(c)(3). The Tier 1 Calculation Method was used to calculate GHGs from Y-12. The amount of natural gas supplied to the site, along with the fuel use logs, provides the basic information for calculation of the GHG emissions.

The emissions report is submitted electronically in a format specified by the EPA administrator. Each report is signed by a designated representative of the owner or operator, certifying under penalty of law that the report has been prepared in accordance with the requirements of the rule. The total amount of GHGs, subject to the mandatory reporting rule, emitted from Y-12 is shown in Table 4.9. The decrease in emissions from 2010 to 2017 is associated with the fact that coal is no longer burned since the natural-gas-fired steam plant came on line. The slight increase in CO_2e emissions was due to the fact that fuel oil was burned for a few days in December 2018.

Table 4.9. Greenhouse gas emissions from Y-12 National Security Complex stationary fuel combustion sources

Year	GHG emissions (metric tons CO_2e)
2010	97,610
2011	70,187
2012	63,177
2013	61,650
2014	58,509
2015	51,706.9
2016	50,671.6
2017	50,292.7
2018	51,010.7

CO_2e = CO_2 equivalent GHG = greenhouse gas

4.4.1.6 Hazardous Air Pollutants (Non-radiological)

Beryllium emissions from machine shops are regulated under a State-issued permit and are subject to a limit of 10 g/24 hr. Compliance is demonstrated through a one-time stack test and through monitoring of control device operations. Hydrogen fluoride is used at one emission source, and emissions are controlled through the use of scrubber systems. The beryllium control devices and the scrubber systems were monitored during 2018 and were found to be operating properly.

Methanol is released as fugitive emissions (e.g., pump and valve leaks) as part of the brine/methanol system. Methanol is subject to State air permit requirements; however, due to the nature of its release (fugitive emissions only), there are no specific emission limits or mandated controls. Mercury is a significant legacy contaminant at Y-12, and cleanup is being addressed under the environmental remediation program. Like methanol emissions, mercury air emissions from legacy sources are fugitive in nature and, therefore, are not subject to specific air emission limits or controls. On-site monitoring of mercury is conducted and is discussed under Section 4.4.2.

In 2007, EPA vacated a proposed Maximum Achievable Control Technology (MACT) standard that was intended to minimize HAP emissions. At that time, a case-by-case MACT review was conducted as part of the construction-permitting process for the Y-12 replacement steam plant. The new natural-gas-fired steam plant came on line on April 20, 2010, and coal is no longer combusted. Specific conditions aimed at minimizing HAP emissions from the new steam plant were incorporated into the operating permit issued on January 9, 2012 (see Section 4.4.1). In addition, the boiler MACT standard was revised and reissued on January 31, 2013. TDEC issued a minor modification to the Title V air permit on October 29, 2014, which included the new boiler MACT requirements. The new requirements (work practice standards) include conducting annual tune-ups and a one-time energy assessment of the boilers to meet these requirements. There are no numeric emission-limit requirements for the steam plant. The new rule requires that a one-time energy assessment for the steam plant must be completed on or after January 1, 2008. The new rule requires that tune-ups for the boilers must be completed 13 months from the previous tune-ups. To comply with that requirement, an energy assessment for the Y-12 steam plant, performed by a qualified energy assessor, was completed in July 2013. The tune-ups for boilers were completed on January 8 and 9, 2019.

Unplanned releases of HAPs are regulated through the Risk Management Planning regulations. Y-12 personnel have determined no processes or facilities contain inventories of chemicals in quantities exceeding thresholds specified in rules pursuant to CAA, Title III, Section112(r), *Prevention of Accidental*

Releases. Therefore, Y-12 is not subject to that rule. Procedures are in place to continually review new processes and/or process changes against the rule thresholds.

EPA has created multiple national air pollution regulations to reduce air emissions from Reciprocating Internal Combustion Engines (RICEs). Two types of federal air standards are applicable to RICEs: (1) new source performance standards (Title 40 CFR Part 60, Subpart IIII), and (2) NESHAPs (EPA 2013; Title 40 CFR Part 63, Subpart DDDDD). The compression ignition engines/generators located at Y-12 are subject to these rules. EPA is concerned about how RICEs are used and the emissions generated from these engines in the form of both HAPs and criteria pollutants.

All previous stationary emergency engines/generators were listed in Y-12's Title V air permit application as "insignificant activities." However, on January 16, 2013, EPA finalized revisions to standards to reduce air pollution from stationary engines that generate electricity and power equipment at sites of major sources of HAPs. Regardless of engine size, the rules apply to any existing, new, or reconstructed stationary RICE located at a major source of HAP emissions.

To comply with the rules, Y-12 prepared a significant permit modification to Y-12's Title V (Major Source) Operating Air Permit to add numerous stationary, emergency-use engines/generators located throughout Y-12. The permit application was submitted to TDEC on May 6, 2013, for review and approval. TDEC downgraded the significant modification to a minor modification per EPA's review and request. In a prior, updated permit application for renewal of Y-12's Title V (Major Source) Operating Air Permit dated March 9, 2011, Y-12 staff identified Title 40 CFR, Part 60, Subpart IIII, and "Standards of Performance for Stationary Compression Ignition Internal Combustion Engines," as requirements applicable to the stationary emergency-use engines located at Y-12. TDEC issued Y-12 a minor permit modification to the Title V air permit on March 3, 2014, for the emergency engines/generators. Compliance for the engines/generators is determined through monthly records of the operation of the engines/generators that are recorded through a non-resettable hour meter on each engine/generator. Documentation must be maintained of how many hours are spent for emergency operation, maintenance checks and readiness testing, and non-emergency operation. Each engine/generator must use only diesel fuel with low sulfur content (15 parts per million) and acetane index of 40.

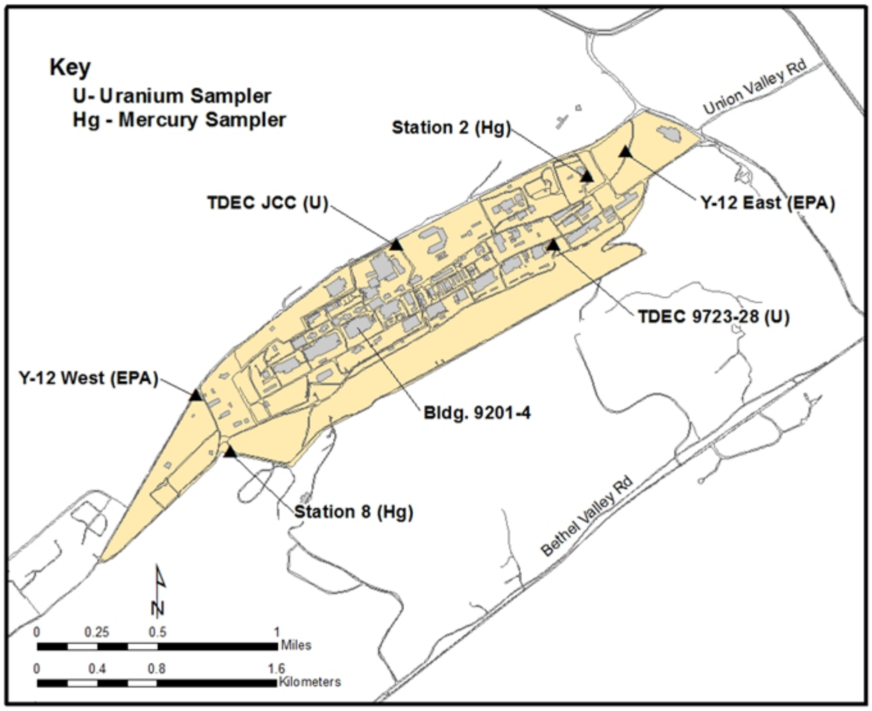
4.4.2 Ambient Air

To understand the complete picture of ambient air monitoring in and around Y-12, data from on- and off-site monitoring conducted specifically for Y-12, DOE reservation-wide monitoring, and on- and off-site monitoring conducted by EPA and TDEC personnel must be considered. No federal regulations, state regulations, or DOE Orders require ambient air monitoring within the Y-12 boundary; however, on-site ambient air monitoring for mercury and radionuclides is conducted as a best management practice. With the reduction of plant operations and improved emission and administrative controls, levels of measured pollutants have decreased significantly during the past several years. In addition, major processes that result in emission of enriched and depleted uranium are equipped with stack samplers that have been reviewed and approved by EPA to meet requirements of the NESHAP regulations.

4.4.2.1 Mercury

Y-12's ambient air monitoring program for mercury was established in 1986 as a best management practice. The objectives of the program have been to maintain a database of mercury concentrations in ambient air, to track long-term spatial and temporal trends in ambient mercury vapor, and to demonstrate protection of the environment and human health from releases of mercury to the atmosphere at Y-12. The two atmospheric mercury monitoring stations currently operating at Y-12, ambient air (monitoring) station (AAS)2 and AAS8, are located near the east and west boundaries of Y-12, respectively

(Figure 4.10). Since their establishment in 1986, AAS2 and AAS8 have monitored mercury in ambient air continuously, with the exception of short intervals of downtime because of electrical or equipment outages. In addition to the monitoring stations located at Y-12, two additional monitoring sites were operated: a reference site (rain gauge 2) was operated on Chestnut Ridge in the Walker Branch Watershed for a 20-month period in 1988 and 1989 to establish a reference concentration, and a site was operated at New Hope Pond for a 25-month period from August 1987 to September 1989.



EPA = US Environmental Protection Agency [sampler] TDEC = Tennessee Department of Environment and Conservation
JCC = Jack Case Center

Figure 4.10. Locations of ambient air monitoring stations at the Y-12 National Security Complex

To determine mercury concentrations in ambient air, airborne mercury vapor is collected by pulling ambient air through a sampling train consisting of a Teflon filter and an iodinated-charcoal sampling trap. A flow-limiting orifice upstream of the sampling trap restricts airflow through the sampling train to approximately 1 L/min. Actual flows are measured bi-weekly with a calibrated Gilmont flowmeter in conjunction with the bi-weekly change-out of the sampling trap. The charcoal in each trap is analyzed for total mercury using cold vapor atomic fluorescence spectrometry after acid digestion. The average concentration of mercury vapor in ambient air for each 14-day sampling period is then calculated by dividing the total mercury per trap by the volume of air pulled through the trap during the corresponding 14-day sampling period.

As reported previously, average mercury concentration at the ambient air monitoring sites has declined significantly since the late 1980s. Recent average annual concentrations at the two boundary stations are comparable to concentrations measured in 1988 and 1989 at the Chestnut Ridge reference site (Table 4.10). Average mercury concentration at the AAS2 site for 2018 is 0.0038 µg/m^3 (N = 25), comparable to averages measured since 2003. After an increase in average concentration at AAS8 for the period 2005 through 2007, thought to be possibly due to increased decontamination and decommissioning work on the west end, the average concentration at AAS8 for 2018 was 0.0049 µg/m^3 (N = 24), similar to levels reported for 2008 and the early 2000s.

Table 4.10. Summary of data for the Y-12 National Security Complex ambient air monitoring program for mercury, Calendar Year 2018

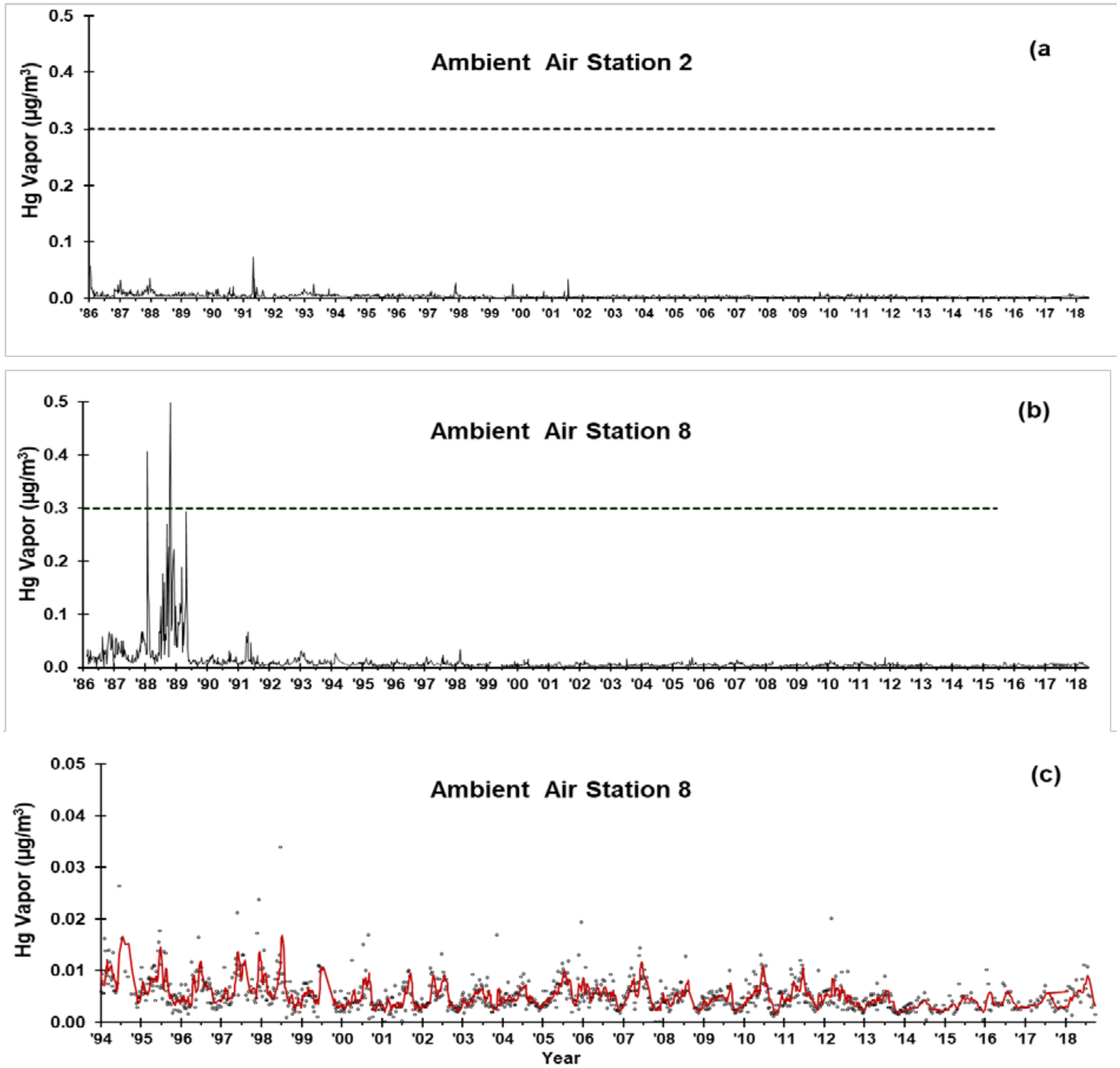
Ambient air monitoring stations	Mercury vapor concentration (µg/m³)			
	2018 Minimum	2018 Maximum	2018 Average	1986–1988[a] Average
AAS2 (east end of Y-12)	0.0019	0.0090	0.0038	0.010
AAS8 (west end of Y-12)	0.0013	0.0110	0.0049	0.033
Reference site, rain gauge 2 (1988[b])	N/A	N/A	N/A	0.006
Reference site, rain gauge 2 (1989[c])	N/A	N/A	N/A	0.005

[a] Period in late 1980s with elevated ambient air mercury levels; shown for comparison.
[b] Data for period from February 9 through December 31, 1988.
[c] Data for period from January 1 through October 31, 1989.

AAS = ambient air (monitoring) station
Y-12 = Y-12 National Security Complex

Table 4.10 summarizes the 2018 mercury results, with results from the 1986 through 1988 period included for comparison. Figure 4.11 illustrates temporal trends in mercury concentration for the two active mercury monitoring sites for the period since the inception of the program in 1986 through 2018 [parts (a) and (b)] and seasonal trends at AAS8 from 1994 through 2018 [part (c)]. The dashed line superimposed on the plots in Figures 4.11(a) and (b) is the EPA reference concentration of 0.3 µg/m^3 for chronic inhalation exposure. The large increase in mercury concentration at AAS8 observed in the late 1980s [part (b)] was thought to be related to disturbances of mercury-contaminated soils and sediments during the Perimeter Intrusion Detection Assessment System installation and storm drain restoration projects under way at that time. In Figure 4.11(c), a monthly moving average has been superimposed over the AAS8 data to highlight seasonal trends in mercury at AAS8 from January 1994 through 2018.

In conclusion, 2018 average mercury concentrations at the two mercury monitoring sites were comparable to reference levels measured for the Chestnut Ridge reference site in 1988 and 1989. More importantly, measured concentrations continue to be well below current environmental and occupational health standards for inhalation exposure to mercury vapor (i.e., the National Institute for Occupational Safety and Health-recommended exposure limit of 50 µg/m^3 time-weighted average [TWA] for up to a 10-hr workday, 40-hr workweek; the American Conference of Governmental Industrial Hygienists workplace threshold limit value of 25 µg/m^3 as a TWA for a normal 8-hr workday and 40-hr workweek; and the current EPA reference concentration of 0.3 µg/m^3 for elemental mercury for a continuous inhalation exposure to the human population without appreciable risk of harmful effects during a lifetime).



The dashed lines superimposed on (a) and (b) represent the US Environmental Protection Agency reference concentration of 0.3 µg/m³ for chronic inhalation exposure. In (c) [note the different concentration scale], a monthly moving average has been superimposed over the data to highlight seasonal trends in mercury at ambient air station 8 from January 1993 to December 2018, with higher concentrations generally measured during the warm weather months.

Figure 4.11. Temporal trends in mercury vapor concentration for the boundary monitoring stations at the Y-12 National Security Complex, July 1986–December 2018 [(a) and (b)] and January 1994–December 2018 for ambient air station 8 [(c)]

4.4.2.2 Quality Control

A number of QA/quality control (QC) steps are taken to ensure the quality of the data for Y-12 mercury in the ambient air monitoring program.

An hour meter records the actual operating hours between sample changes. This allows for correction of total flow in the event of power outages during the weekly sampling interval.

The Gilmont correlated flowmeter, used for measuring flows through the sampling train, is purchased annually or, if not new, shipped back to the manufacturer annually for calibration in accordance with standards set by the National Institute of Standards and Technology (NIST).

A minimum of 5 percent of the samples in each batch submitted to the analytical laboratory are blank samples. The blank sample traps are submitted blind to verify trap blank values and to serve as a field blank for diffusion of mercury vapor into used sample traps during storage before analysis.

To verify the absence of mercury breakthrough, 5 to 10 percent of the field samples have the front (upstream) and back segments of the charcoal sample trap analyzed separately. The absence of mercury above blank values on the back segment confirms the absence of breakthrough.

Chain-of-custody forms track the transfer of sample traps from the field technicians to the analytical laboratory.

A field performance evaluation is conducted annually by the project manager to ensure that proper procedures are followed by the sampling technicians. No issues were identified in the last evaluation conducted on November 29, 2018.

Analytical QA/QC requirements include the following:

- use of prescreened and/or laboratory purified reagents
- analysis of at least two method blanks per batch
- analysis of standard reference materials
- analysis of laboratory duplicates [1 per 10 samples; any laboratory duplicates differing by more than 10 percent at 5 or more times the detection limit are to be rerun (third duplicate) to resolve the discrepancy]
- archiving all primary laboratory records for at least 1 year

4.4.2.3 Ambient Air Monitoring Complementary to the Y-12 National Security Complex Ambient Air Monitoring

Ambient air monitoring is conducted at multiple locations near ORR to measure radiological and other selected parameters directly in the ambient air. These monitors are operated in accordance with DOE Orders. Their locations were selected so that areas of potentially high exposure to the public are monitored continuously for parameters of concern. This monitoring provides direct measurement of airborne concentrations of radionuclides and other HAPs, allows facility personnel to determine the relative level of contaminants at the monitoring locations during an emergency, verifies that the contributions of fugitive and diffuse sources are insignificant, and serves as a check on dose-modeling calculations. As part of the ORR network, an AAS located in the Scarboro Community of Oak Ridge (Station 46) measures off-site impacts of Y-12 operations. This station is located near the theoretical area of maximum public pollutant concentrations, as calculated by air-quality modeling. ORR network stations are also located at the east end of Y-12 (Station 40) and just south of the Country Club Estates neighborhood (Station 37).

In addition to the monitoring described above, the State of Tennessee (TDEC) and EPA perform ambient air monitoring to characterize the region in general and to characterize and monitor DOE operations locally. Specific to Y-12 operations, there are three uranium ambient air monitors within the Y-12 boundary that, since 1999, have been used by TDEC personnel in their environmental monitoring program. Each of the monitors uses 47-mm, borosilicate glass-fiber filters to collect particulates as air is pulled through the units. The monitors control airflow with a pump and rotometer set to average about 2 standard ft^3/min. During 2012, these uranium monitors at Stations 4, 5, and 8 were phased out of service, and two additional high-volume samplers (Figure 4.10) are now being used by TDEC to provide isotopic uranium monitoring capability. These are located on the east side of the Jack Case Center and on the south side of the Building 9723-28 change house. EPA performs ambient air monitoring on the east end of the plant near the intersection of Scarboro Road and Bear Creek Road and on the west end of the plant near the intersection of Bear Creek Road and Old Bear Creek Road.

In addition, TDEC DOE Oversight Division air quality monitoring includes several other types of monitoring on ORR, for example:

- RADNet air monitoring
- fugitive radioactive air emission monitoring
- ambient VOC air monitoring
- perimeter air monitoring
- real-time monitoring of gamma radiation
- ambient gamma radiation monitoring using external dosimetry
- program-specific monitoring associated with infrastructure-reduction activities

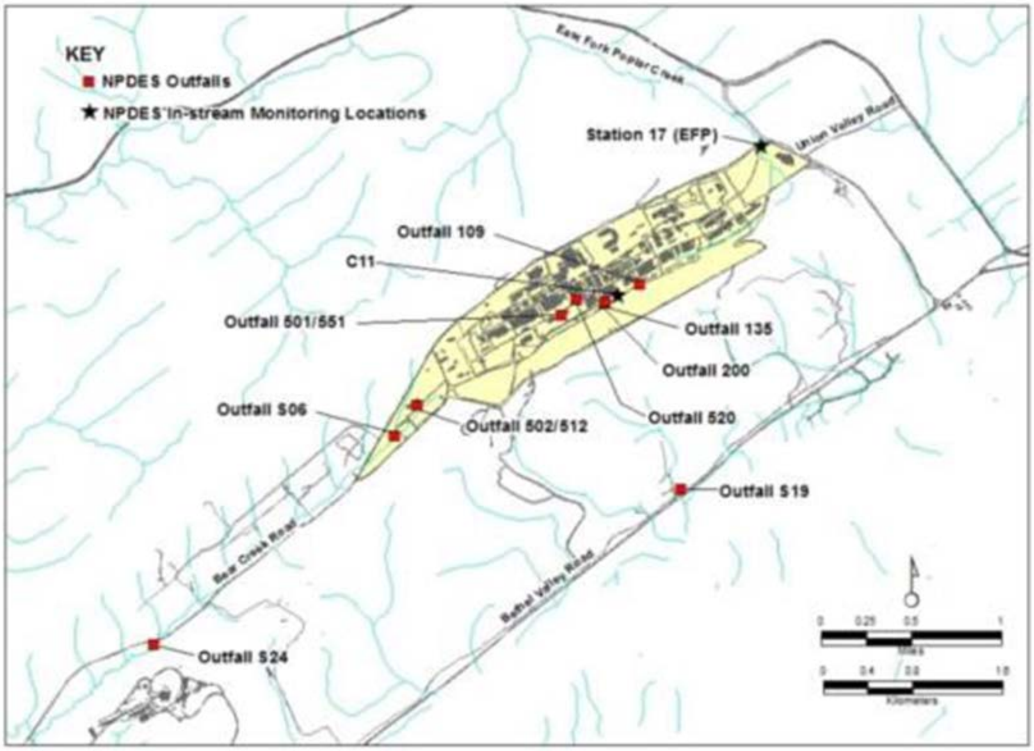
Results of these activities are summarized in annual status reports, which are issued by the TDEC DOE Oversight Division.

The State of Tennessee also operates a number of regional monitors to assess ambient concentrations of criteria pollutants, such as sulfur dioxide, particulate (various forms), and ozone, for comparison against ambient standards. The results are summarized and available through EPA and state reporting mechanisms.

4.5 Water Quality Program

4.5.1 National Pollutant Discharge Elimination System Permit and Compliance Monitoring

The current Y-12 NPDES Permit (TN0002968) requires sampling, analysis, and reporting for about 56 outfalls. Major outfalls are depicted in Figure 4.12. The number is subject to change as outfalls are eliminated or consolidated or if permitted discharges are added. Currently, Y-12 has outfalls and monitoring points in the following water drainage areas: EFPC, Bear Creek, and several tributaries on the south side of Chestnut Ridge, all of which eventually drain to the Clinch River.



EFP = East Fork Poplar

Figure 4.12. Major Y-12 National Security Complex National Pollutant Discharge Elimination System (NPDES) outfalls and monitoring locations

Discharges to surface water allowed under the permit include storm drainage; cooling water; cooling tower blowdown; steam condensate; and treated process wastewaters, including effluents from wastewater treatment facilities. Groundwater inflow into sumps in building basements and infiltration to the storm drain system are also permitted for discharge to the creek. The monitoring data collected by the sampling and analysis of permitted discharges are compared with NPDES limits where applicable for each parameter. Some parameters, defined as “monitor only,” have no specified limits.

The water quality of surface streams in the vicinity of Y-12 is affected by current and legacy operations. Discharges from Y-12 processes flow into EFPC before the water exits Y-12. EFPC eventually flows through the City of Oak Ridge to Poplar Creek and into the Clinch River. Bear Creek water quality is affected by area source runoff and groundwater discharges. The NPDES Permit requires regular monitoring and storm water characterization in Bear Creek and several of its tributaries.

Requirements of the NPDES Permit for 2018 were satisfied and monitoring of outfalls and instream locations indicated excellent compliance. Data obtained as part of the NPDES program, along with other events and observations, are provided in a monthly discharge monitoring report to TDEC. The percentage of compliance with permit discharge limits for 2018 was 99.9 percent (see Table 4.11).

Table 4.11. National Pollutant Discharge Elimination System compliance monitoring requirements and record for the Y-12 National Security Complex, January–December 2018

Discharge point	Effluent parameter	Daily average (lb)	Daily maximum (lb)	Monthly average (mg/L)	Daily maximum (mg/L)	Percentage of compliance	Number of samples
Outfall 501 (Central Pollution Control)	pH, standard units			*a*	9.0	*b*	0
	Total suspended solids			31.0	40.0	*b*	0
	Total toxic organic				2.13	*b*	0
	Hexane extractables			10	15	*b*	0
	Cadmium	0.16	0.4	0.07	0.15	*b*	0
	Chromium	1.0	1.7	0.5	1.0	*b*	0
	Copper	1.2	2.0	0.5	1.0	*b*	0
	Lead	0.26	0.4	0.1	0.2	*b*	0
	Nickel	1.4	2.4	2.38	3.98	*b*	0
	Nitrate/Nitrite				100	*b*	0
	Silver	0.14	0.26	0.05	0.05	*b*	0
	Zinc	0.9	1.6	1.48	2.0	*b*	0
	Cyanide	0.4	0.72	0.65	1.2	*b*	0
	PCB				0.001	*b*	0
Outfall 502 (West End Treatment Facility)	pH, standard units			*a*	9.0	*b*	0
	Total suspended solids		31		40	*b*	0
	Total toxic organic				2.13	*b*	0
	Hexane extractables			10	15	*b*	0
	Cadmium		0.4		0.15	*b*	0
	Chromium		1.7		1.0	*b*	0
	Copper		2.0		1.0	*b*	0
	Lead		0.4		0.2	*b*	0
	Nickel		2.4		3.98	*b*	0
	Nitrate/Nitrite				100	*b*	0
	Silver		0.26		0.05	*b*	0
	Zinc		0.9		1.48	*b*	0
	Cyanide		0.72		1.20	*b*	0
	PCB				0.001	*b*	0
Outfall 512 (Groundwater Treatment Facility)	pH, standard units			*a*	9.0	100	13
	PCB				0.001	100	2
Outfall 520	pH, standard units			*a*	9.0	*b*	0
Outfall 200 (North/South pipes)	pH, standard units			*a*	9.0	100	53
	Hexane extractables			10	15	100	15
	Cadmium			0.001	0.023	100	13
	IC_{25} *Ceriodaphnia*			37% Minimum		0	2
	IC_{25} *Pimephales*			37% Minimum		100	2
	Total residual chlorine			0.024	0.042	100	12
Outfall 551	pH, standard units			*a*	9.0	100	52
	Mercury			0.002	0.004	100	52

Table 4.11. National Pollutant Discharge Elimination System compliance monitoring requirements and record for the Y-12 National Security Complex, January–December 2018 (continued)

Discharge point	Effluent parameter	Daily average (lb)	Daily maximum (lb)	Monthly average (mg/L)	Daily maximum (mg/L)	Percentage of compliance	Number of samples
Outfall C11	pH, standard units			*a*	9.0	100	14
Outfall 135	pH, standard units			*a*	9.0	100	12
	IC_{25} *Ceriodaphnia*			9% Minimum		100	1
	IC_{25} *Pimephales*			9% Minimum		100	1
Outfall 109	pH, standard units			*a*	9.0	100	5
	Total residual chlorine			0.010	0.017	100	4
Outfall S19	pH, standard units			*a*	9.0	100	1
Outfall S06	pH, standard units			*a*	9.0	100	2
Outfall S24	pH, standard units			*a*	9.0	100	1
Outfall EFP	pH, standard units			*a*	9.0	100	12
Category I outfalls	pH, standard units			*a*	9.0	100	34
Category II outfalls	pH, standard units			*a*	9.0	100	17
	Total residual chlorine				0.5	100	16
Category III outfalls	pH, standard units			*a*	9.0	100	7
	Total residual chlorine			*a*	0.5	100	6

[a] Not applicable.
[b] No discharge.

IC_{25} = 25% inhibition concentration
PCB = polychlorinated biphenyl

4.5.2 Radiological Monitoring Plan and Results

A radiological monitoring plan is in place at Y-12 to address compliance with DOE Orders and NPDES Permit TN0002968. The permit requires Y-12 to submit results from the radiological monitoring plan quarterly as an addendum to the NPDES Discharge Monitoring Report. There were no discharge limits set by the NPDES permit for radionuclides; the requirement is to monitor and report. The radiological monitoring plan was developed based on an analysis of operational history, expected chemical and physical relationships, and historical monitoring results. Under the existing plan, effluent monitoring is conducted at three types of locations: (1) treatment facilities, (2) other point-source and area-source discharges, and (3) instream locations. Operational history and past monitoring results provide a basis for parameters routinely monitored under the plan (Table 4.12). The current Radiological Monitoring Plan for Y-12 (B&W Y-12 2012b) was last revised and reissued in January 2012.

Table 4.12. Radiological parameters monitored at the Y-12 National Security Complex, 2018

Parameters	Specific isotopes	Rationale for monitoring
Uranium isotopes	^{238}U, ^{235}U, ^{234}U, total U, weight % ^{235}U	These parameters reflect the major activity, uranium processing, throughout the history of Y-12 and are the dominant detectable radiological parameters in surface water
Fission and activation products	^{90}Sr, ^{99}Tc, ^{137}Cs	These parameters reflect a minor activity at Y-12, processing recycled uranium from reactor fuel elements from the early 1960s to the late 1980s, and will continue to be monitored as tracers for beta and gamma radionuclides, although their concentrations in surface water are low
Transuranium isotopes	^{241}Am, ^{237}Np, ^{238}Pu, $^{239/240}Pu$	These parameters are related to recycle uranium processing. Monitoring has continued because of their half-lives and presence in groundwater
Other isotopes of interest	^{232}Th, ^{230}Th, ^{228}Th, ^{226}Ra, ^{228}Ra	These parameters reflect historical thorium processing and natural radionuclides necessary to characterize background radioisotopes

Y-12 = Y-12 National Security Complex

Radiological monitoring during storm water events is accomplished as part of the storm water monitoring program. Uranium is monitored at three major EFPC storm water outfalls, two instream monitoring locations, and an outfall on Bear Creek. In addition, the monthly 7-day composite sample for radiological parameters taken at Station 17 on EFPC likely includes rain events.

Radiological monitoring plan locations sampled in 2018 are noted on Figure 4.13. Table 4.13 identifies the monitored locations, the frequency of monitoring, and the sum of the percentages of the derived concentration standards (DCS) for radionuclides measured in 2018. Radiological data were well below the allowable DCS.

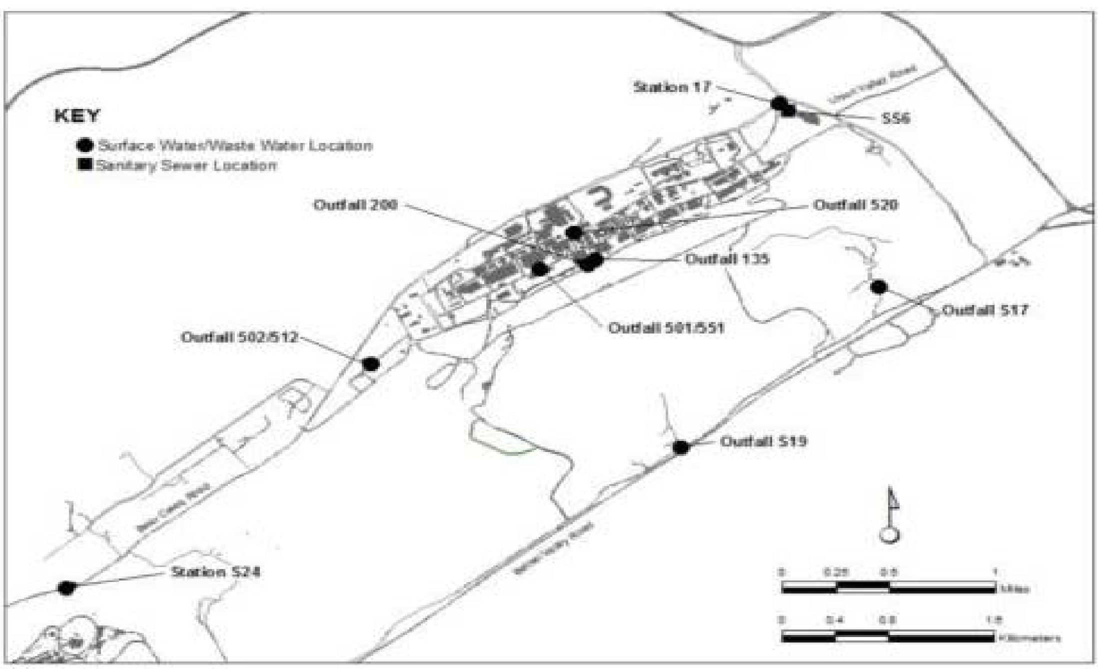


Figure 4.13. Surface water and sanitary sewer radiological sampling locations at the Y-12 National Security Complex

Table 4.13. Summary of Y-12 National Security Complex radiological monitoring plan sample requirements and 2018 results

Location	Sample frequency	Sample type	Sum of DCS percentages
	Y-12 wastewater treatment facilities		
Central Pollution Control Facility	1/batch	Composite during batch operation	No flow
West End Treatment Facility	1/batch	24-hr composite	No flow
Groundwater Treatment Facility	4/year	24-hr composite	1.8
Steam condensate	1/year	Grab	No flow
Central Mercury Treatment Facility	4/year	24-hr composite	0.7
	Other Y-12 point- and area-source discharges		
Outfall 135	4/year	24-hr composite	0.77
Kerr Hollow Quarry	1/year	24-hr composite	4.5
Rogers Quarry	1/year	24-hr composite	0.54
	Y-12 instream locations		
Outfall S24	1/year	7-day composite	7.4
East Fork Poplar Creek, complex exit (east)	1/month	7-day composite	1.7
North/south pipes	1/month	24-hr composite	4.1
	Y-12 Sanitary Sewer		
East End Sanitary Sewer Monitoring Station	1/year	7-day composite	35

DCS = derived concentration standard
Y-12 = Y-12 National Security Complex

In 2018, the total mass of uranium and associated curies released from Y-12 at the easternmost monitoring station, Station 17 on upper EFPC, was 205 kg or 0.084 Ci (Table 4.14).

Table 4.14. Release of uranium from the Y-12 National Security Complex to the off-site environment as a liquid effluent, 2011–2018

Year	Quantity released	
	Ci[a]	kg
	Station 17	
2013	0.055	140
2014	0.061	90
2015	0.068	116
2016	0.045	88
2017	0.080	154
2018	0.084	205

[a] 1 Ci = 3.7E+10 Bq.

Figure 4.14 illustrates a 5-year trend of these releases. The total release is calculated by multiplying the average concentration (g/L) by the average flow (million gallons per day [mgd]). Converting units and multiplying by 365 days per year yields the calculated discharge.

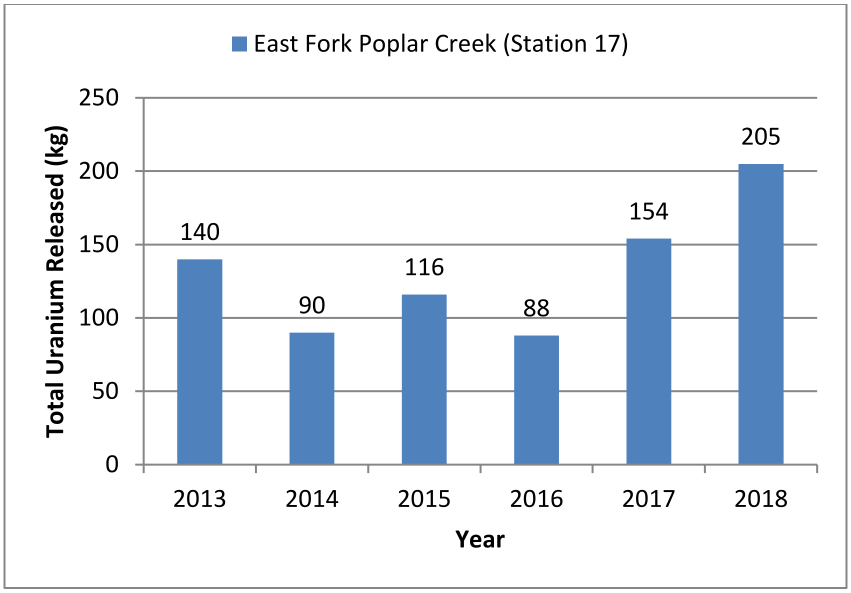


Figure 4.14. Six-year trend of Y-12 National Security Complex releases of uranium to East Fork Poplar Creek

Y-12 is permitted to discharge domestic wastewater to the City of Oak Ridge's publicly owned treatment works. Radiological monitoring of the sanitary sewer system discharge is conducted and reported to the City of Oak Ridge, although there are no City-established radiological limits. Alpha and beta levels are measured weekly, and subsequent uranium analyses are performed if the alpha or beta levels are above prescribed levels. Potential sources of radionuclides discharging to the sanitary sewer have been identified in previous studies at Y-12 as part of an initiative to meet goals to keep levels as low as reasonably achievable. Results of radiological monitoring were reported to the City of Oak Ridge in 2018 quarterly monitoring reports.

4.5.3 Storm Water Pollution Prevention

The Storm Water Pollution Prevention Plan (SWPPP) at Y-12 is designed to minimize the discharge of pollutants in storm water runoff. The plan identifies areas that can reasonably be expected to contribute contaminants to surface water bodies via storm water runoff and describes the development and implementation of storm water management controls to reduce or eliminate the discharge of such pollutants. This plan requires characterization of storm water by sampling during storm events, implementation of measures to reduce storm water pollution, facility inspections, and employee training.

Y-12's SWPPP underwent a significant rewrite in September 2012 in response to issuance of a modified NPDES permit in November 2011. Significant changes included the elimination of two instream monitoring locations (C05 and C08) and the removal of the requirement to perform instream base-load sediment sampling. Other requirements remained essentially the same, with the exception of the lowering of a few benchmark values for certain sector outfalls. The NPDES permit defines the primary function of Y-12 to be a fabricated metal products industry. However, it also requires that storm water monitoring be conducted for three additional sectors: scrap/waste recycling activities; landfill and land application activities; and discharges associated with treatment, storage, and disposal facilities as they are defined in the Tennessee Storm Water Multi Sector General Permit for Industrial Activities (TNR050000). Each sector has prescribed benchmark values, and some have defined sector mean values. The "rationale" portion of the NPDES permit for Y-12 states "These benchmark values were developed by the EPA and the State of Tennessee and are based on data submitted by similar industries for the development of the multi-sector general storm water permit. The benchmark concentrations are target values and should not be construed to represent permit limits."

Storm water sampling was conducted in 2018 during rain events that occurred on March 29, August 1, and September 10. Results were published in the *Annual Storm Water Report* (CNS 2018), which was submitted to TDEC, Division of Water Pollution Control in January 2019. Consistent with permit requirements, storm water monitoring is performed each year for sector outfalls, three major outfalls that drain large areas of Y-12, and two instream monitoring locations on EFPC (Figure 4.15).

The permit no longer calls for sampling of stream base-load sediment that is being transported as a result of the heavy flow.

A significant change from 2013 to 2014 was the elimination of flow augmentation in EFPC. This discharge of raw water into EFPC was discontinued on April 30, 2014; thus, raw water is no longer required to be sampled. The discontinuation of flow augmentation has reduced the flow in EFPC by a significant amount (about 3.3 mgd, or about 60 percent).

An area of concern continues to be the concentration of mercury being measured in the discharge from Outfall 014. Since the first unexpected elevated result in 2013 (7.12 µg/L), this sector outfall has been on an annual monitoring schedule; however, it was not monitored in 2018 due to the degraded condition of the outfall piping and the inability to gather reliable flow rate data. Data collected to date are presented in Table 4.15.

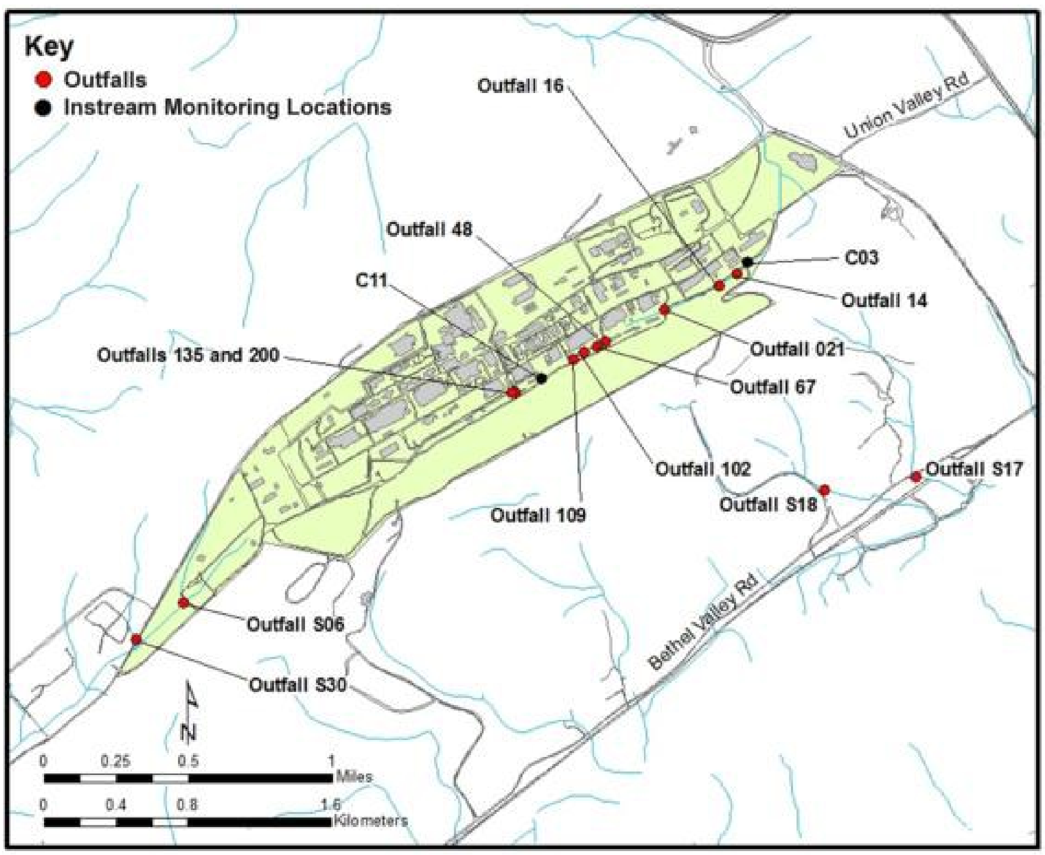


Figure 4.15. Y-12 National Security Complex storm water monitoring locations, East Fork Poplar Creek

Table 4.15. Mercury concentrations at Outfall 014

Calendar year	2013	2014	2015	2016	2017	2018
Mercury concentration (µg/L)	7.12	0.892	9.11	0.49	0.237	N/A

N/A = not available

Sampling conducted in 2018 revealed unusually high concentrations of *Escherichia coli* in the two instream locations and two of the major outfalls. The reason for the elevated concentrations is unknown at this time. Additional sampling and analysis for this contaminant will occur in 2019.

4.5.4 Y-12 National Security Complex Ambient Surface Water Quality

To monitor key indicators of water quality, a network of real-time monitors located at three instream locations along upper EFPC is used. The Surface Water Hydrological Information Support System (SWHISS) is available for real-time water quality measurements, such as pH, temperature, dissolved oxygen, conductivity, and chlorine. The locations are shown in Figure 4.16. The primary function of SWHISS is to indicate potential adverse conditions that could be causing an impact on the quality of water in upper EFPC. It is operated as a best management practice.

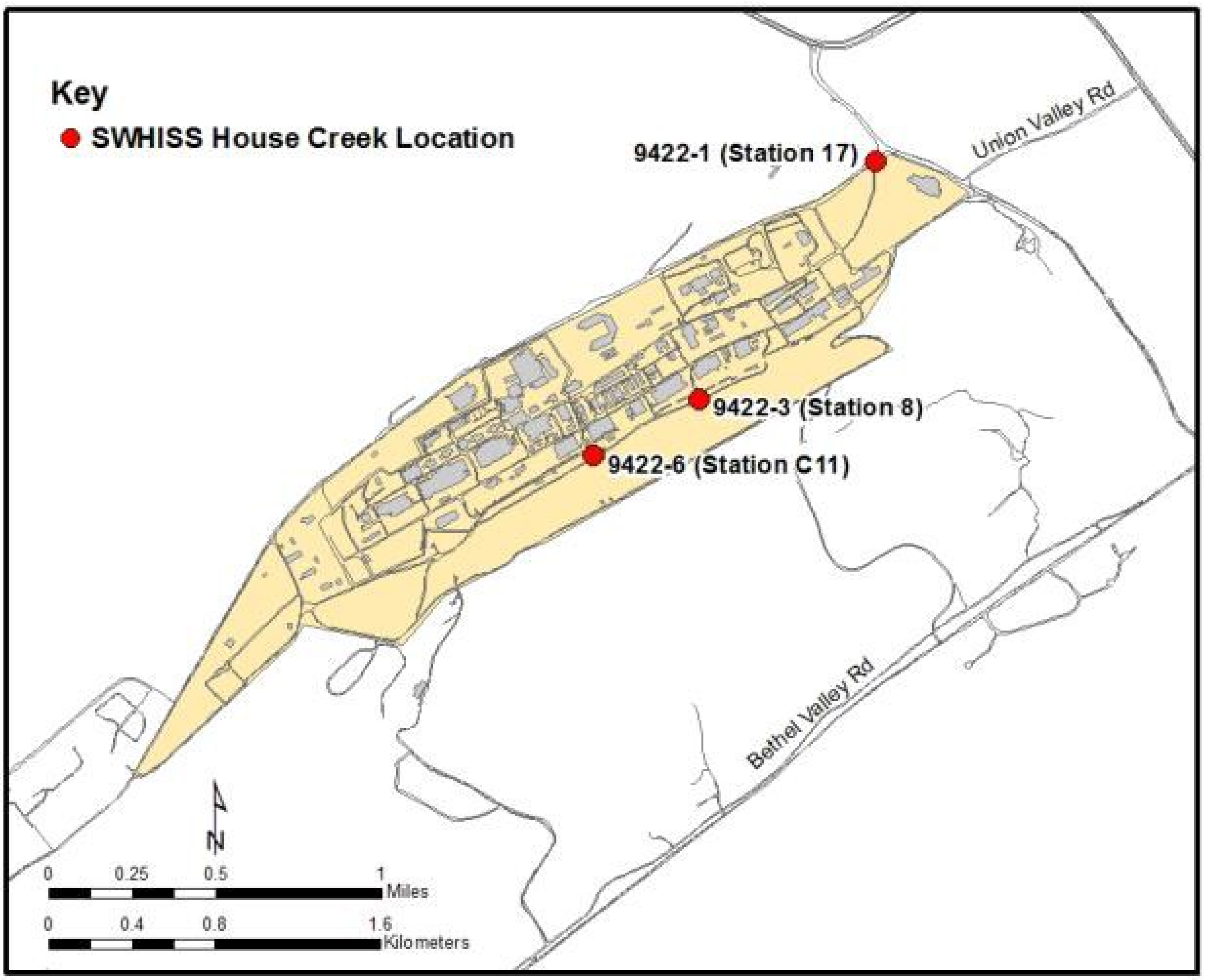


Figure 4.16. Surface Water Hydrological Information Support System monitoring locations

Additional sampling of springs and tributaries is conducted in accordance with Y-12's Groundwater Protection Program (GWPP) to monitor trends throughout the three hydrogeologic regimes (see Section 4.6).

4.5.5 Industrial Wastewater Discharge Permit

Industrial and Commercial User Wastewater Discharge Permit 1-91 defines requirements for the discharge of wastewaters to the sanitary sewer system as well as prohibitions for certain types of wastewaters. It prescribes requirements for monitoring certain parameters at the East End Sanitary Sewer Monitoring Station. The permit sets limits for most parameters. Samples for gross alpha, gross beta and uranium are taken in a weekly 24-hr composite sample. The sample is analyzed for uranium if the alpha and beta values exceed certain levels. Other parameters (including metals, oil and grease, solids, and biological oxygen demand) are monitored on a monthly basis. Organic parameters are monitored once per quarter. Results of compliance sampling are reported quarterly. Flow is measured continuously at the monitoring station.

As part of the City of Oak Ridge's pretreatment program, city personnel also use the east end monitoring station (also known as SS6, see Figure 4.16) to conduct compliance monitoring as required by the pretreatment regulations. City personnel also conduct twice-yearly compliance inspections.

Monitoring results from 2018 are contained in Table 4.16. There were a total of four exceedances of permit limits in 2018; three exceedances of the 2,100-gpm instantaneous limit and one exceedance of the average daily flow limit.

Table 4.16. Y-12 National Security Complex Plant discharge point SS6 (all units are mg/L unless noted otherwise)

Effluent parameter	Number of samples	Average value	Daily maximum (gpm)[a]	Monthly average (effluent limit)[a]	Number of limit exceedances
Max flow rate (gpm)	365	N/A	2,100	N/A	4
Flow (average kgpd) January through March	90	510.6	N/A	500	1
Flow (average kgpd) April through June	91	299.9	N/A	500	0
Flow (average kgpd) July through September	92	298.3	N/A	500	0
Flow (average kgpd) October through December	92	393.6	N/A	500	0
pH (standard units)	15	N/A	N/A	9/6[b]	0
Biochemical oxygen demand	13	59.2	N/A	200	0
Kjeldhal nitrogen	15	22.0	N/A	45	0
Phenols—total recoverable	15	<0.027	N/A	0.15	0
Oil and grease	24	<15	N/A	25	0
Suspended solids	17	85.6	N/A	200	0
Cyanide	15	<0.0027	N/A	0.005	0
Arsenic	14	<0.005	N/A	0.010	0
Cadmium	14	<0.0006	N/A	0.0033	0
Chromium, hexavalent	12	0.006U	N/A	0.053	0
Copper	14	0.0275	N/A	0.14	0
Iron	14	0.592	N/A	10	0
Lead	14	<0.006	N/A	0.049	0
Mercury	14	0.00137[d]	N/A	0.035[d]	0
Nickel	14	<0.005	N/A	0.021	0
Silver	14	<0.002	N/A	0.05	0

Table 4.16. Y-12 National Security Complex Plant discharge point SS6 (all units are mg/L unless noted otherwise) (continued)

Effluent parameter	Number of samples	Average value	Daily maximum (gpm)[a]	Monthly average (effluent limit)[a]	Number of limit exceedances
Zinc	14	0.19	N/A	0.35	0
Molybdenum	14	0.0479	N/A	0.05[c]	N/A
Selenium	14	<0.001	N/A	0.01[c]	N/A
Toluene	3	0.005U	N/A	0.005[c]	N/A
Ammonia	4	20.2	N/A	0.10[c]	N/A
Methanol	3	0.98U	N/A	1.0[c]	N/A
Benzene	3	0.005U	N/A	0.005[c]	N/A
1,1,1-Trichloroethane	3	0.005U	N/A	0.005[c]	N/A
Ethylbenzene	3	0.005U	N/A	0.005[c]	N/A
Carbon tetrachloride	3	0.005U	N/A	0.005[c]	N/A
Chloroform	3	0.004UJ	N/A	0.005[c]	N/A
Tetrachloroethene	3	0.003J	N/A	0.005[c]	N/A
Trichloroethene	3	0.005U	N/A	0.005[c]	N/A
trans-1,2-Dichloroethylene	3	0.005U	N/A	0.005[c]	N/A
Methylene chloride	3	0.005U	N/A	0.005[c]	N/A

Units are pounds per day.
[a] Industrial and commercial users wastewater permit limits.
[b] Maximum value/minimum value.
[c] There is not a permit limit for this parameter. This value is the required detection limit.
gpm = gallons per minute   kgpm = thousand gallons per minute   N/A = not applicable

Additionally, there was one failure to perform required monitoring during CY 2018. Eleven of the organic compounds listed in Table 4.16 are listed as having three samples taken instead of the required four (one per calendar quarter). This occurred due to an administrative oversight during the July through September timeframe. The regulatory authority (City of Oak Ridge) issued a Notice of Violation to Y-12, and a corrective action plan to prevent recurrence has been approved and is being implemented.

4.5.6 Quality Assurance/Quality Control

The Environmental Monitoring Management Information System (EMMIS) is used to manage surface water monitoring data at Y-12. EMMIS uses standard sample definitions to ensure that samples are taken at the correct location at a specified frequency using the correct sampling protocol.

Field sampling QA encompasses many practices that minimize error and evaluate sampling performance. Some key quality practices include the following:

- Use of standard operating procedures for sample collection and analysis.
- Use of chain-of-custody and sample identification, customized chain-of-custody documents, and sample labels provided by EMMIS.
- Instrument standardization, calibration, and verification.
- Sample technician training.
- Sample preservation, handling, and decontamination.
- Use of QC samples such as field and trip blanks, duplicates, and equipment rinses.

Surface water data are entered directly by the analytical laboratory into the Laboratory Information Management System on the day of approval. EMMIS routinely accesses the Laboratory Information Management System electronically to capture pertinent data. Generally, the system will store the data in the form of concentrations.

A number of electronic data management tools enable automatic flagging of data points and allow for monitoring and trending data over time. Field information on all routine samples taken for surface water monitoring is entered in EMMIS, which also retrieves data nightly from the analytical laboratory. The system then performs numerous checks on the data, including comparisons of the individual results against any applicable screening criteria, regulatory thresholds, compliance limits, best management practices, or other water quality indicators, and produces required reports.

4.5.7 Biomonitoring Program

The NPDES Permit for Y-12 (TN0002968, Part III, Section E) contains chronic toxicity testing requirements. These requirements specify that chronic toxicity testing (a 3-Brood *Ceriodaphnia dubia* survival and reproduction test and a 7-day fathead minnow larval survival and growth test) is required annually at Outfalls 135 and 200 to determine whether the effluent is contributing chronic toxicity to the receiving water. According to permit requirements, chronic toxicity testing is to be performed using 100 percent effluent and the dilution series shown below in Table 4.17.

Table 4.17. Serial dilutions for whole effluent toxicity testing, as a percent of effluent

Outfall 200	Control	0.25 x PL	0.50 x PL	PL	(100+ PL)/2	100% Effluent
	0	9.3	18	37	74	100
Outfall 135	**Control**	**0.25 x PL**	**0.50 x PL**	**PL**	**2 x PL**	**4 x PL**
	0	2.3	4.5	9	18	36

NOTE: The effluent water is diluted with control laboratory water. PL = permit limit

Table 4.18 summarizes the results of the 2018 outfall biomonitoring tests in terms of the 25 percent inhibition concentration (IC_{25}), which is the concentration (i.e., a percentage of full-strength effluent diluted with laboratory control water) of each outfall effluent that causes a 25-percent reduction in the survival or reproduction of water fleas (*Ceriodaphnia dubia*) or the survival or growth of fathead minnow (*Pimephales promelas*) larvae (with respect to these same endpoints for these animals measured in control laboratory water). The lower the value of the IC_{25}, the more toxic the effluent. According to the NPDES permit, toxicity is demonstrated if the IC_{25} is less than or equal to the permit limit (9 percent whole effluent for Outfall 135 and 37 percent whole effluent for Outfall 200).

Effluent from Outfall 135 did not reduce fathead minnow (*Pimephales promelas*) survival or growth of water fleas (*Ceriodaphnia dubia*) survival or reproduction by 25 percent or more at any of the tested concentrations. For both species, the IC_{25} for survival, growth, or reproduction was >36 percent (the highest concentration of this effluent that was tested) (Table 4.18). However, toxicity was observed in Outfall 200 effluent in July 2018 in water fleas (*Ceriodaphnia dubia*), with the IC_{25} for reproduction being 26.3 percent effluent, which is lower than the permit limit of 37 percent (Table 4.18). According to the NPDES permit, if toxicity is found, a follow-up test must be initiated using the same serial dilutions within 2 weeks. Toxicity was again observed in the follow-up test in August 2018, with IC_{25} values of 33.8 and 25.2 percent effluent for water fleas (*Ceriodaphnia dubia*) survival and reproduction, respectively. With toxicity observed in two consecutive tests, a toxicity identification/evaluation reduction plan was initiated. This investigation included follow-on toxicity tests and characterization of the water chemistry in the storm drain network leading to Outfall 200. After the August 2018 test, no further toxicity was observed in the remainder of CY 2018 at this outfall.

Table 4.18. Y-12 National Security Complex biomonitoring program summary information for Outfalls 200 and 135, 2018[a]

Water collection dates	Outfall	Test type	Test organism	End point	Metric	IC_{25}[b] (%)
07/18–23/18	200	Chronic	Fathead minnow (*Pimephales promelas*)	Survival	IC_{25}	>100%
				Growth	IC_{25}	86.3%
			Water fleas (*Ceriodaphnia dubia*)	Survival	IC_{25}	55.5%
				Reproduction	IC_{25}	26.3%
07/18–23/18	135	Chronic	Fathead minnow (*Pimephales promelas*)	Survival	IC_{25}	>36%
				Growth	IC_{25}	>36%
			Water fleas (*Ceriodaphnia dubia*)	Survival	IC_{25}	>36%
				Reproduction	IC_{25}	>36%
08/07/18–08/13/18	200	Chronic	Water fleas (*Ceriodaphnia dubia*)	Survival	IC_{25}	33.80%
				Reproduction	IC_{25}	25.20%
			Fathead minnow (*Pimephales promelas*)	Survival	IC_{25}	>100%
				Growth	IC_{25}	89.40%

NOTE: Red font highlights IC_{25} values that were below permit limits, indicating toxicity as defined by the National Pollutant Discharge Elimination System Permit.

[a] IC_{25} is summarized for the discharge monitoring locations, Outfalls 200 and 135.

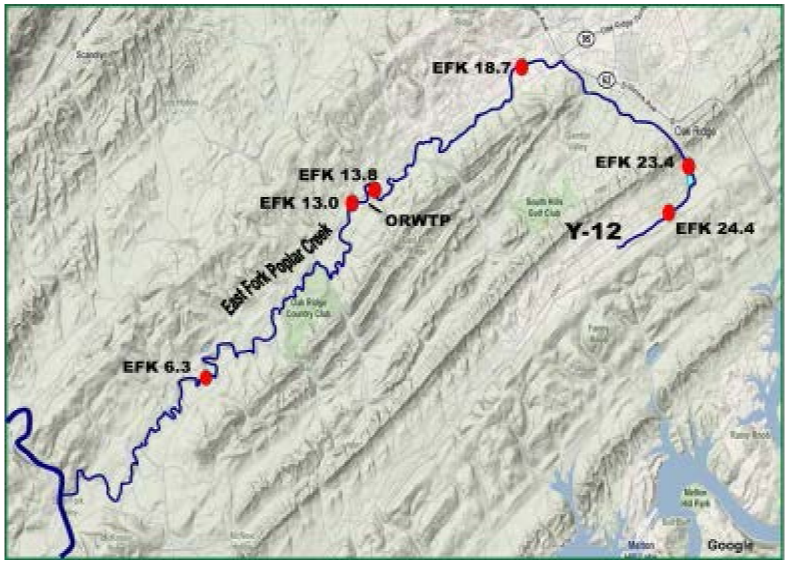
[b] IC_{25} as a percentage of full-strength effluent from Outfalls 200 and 135 diluted with laboratory control water. IC_{25} is the concentration that causes a 25% reduction in water fleas (*Ceriodaphnia dubia*) survival or reproduction or fathead minnow (*Pimephales promelas*) survival or growth; 36% is the highest concentration of Outfall 135 tested.

IC_{25} = 25% inhibition concentration

4.5.8 Biological Monitoring and Abatement Program

The NPDES permit issued for Y-12 mandates a Biological Monitoring and Abatement Program (BMAP) with the objective of demonstrating that the effluent limitations established for the facility protect the classified uses of the receiving stream, EFPC. The 2018 BMAP sampling efforts reported in this chapter follow the NPDES-required Y-12 BMAP Plan (Peterson et al. 2013). Y-12's BMAP, which has been monitoring the ecological health of EFPC since 1985, currently consists of three major tasks that reflect complementary approaches to evaluating the effects of Y-12 discharges on the aquatic integrity of EFPC. These tasks include: (1) bioaccumulation monitoring, (2) benthic macroinvertebrate community monitoring, and (3) fish community monitoring. Data collected on contaminant bioaccumulation and the composition and abundance of communities of aquatic organisms provide a direct evaluation of the effectiveness of abatement and remedial measures in improving ecological conditions in the stream.

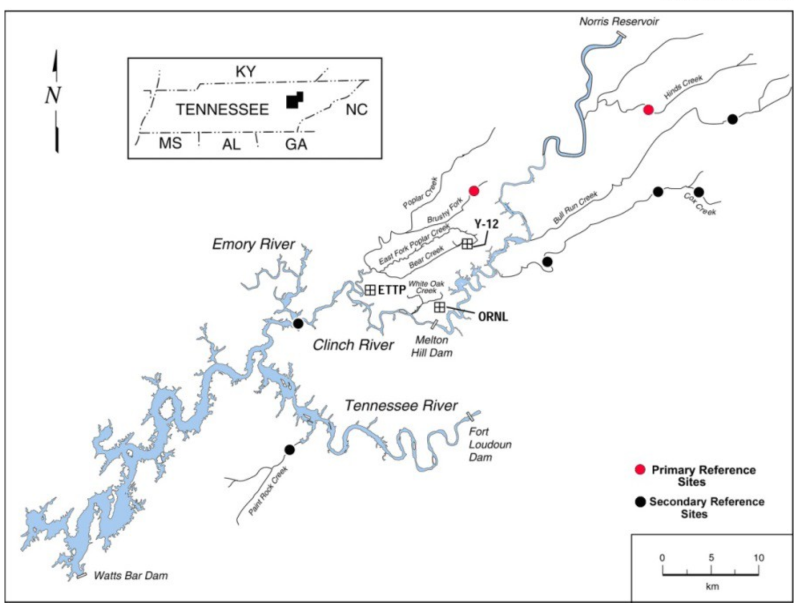
Monitoring is currently being conducted at five primary EFPC sites, although sites may be excluded or added depending on the specific objectives of the various tasks. The primary sampling sites include upper EFPC at EFPC kilometers (EFKs) 24.4 and 23.4 (upstream and downstream of Lake Reality, respectively); EFK 18.7 and EFK 18.2, located off-ORR and below an area of intensive commercial and light industrial development; EFK 13.8 and EFK 13.0, located upstream and downstream of the Oak Ridge Wastewater Treatment Facility, respectively; and EFK 6.3, located about 1.4 km downstream of the ORR boundary (Figure 4.17). Brushy Fork at Brushy Fork kilometer (BFK) 7.6 is used as a reference stream in two BMAP tasks. Additional sites off-ORR are also occasionally used for reference, including Beaver Creek, Bull Run, Cox Creek, Hinds Creek, Paint Rock Creek, and Emory River in the Watts Bar Reservoir (Figure 4.18).



EFK = East Fork Poplar Creek kilometer ORWTP = Oak Ridge Water Treatment Plant

Figure 4.17. Locations of biological monitoring sites on East Fork Poplar Creek in relation to the Y-12 National Security Complex

ORNL-DWG-95M-7421R



ETTP = East Tennessee Technology Park ORNL = Oak Ridge National Laboratory Y-12 = Y-12 National Security

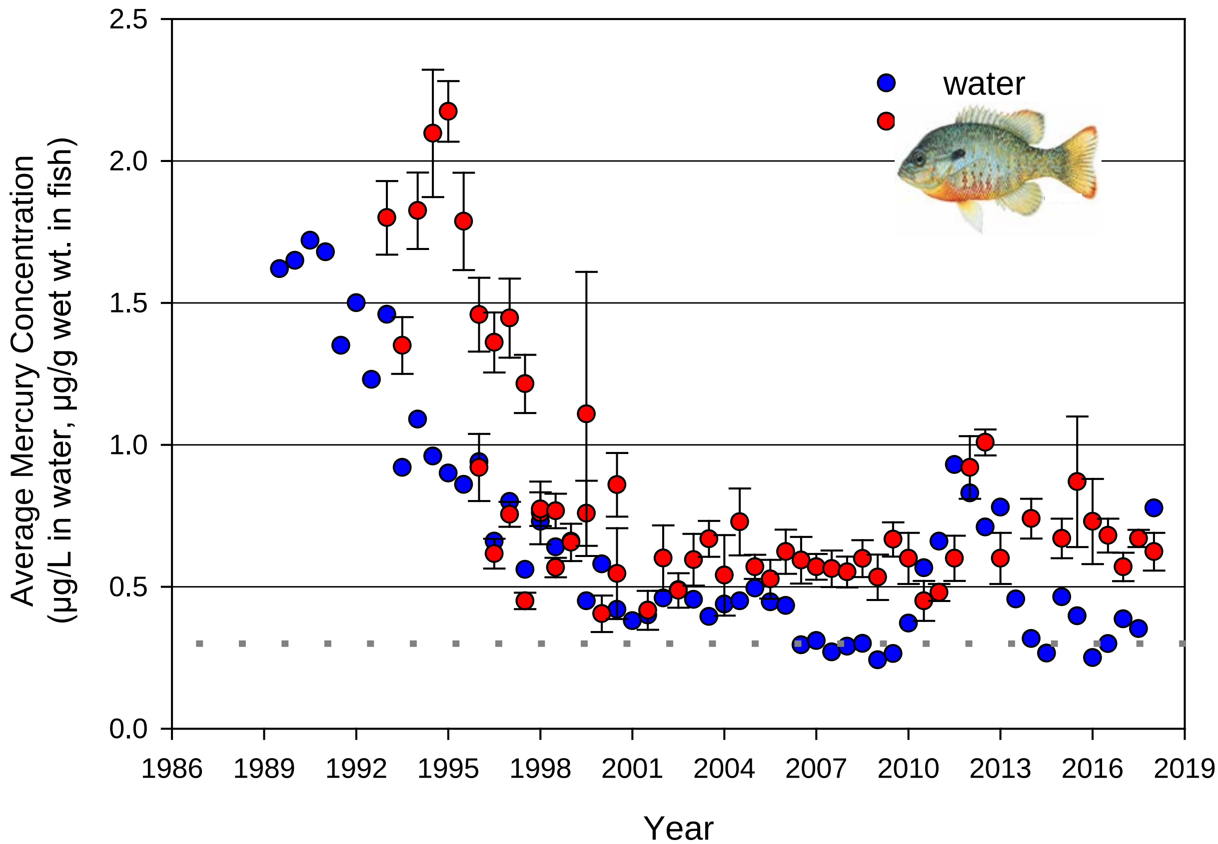
Figure 4.18. Locations of biological monitoring reference sites in relation to the Y-12 National Security Complex

Significant increases in the number of invertebrate and fish species in EFPC over the last three decades demonstrate that the overall ecological health of the stream continues to improve. However, the pace of improvement in upper EFPC near Y-12 has slowed in recent years, and fish and invertebrate communities continue to have fewer species than the corresponding communities in reference streams.

4.5.8.1 Bioaccumulation Studies

Historically, mercury and PCB levels in fish from EFPC have been elevated relative to fish in uncontaminated reference streams. Fish in EFPC are monitored regularly for mercury and PCBs to assess spatial and temporal trends in bioaccumulation associated with ongoing remedial activities and Y-12 operations.

As part of this monitoring effort, redbreast sunfish (*Lepomis auritus*) and rock bass (*Ambloplites rupestris*) are collected twice a year from five sites throughout the length of EFPC and are analyzed for tissue concentrations of mercury (twice yearly) and PCBs (annually) (Figure 4.19). Mercury concentrations remained higher in fish from EFPC in 2018 than in fish from reference streams. Elevated mercury concentrations in fish from the upper reach of EFPC indicate that Y-12 remains a continuing source of mercury to fish in the stream.

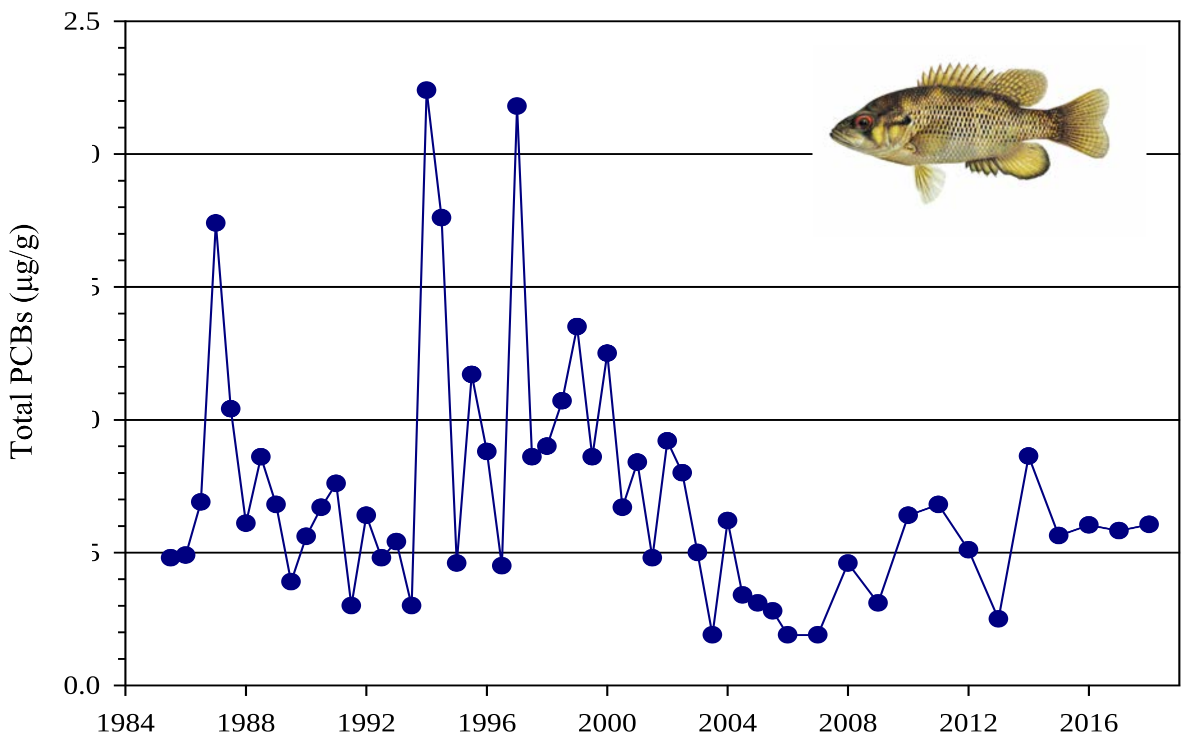


Dashed grey line represents the ambient water quality criterion for methylmercury in fish fillets [0.3 µg/g]

Figure 4.19. Semiannual average mercury concentration in muscle fillets of redbreast sunfish and water from East Fork Poplar Creek at East Fork Poplar Creek kilometer 23.4 (water) and East Fork Poplar Creek kilometer 24.4 (fish), Fiscal Year 2018

Figure 4.19 shows temporal trends for mercury concentrations in water collected from EFK 23.4 (Station 17) and in fish collected just upstream of this monitoring station at EFK 24.4. Water-borne mercury concentrations in the upper reach of EFPC have decreased substantially over the years in response to various remedial actions, first over the 1990s time period and then again in response to the Big Springs Treatment System in 2006. Although mercury concentrations in fish over time have not decreased commensurate with mercury levels in water in the lower sections of EFPC, mercury concentrations in fish at the uppermost sampling site (EFK 24.4) decreased steadily in the 1990s, consistent with decreased concentrations in water (Figure 4.19). Significant fluctuations in aqueous mercury concentrations (thought to be the result of storm drain relining and cleanout) have been seen at EFK 23.4 since 2009. Redbreast sunfish collected from the EFK 24.4 sampling site, about 1 km upstream of Station 17, appear to have responded to the recent peak and decline in aqueous mercury concentrations. Mean concentrations at EFK 24.4 increased from approximately 0.6 µg/g in 2011 to above 1 µg/g in 2012 and dropped back down in 2013 through 2018 (approximately 0.6 µg/g). These concentrations are above the EPA-recommended ambient water quality criterion for mercury (0.3 µg/g mercury as methylmercury in fish fillet). That this species appears to have responded to changes in water mercury concentrations in the upper reaches of the creek is interesting, given it has not responded to decreases in aqueous total mercury concentrations at downstream sites throughout EFPC in the past 20 years. The relationship between aqueous total mercury concentrations and fish tissue concentrations is complex. Aqueous mercury concentrations vary by orders of magnitude throughout the various watersheds across ORR, but fish tissue concentrations tend not to vary greatly (twofold to threefold). Multiple ongoing investigations are being conducted to better understand mercury bioaccumulation dynamics in EFPC and to better predict how remedial changes may impact mercury concentrations in fish in the future.

The mean total PCB concentration in sunfish fillets at EFK 23.4 was 0.61 µg/g in FY 2018, which was comparable to the concentration in FY 2017 (0.58 µg/g) (Figure 4.20). Regulatory guidance and human health risk levels have varied widely for PCBs, depending on the regulatory program and the assumptions used in the risk analysis. The Tennessee water quality criteria for individual Aroclors and total PCBs are both 0.00064 µg/L under the recreation designated-use classification and are the targets for PCB-focused total maximum daily loads, including for local reservoirs (Melton Hill, Watts Bar, and Fort Loudoun; TDEC 2010a, 2010b, 2010c).



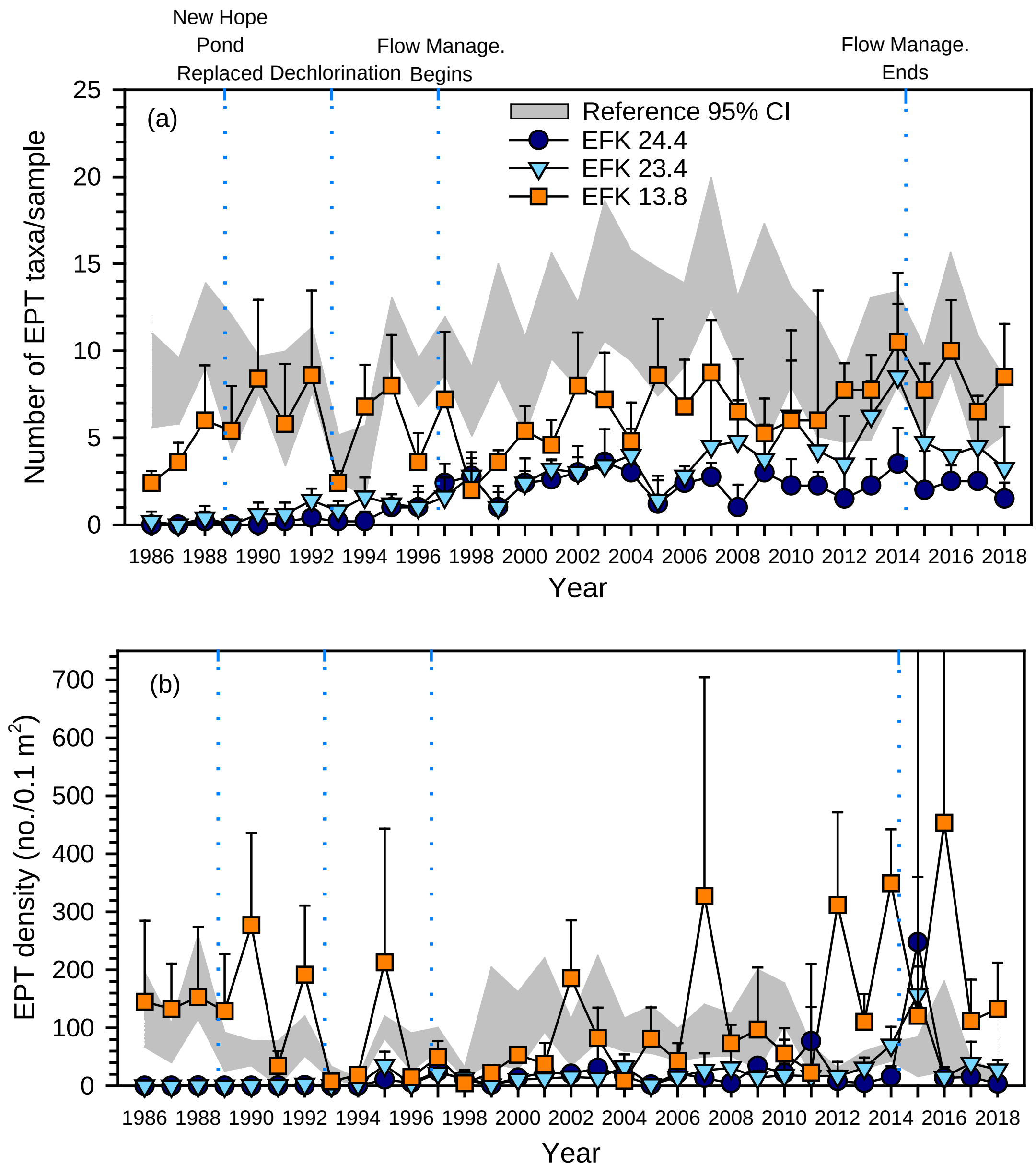
PCB = polychlorinated biphenyl

Figure 4.20. Annual mean concentrations of polychlorinated biphenyls in rock bass muscle fillets at East Fork Poplar Creek kilometer 23.4, Fiscal Year 2018

In the state of Tennessee, assessments of impairment for water body segments, as well as public fishing advisories, are based on fish tissue concentrations. Historically, the US Food and Drug Administration threshold limit of 2-µg/g PCBs in fish fillets was used for advisories, and then for many years, an approximate range of 0.8 to 1 µg/g was used, depending on the data available and factors such as the fish species and size. The remediation goal for fish fillets at ETTP K-1007-P1 pond on ORR is 1-µg/g PCBs. Most recently, the water quality criterion has been used to calculate the fish tissue concentration triggering impairment and a total maximum daily load (TDEC 2007). This concentration is 0.02 µg/g PCBs in fish fillets (TDEC 2010a, 2010b, 2010c). The mean fish PCB concentration in upper EFPC, 0.60 µg/g in fish fillets, is well above this concentration.

4.5.8.2 Benthic Invertebrate Surveys

Monitoring of the benthic macroinvertebrate community continued in the spring of 2018 at three sites in EFPC and at two reference streams. The numbers of pollution-intolerant taxa (Ephemeroptera, Plecoptera, and Tricoptera [EPT taxa]) increased at EFK 13.8 and decreased at EFKs 23.4 and 24.4 (Figure 4.21a). The densities of these pollution-intolerant taxa increased at EFK 13.8 but decreased at the two sites nearest Y-12 (EFK 23.4 and EFK 24.4) and at the reference sites (Figure 4.21b). Of particular significance, the mean densities of the pollution-intolerant taxa at EFK 13.8 have continued to exceed the upper bound of the reference site confidence limits since 2012. However, at EFK 23.4 and EFK 24.4, mean densities for pollution-intolerant taxa remain at typical low levels, indicative of degraded conditions after exceeding densities at reference sites in 2015 for the first time since monitoring began in 1985. The implications of ending flow management in 2014 on invertebrate communities in EFPC are still uncertain; however, EPT taxa richness at EFK 23.4 suggests that changes in hydrology may have influenced the community. EPT taxa richness at EFK 23.4 displayed consistent increases in EPT taxa richness from the mid-2000s to 2014, but after flow augmentation ceased, values have consistently declined. The effects of ending flow augmentation on lower EFPC (EFK 13.8) do not seem as evident, which makes intuitive sense as flow augmentation contributed a smaller percentage of total discharge at downstream sites. The long-term effects on the invertebrate community of ending flow management in EFPC will become more evident as conditions stabilize and additional data become available.

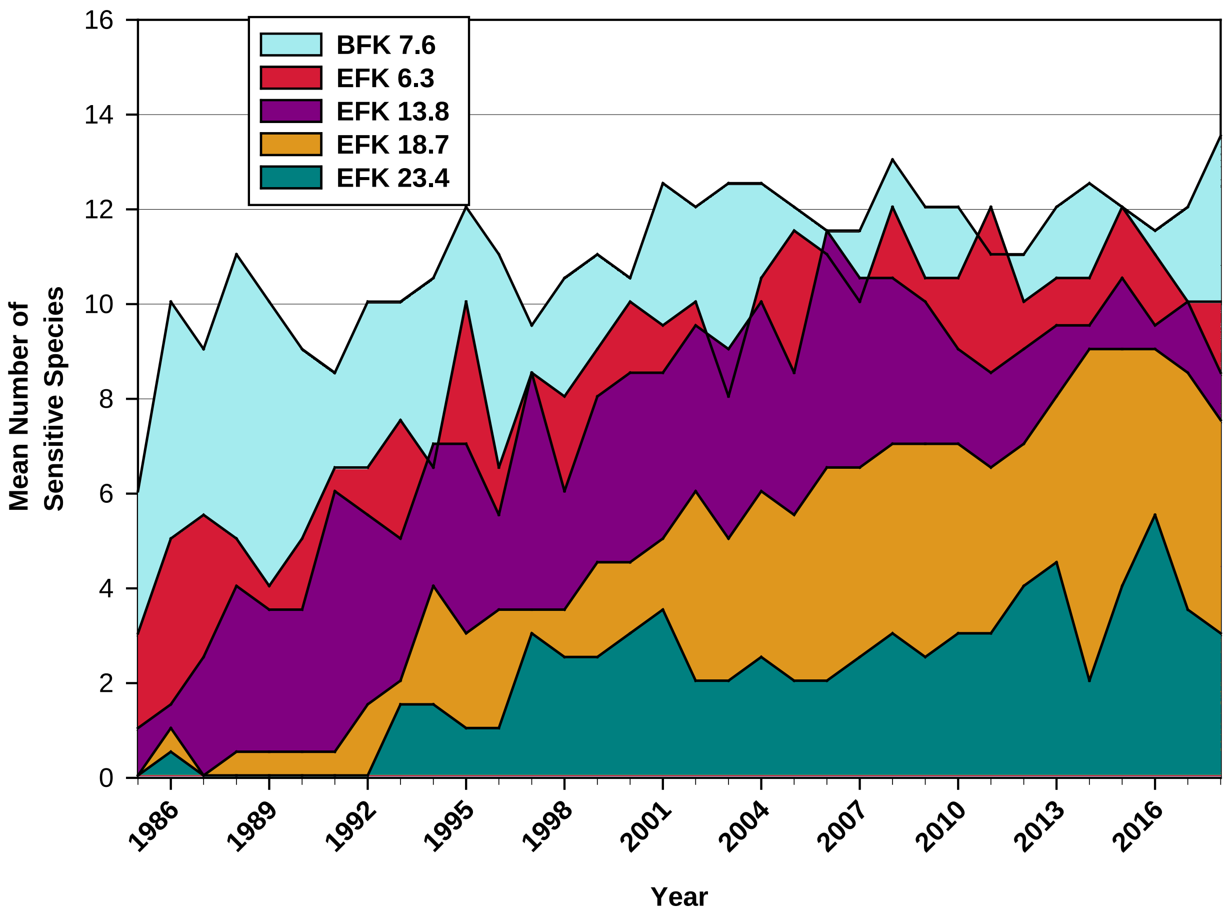


EFK = East Fork Poplar Creek kilometer
EPT taxa = Ephemeroptera, Plecoptera, and Tricoptera

Figure 4.21. (a) Taxonomic richness (mean number of taxa per sample), and (b) density (mean number of taxa per square meter) of Ephemeroptera, Plecoptera, and Tricoptera in the benthic macroinvertebrate communities sampled in the spring from East Fork Poplar Creek and two nearby reference streams (Brushy Fork and Hinds Creek), 1986–2018

4.5.8.3 Fish Community Monitoring

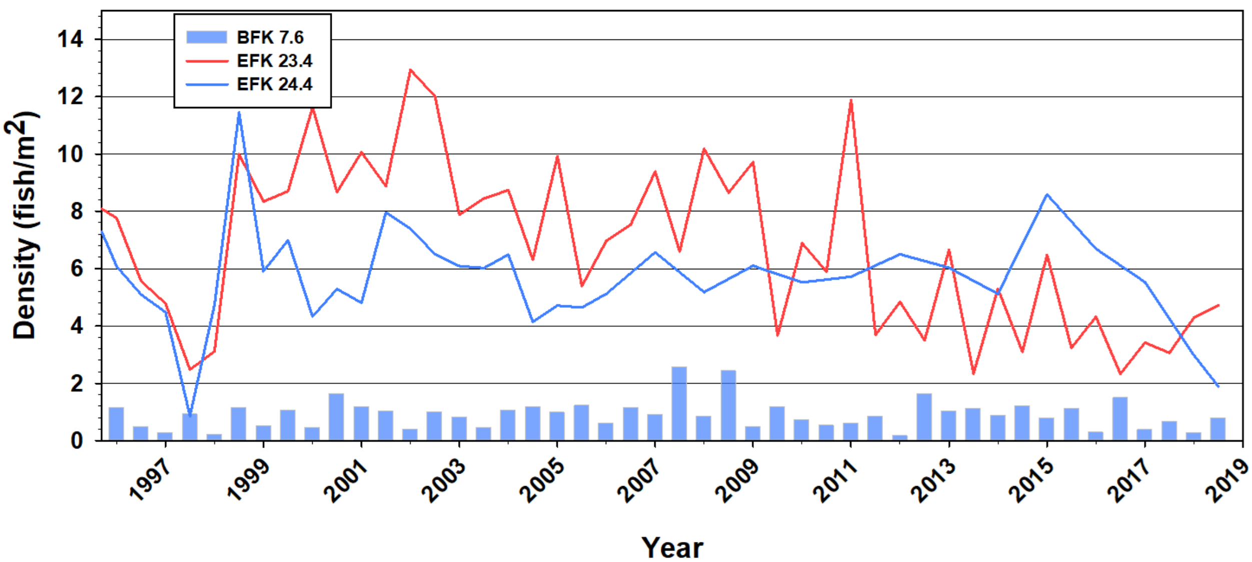
Fish communities were monitored in the spring and fall of 2018 at five sites along EFPC and at a comparable local reference stream (Brushy Fork). In the past three decades, overall species richness, density, biomass, and number of pollution-sensitive fish species improved at all sampling locations below Lake Reality. Some species of fish are considered sensitive and require very specific habitat conditions to survive and can only tolerate a narrow range of environmental disturbance. The mean number of sensitive species at four sites in EFPC and the reference stream is shown in Figure 4.22, dramatically highlighting major improvements in the fish community in the middle to lower sections (EFK 6.3 and EFK 13.8) of the stream. However, the EFPC fish community continues to lag behind the reference stream community (BFK 7.6) in the most important metrics of fish diversity and community structure, especially at the monitoring sites closest to Y-12 (EFK 23.4 and EFK 24.4).



BFK = Brushy Fork kilometer EFK = East Fork Poplar Creek kilometer

Figure 4.22. Comparison of mean sensitive species richness (number of species) collected each year (1985–2018) from four sites in East Fork Poplar Creek and a reference site (Brushy Fork)

Fish communities in upper EFPC in 2018 continued to experience some fluctuation in density. Reduced stream flows associated with the termination of flow augmentation from Melton Hill in April 2014 and the extreme drought in 2016 are likely factors driving the decrease in fish densities in these upper sites (Figure 4.23). Despite this, the fish diversity remained relatively consistent. Very high densities are not always a positive indicator of fish health, and the most abundant species within these sites continue to be those that are considered tolerant. Continued monitoring will provide additional insight into these variabilities.



BFK = Brushy Fork kilometer EFK = East Fork Poplar Creek kilometer
The interval of time between the dashed lines represents the period of flow management in East Fork Poplar Creek

Figure 4.23. Fish density (number of fish per square meter) for two sites in upper East Fork Poplar Creek and a reference site (Brushy Fork), 1996–2018

The fish communities in upper EFPC were impacted in 2018 by two incidents that resulted in fish kills. On January 29, 2018, a high-water event associated with a water line break resulted in 58 fish mortalities in the upper end of EFPC above Station 8. A second incident occurred in July 2018 when most of the dead fish were encountered, but low-level fish mortality was observed through October 2018. In total, 416 fish and 309 crayfish were collected during 30 surveys from July 11 through October 29, 2018. Fish community surveys were conducted in fall (August) 2018 to assess the potential impact of the fish kill and current status of the communities. These surveys indicated that the fish community in upper EFPC (EFK 25.1 and EFK 24.4) was considerably lower than in spring 2018. Future monitoring of these sites will provide additional insight into the condition of these fish communities.

4.5.8.4 Upper Bear Creek Remediation

As part of the construction of the UPF inside Y-12, a haul road was constructed in 2013 and 2014, and several wetlands were lost or negatively affected. This resulted in the need for mitigation, including the creation and expansion of wetlands in the Bear Creek watershed. All wetland mitigation sites were constructed during the haul road expansion except one, which will be completed in the future. Wetland soils available after road construction, with their associated wetland plant seed banks, were used to support the establishment of hydric soils and wetland plant species in the mitigation areas. In all, 3.51 acres of wetlands will be constructed to compensate for the removal of 1 acre. The compensation ratios are intended to ensure that there is no net loss of wetland resource value.

As part of haul road construction, it was also necessary to culvert two sections of north tributary streams to Bear Creek. To mitigate the loss of natural streams, a previously impacted section of Bear Creek was identified for restoration to more natural conditions. Approximately 300 ft of upper Bear Creek was remediated in 2014 by diverting the stream out of a channelized section and back into its original channel. This remediated section was lined extensively with erosion matting along both banks, and various-size river rocks were added to the channel to create pool/riffle complexes throughout the site. The natural meander of the channel was kept, and only slight modifications were made. All disturbed soils were seeded, and native plants were added to the site to stabilize sediments and to re-establish the stream’s riparian zone following the construction.

Annual monitoring of the remediated wetland sites through 2018 revealed that, in general, the wetlands are responding as intended and have shown remarkable wetland plant coverage over the past couple of years. The wetland soil bank was undoubtedly key to the restoration effort. There are some wetlands with extensive open water areas, and at these sites, additional deeper-water species of plants were added in 2018. Some additional actions to lower the water level are being considered in 2019.

The stream remediation site in upper Bear Creek appears to be a remediation success story. After some initial issues with drainage in the new channel, the old channel was backfilled to prevent this issue, and now flows appear to be much more stable. Native flora is abundant in the area adjacent to the stream. The fish and aquatic invertebrate communities in the remediated section of Bear Creek were slightly impacted by the drought in summer 2016, but the fish community appears to be recovering in 2017 and 2018 samples.

4.6 Groundwater at the Y-12 National Security Complex

Groundwater monitoring is performed to comply with federal, state, and local requirements and to determine the environmental impact from legacy and current operations. More than 140 known or potential sources of contamination are identified in the FFA (DOE 2018b). Groundwater monitoring provides information on the nature and extent of contamination, which is used to identify actions needed to protect the worker, the public, and the environment. Figure 4.24 depicts the major areas for which groundwater monitoring is performed.

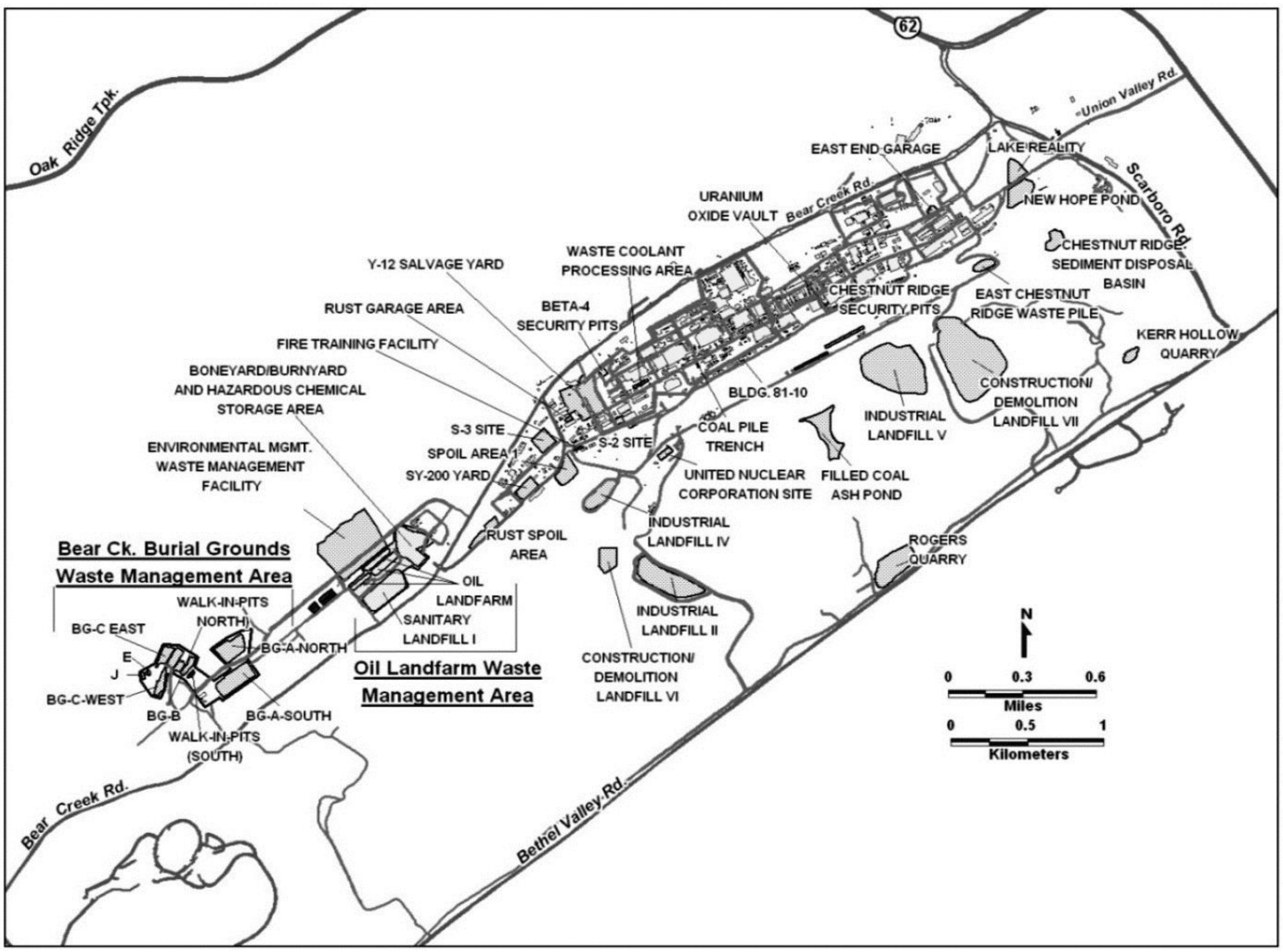
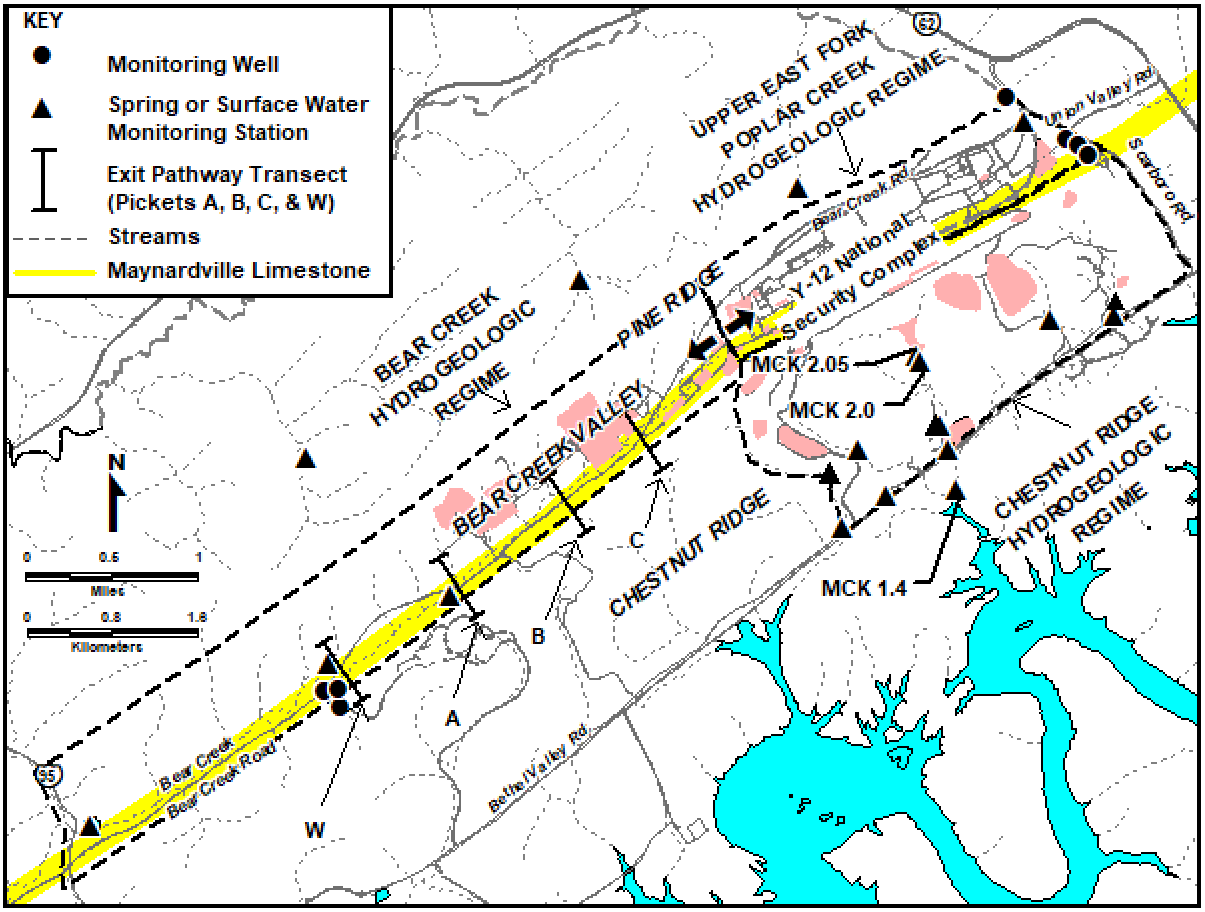


Figure 4.24. Known or potential contaminant sources for which groundwater monitoring is performed at the Y-12 National Security Complex

4.6.1 Hydrogeologic Setting

Y-12 is divided into three hydrogeologic regimes (Bear Creek, upper EFPC, and Chestnut Ridge) (Figure 4.25). Most of the Bear Creek and upper EFPC regimes are underlain by shale, siltstone, and sandstone bedrock, which act as an aquitard. An aquitard can contain water but does not readily yield that water to pumping wells. However, the southern portion of the Bear Creek and upper EFPC regimes is underlain by the Maynardville Limestone, which is part of the Knox aquifer. (An aquifer more readily yields water to pumping wells.) The Chestnut Ridge regime is almost entirely underlain by the Knox aquifer.



MCK = McCoy Branch kilometer

Figure 4.25. Hydrogeologic regimes; flow directions; and perimeter/exit pathway well, spring, and surface water monitoring stations, and the position of the Maynardville Limestone in Bear Creek Valley at the Y-12 National Security

In general, groundwater flow in the water table interval follows the topography; therefore, it flows off areas of higher elevation into the valleys and then flows parallel to the valley, along geologic strike (Figure 4.25). Shallow flow in the Bear Creek and upper EFPC regimes is divergent from a topographic and groundwater divide located near the western end of Y-12. In the Chestnut Ridge regime, a groundwater divide nearly coincides with the crest of the ridge. On Chestnut Ridge, shallow groundwater flow tends to be toward either flank of the ridge, with discharge primarily to surface streams and springs in Bethel Valley to the south and Bear Creek Valley to the north.

In Bear Creek Valley, groundwater in the intermediate and deep intervals moves through fractures in the aquitard, converging on and then moving through fractures and solution conduits in the Maynardville Limestone (Figure 4.25). Karst development in the Maynardville Limestone has a significant impact on groundwater flow paths in the water table and intermediate intervals. Groundwater flow rates in Bear Creek Valley vary; they are slow within the deep interval of the fractured non-carbonate rock (less than 10 ft/year) but can be quite rapid within solution conduits in the Maynardville Limestone (10 to 5,000 ft/day).

Contaminants are transported along with flowing groundwater through the pore spaces, fractures, or solution conduits of the hydrogeologic system. Strike-parallel transport of some contaminants can even occur within the aquitard units for significant distances, where they discharge to surface water tributaries or underground utility and storm water distribution systems in industrial areas. For example, elevated levels of nitrate (a contaminant from legacy waste disposals) within the fractured bedrock of the aquitard are known to extend east and west from the S-2 and S-3 sites for thousands of feet. VOC contamination from multiple sources is observed in both the Bear Creek and upper EFPC regimes, and to a lesser extent in the Chestnut Ridge regime. However, VOCs (e.g., petroleum products, coolants, and solvents) at source units over or in the fractured bedrock can remain close to source areas because they tend to adsorb to the bedrock matrix, diffuse into pore spaces within the matrix, and degrade before migrating to exit pathways, where more rapid transport occurs for longer distances.

Groundwater flow in the Chestnut Ridge regime is through fractures and solution conduits in the Knox Group. Discharge points for intermediate and deep flow are not well known. Following the crest of the Chestnut Ridge, water table elevations decrease from west to east, demonstrating an overall easterly trend in groundwater flow.

4.6.2 Well Installation and Plugging and Abandonment Activities

Monitoring wells are devices used for the collection of groundwater samples. Figure 4.26 shows a cross-section of a typical groundwater monitoring well.

In CY 2018, 30 piezometers (small-diameter boreholes for measuring water levels and collecting water samples) were installed for the hydrologic investigation of the proposed EM Disposal Facility.

One well (GW-923) at the Environmental Management Waste Management Facility was plugged and abandoned in CY 2018.

4.6.3 Calendar Year 2018 Groundwater Monitoring

Groundwater monitoring in CY 2018 was performed as part of Y-12's GWPP, DOE EM programs such as the Water Resources Restoration Program, and other projects. Compliance requirements were met by monitoring 182 wells and 51 surface water locations and springs (Table 4.19). Specific wells of interest based on the CY 2018 data are called out later in this section. However, Figure 4.25 shows the locations of perimeter/exit pathway stations that are monitored closely because they are the locations closest to the reservation boundaries.

Most of the conventional monitoring wells at Y-12 were sampled using industry standard methods approved by TDEC and EPA (Figure 4.27).

Water quality results of groundwater monitoring activities in CY 2018 are presented in the *Calendar Year 2018 Groundwater Monitoring Report* (CNS 2019).

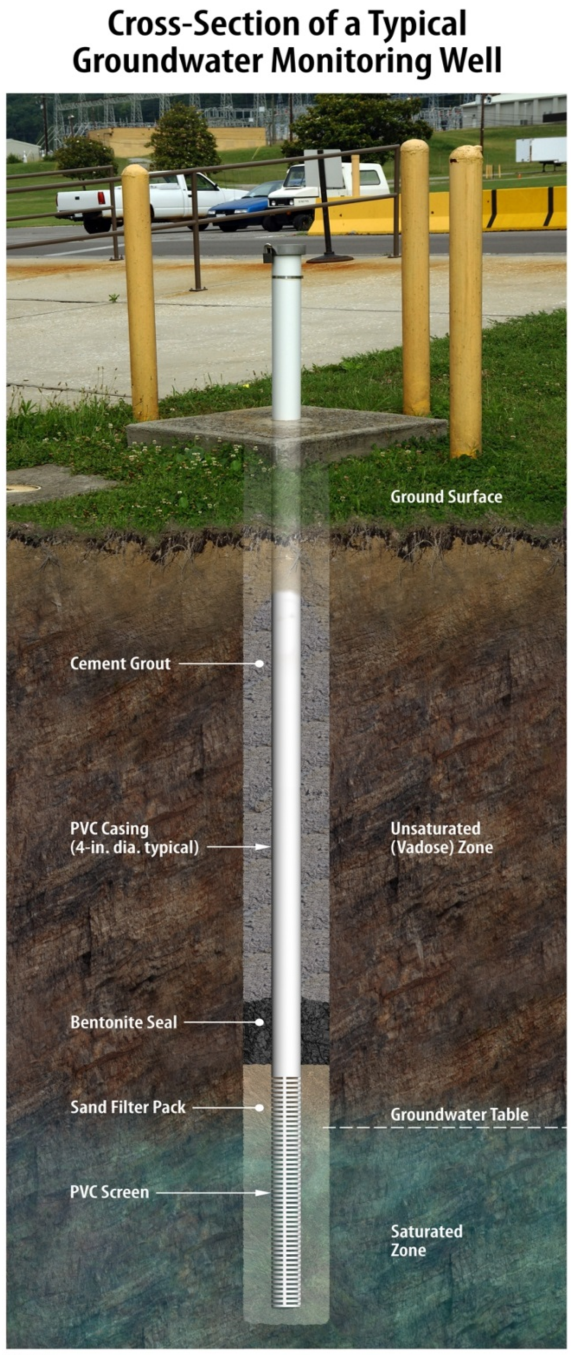


Figure 4.26. Cross-section of a typical groundwater monitoring well

Monitoring efforts performed specifically for CERCLA baseline and remediation evaluation are published in the FY 2018 and FY 2019 Water Resources Restoration Program Sampling and Analysis Plans (UCOR 2017, 2018b, respectively) and the Annual CERCLA Remediation Effectiveness Reports (DOE 2018c, 2019).

Table 4.19. Summary of groundwater monitoring at the Y-12 National Security Complex, 2018

	Purpose for which monitoring was performed				
	Restoration[a]	**Waste management**[b]	**Surveillance**[c]	**Other**[d]	**Total**
Number of active wells	65	33	84	24	206
Number of other monitoring stations (e.g., springs, seeps, and surface water)	31	6	14	3	54
Number of samples taken[e]	160	134	99	134	527
Number of analyses performed	7,823	6,279	7,622	2,615	24,336
Percentage of analyses that are non- detects	64.8	86.9	83.5	25.0	72.0
Ranges of results for positive detections, VOCs (µg/L)[f]					
Chloroethenes	0.32–2,500	2.73–6.64	1–37,000	NA	
Chloroethanes	0.32–240	4.58–75.5	1–1,900	NA	
Chloromethanes	0.33–1,100	ND	1–4,200	NA	
Petroleum hydrocarbons	0.41–6,500	ND	1–510	NA	
Uranium (mg/L)	0.0005–0.26	0.00141–0.0371	0.000546–0.0266	0.000148–23.5	
Nitrates (mg/L)	0.0032–6,600	0.513–1.96	0.0477–9,250	0.15–25.13	
Ranges of results for positive detections, radiological parameters (pCi/L)[g]					
Gross-alpha activity	4.23–351	0.872–4.98	5–110	NA	
Gross-beta activity	2.94–9,060	2.08–11.5	10–8,600	NA	

[a] Monitoring to comply with Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) requirements and with Resource Conservation and Recovery Act (RCRA) post-closure detection and corrective action monitoring.
[b] Solid waste landfill detection monitoring and CERCLA landfill detection monitoring.
[c] US Department of Energy (DOE) Order surveillance monitoring.
[d] Research-related groundwater monitoring associated with activities of the DOE Oak Ridge Field Research Center and Ecosystems and Networks Integrated with Genes and Molecular Assemblies.
[e] The number of unfiltered samples, excluding duplicates, determined for unique location/date combinations.
[f] These ranges reflect concentrations of individual contaminants (not summed VOC concentrations):
Chloroethenes—includes tetrachloroethene; trichloroethene; 1,2-dichloroethene (cis- and trans-); 1,1-dichloroethene; and vinyl chloride.
Chloroethanes—includes 1,1,1-trichloroethane; 1,2-dichloroethane; and 1,1-dichloroethane.
Chloromethanes—includes carbon tetrachloride, chloroform, and methylene chloride.
Petroleum hydrocarbon—includes benzene, toluene, ethylbenzene, and xylene.
[g] pCi = 3.7×10^{-2} Bq

Bq = becquerel
NA = not analyzed
ND = not detected

Source: Kathryn Fahey, Y-12 National Security Complex photographer

Figure 4.27. Groundwater monitoring well sampling at the Y-12 National Security Complex

4.6.4 Y-12 National Security Complex Groundwater Quality

Historical monitoring shows that four primary contaminants adversely affect groundwater quality at Y-12: nitrate, VOCs, metals, and radionuclides. Of those, VOCs are the most widespread. Uranium and technetium-99 (^{99}Tc) are the radionuclides of greatest concern. Trace metals (e.g., arsenic, barium, cadmium, chromium, and mercury), the least extensive groundwater contaminants, generally occur close to source areas because of their high adsorption characteristics. Data show that plumes from multiple-source units have mixed with one another and that contaminants are not always easily associated with a single source.

4.6.4.1 Upper East Fork Poplar Creek Hydrogeologic Regime

Among the three hydrogeologic regimes, the upper EFPC regime contains most of the known and potential sources of contamination. (Summary descriptions of waste management sites shown on Figure 4.24 have been provided in previous year ASERs and are not repeated this year.) Contaminants from the S-3 site (nitrate and ^{99}Tc) and VOCs from multiple source areas are observed in the groundwater in the western portion of the upper EFPC regime; whereas, groundwater in the eastern portion of the regime is predominantly contaminated with VOCs.

Plume Delineation

Sources of contaminants monitored during CY 2018 include the S-2 site, the Fire Training Facility, the S-3 site, the Waste Coolant Processing Facility, former petroleum UST sites, New Hope Pond, the Beta-4 Security Pits, the Salvage Yard, and process/production buildings throughout Y-12. The S-3 site is located near the hydrologic divide that separates the upper EFPC regime from the Bear Creek regime, and the site has contributed to groundwater contamination to both regimes. Contaminant plumes in both regimes (shown in gray shading on Figures 4.28 through 4.31) are elongated as a result of preferential transport of the contaminants parallel to strike (parallel to the valley axis) in both the Knox aquifer and the fractured bedrock of the aquitard.

The plumes depicted (gray shading) reflect the average concentrations and radioactivity in groundwater between CYs 2013 and 2017. The circular icons presented on the plume maps (Figures 4.28 through 4.31) represent CY 2018 monitoring results for both the upper EFPC regime (discussed in this section) and the Bear Creek regime (discussed in Section 4.6.4.2).

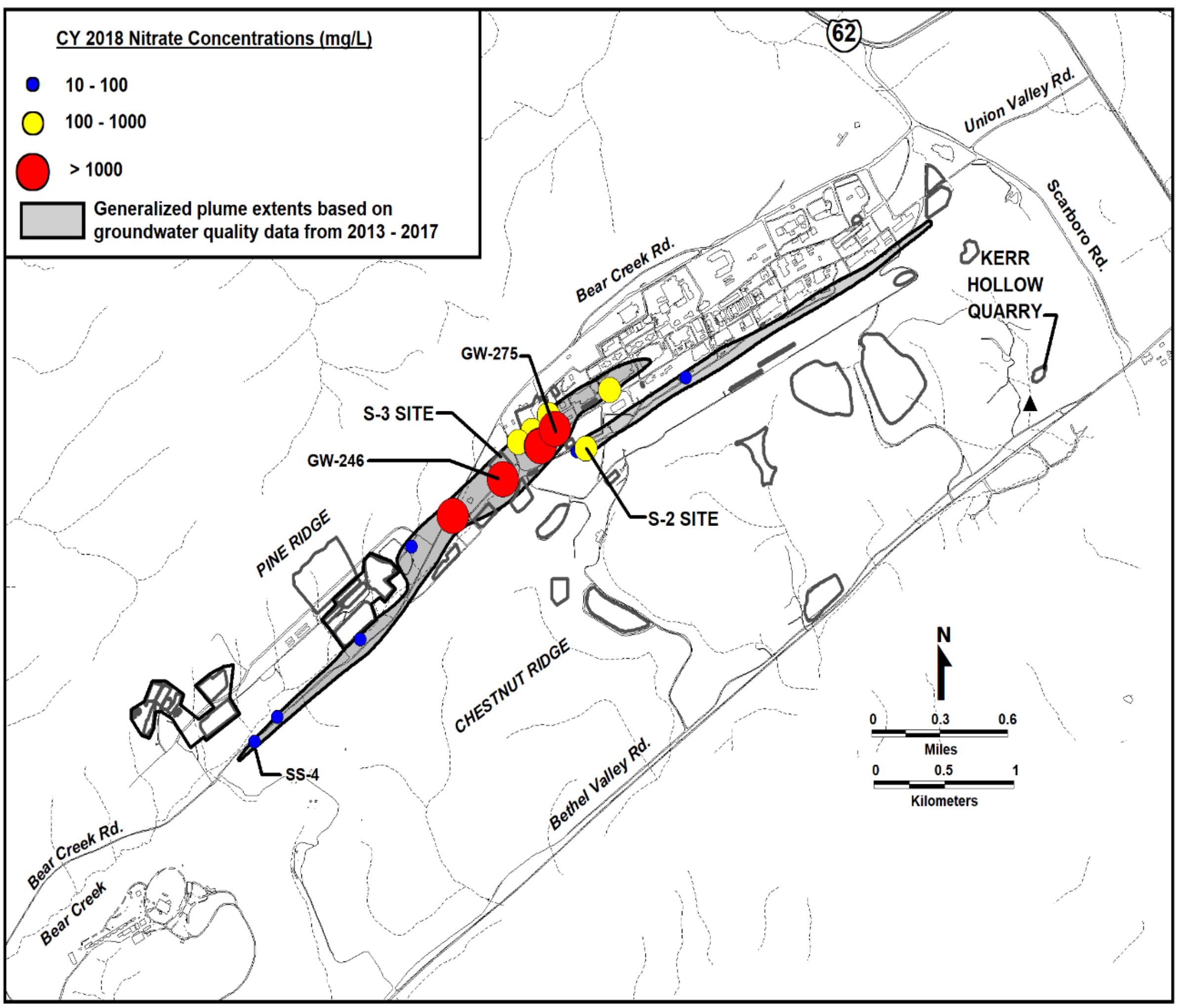


Figure 4.28. Nitrate in groundwater at the Y-12 National Security Complex, 2018

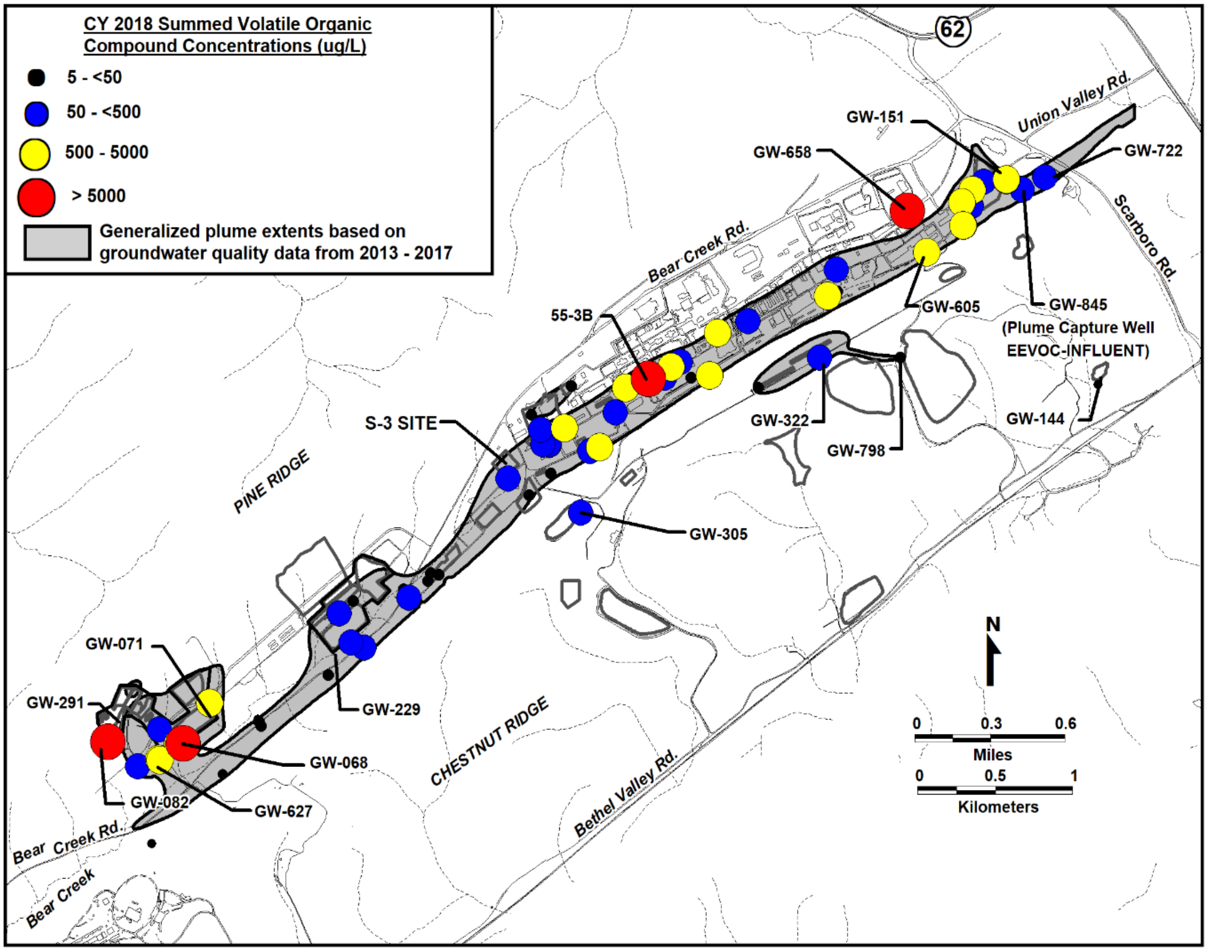


Figure 4.29. Summed volatile organic compounds in groundwater at the Y-12 National Security Complex, 2018

(EEVOC = east end volatile organic compound)

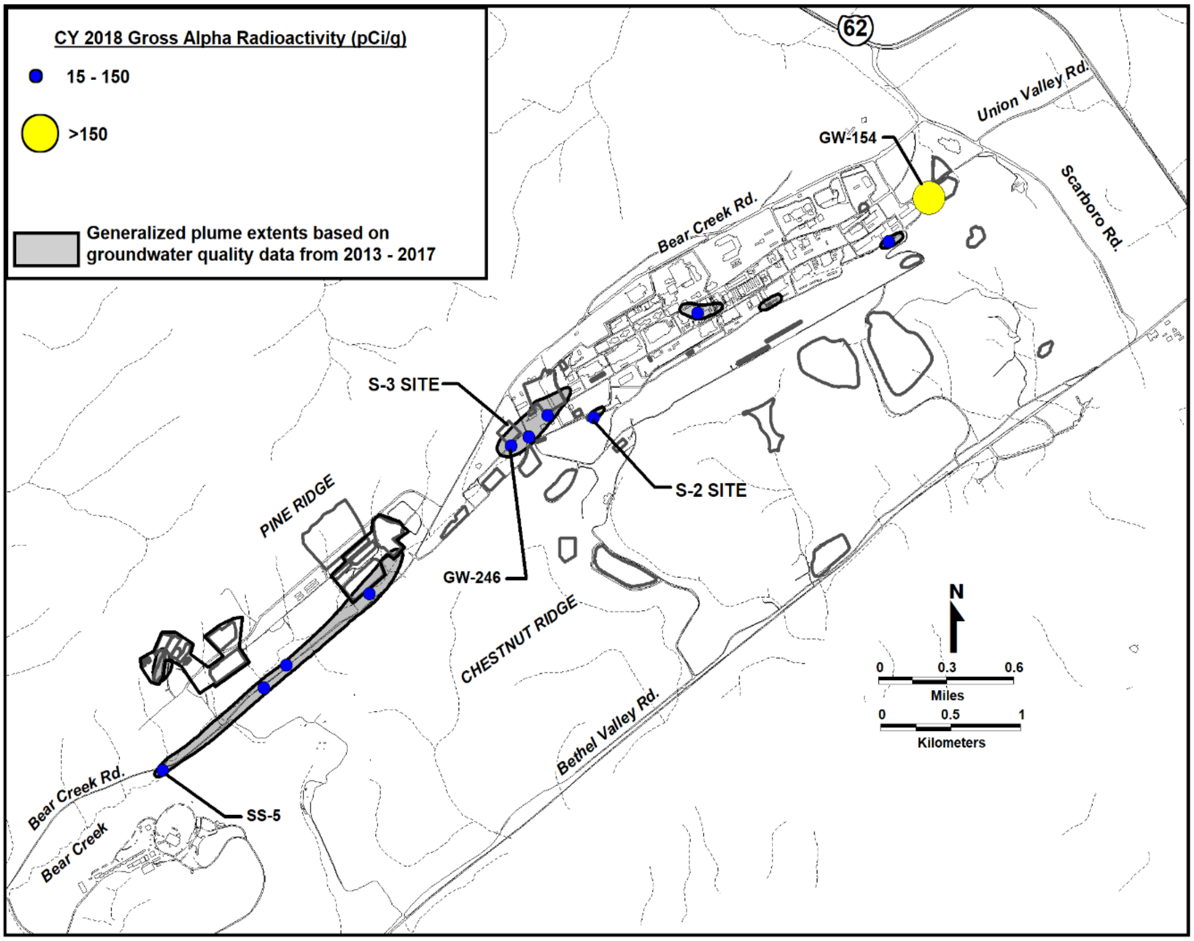


Figure 4.30. Gross-alpha activity in groundwater at the Y-12 National Security Complex, 2018

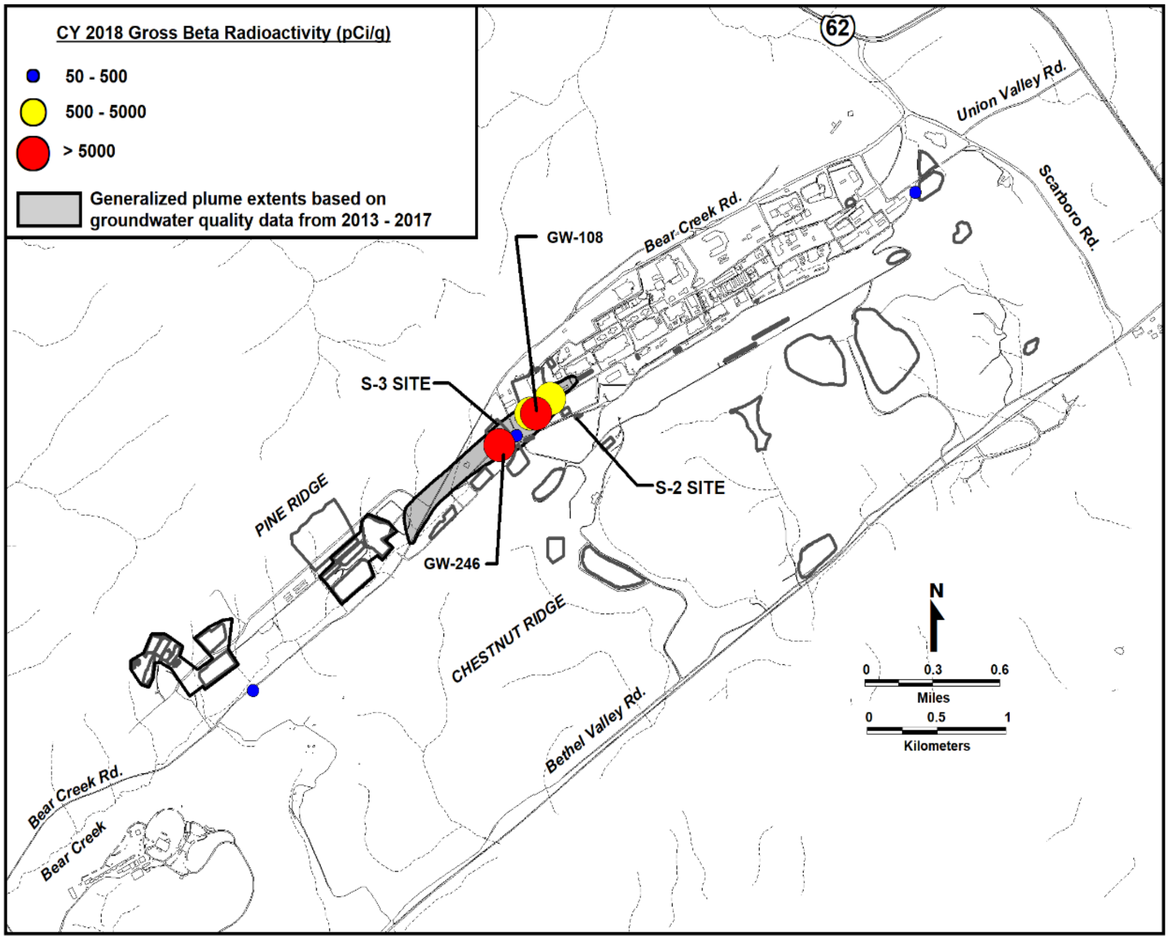


Figure 4.31. Gross-beta activity in groundwater at the Y-12 National Security Complex, 2018

Nitrate

Nitrate is highly soluble and moves easily with groundwater. In the central and western portions of upper EFPC, nitrate concentrations exceed the 10-mg/L drinking water standard. (A list of the national drinking water standards is presented in Appendix C.) The two primary sources of nitrate contamination are the S-2 and S-3 sites. In CY 2018, there was a maximum nitrate concentration of 9,250 mg/L in well GW-275. This well is located about 396 m (1,300 ft) east of the S-3 site and is screened in the shallow-intermediate bedrock interval about 20 m (65 ft) below ground surface (Figure 4.28).

Trace Metals

In CY 2018, barium, beryllium, cadmium, chromium, copper, nickel, thallium, and uranium exceeded primary drinking water standards in groundwater samples across the upper EFPC, but predominately at and downgradient of the S-2 and S-3 sites. Trace metal concentrations above standards tend to occur adjacent to source areas because of their low solubility and high adsorption to the clay-rich soils and bedrock.

Volatile Organic Compounds

VOCs are the most widespread groundwater contaminants in the upper EFPC regime. VOC contaminants in the regime primarily consist of chlorinated and petroleum hydrocarbons. In CY 2018, the highest summed concentration of dissolved chlorinated hydrocarbons (43,837 µg/L) was again found at well 55-3B in the western portion of Y-12, adjacent to currently inactive manufacturing facilities. The highest dissolved concentration of petroleum hydrocarbons (16,698 µg/L) was from well GW-658 at the closed East End Garage.

These monitoring results are consistent with data from the previous years. A dissolved plume of VOCs in the bedrock zone extends eastward from the S-3 site over the entire length of the regime (Figure 4.29). Additional sources are the Waste Coolant Processing Facility, fuel facilities (Rust Garage and East End Garage), and other waste disposal and production areas. Chloroethene compounds (tetrachloroethene [PCE], trichloroethene [TCE], dichloroethene [DCE], and vinyl chloride) tend to dominate the VOC plume composition in the western and central portions of Y-12. However, PCE is almost ubiquitous throughout, indicating many source areas. Chloromethane compounds (carbon tetrachloride, chloroform, and methylene chloride) are the predominant VOCs in the eastern portion of Y-12.

Variability in concentration trends of chlorinated and petroleum VOCs is seen within the upper EFPC regime. Data from most of the monitoring wells have remained relatively constant or have decreased since 1988. However, increasing trends have been observed in wells associated with the Rust Garage, Old Salvage Yard, and S-3 site; some legacy sources at production/process facilities in central areas; and the east end VOC plume.

Within the exit pathway (the Maynardville Limestone underlying EFPC), the general trends are also stable or decreasing. However, one shallow well (GW-605) exhibits an increasing trend in chloroethenes, indicating active transport in that region of the groundwater plume. The well is west and upgradient of the pumping well (GW-845) operated to capture the east end VOC plume before it migrates off the ORR into Union Valley (see additional information in the Exit Pathway and Perimeter Monitoring section below). The pumping well may be causing mobilization in the region of well GW-605. Other than well GW-605, the decreasing and stable trends west of New Hope Pond are indicators that the contaminants are attenuating due to factors such as: (1) dilution by uncontaminated groundwater, (2) dispersion through a network of fractures and conduits, (3) degradation by chemical or biological means, and/or (4) adsorption by surrounding bedrock and soil media.

Wells east of New Hope Pond and north of well GW-845 exhibit stable to increasing trends in VOCs, indicating that little impact from the plume capture system is apparent across lithologic units (perpendicular to strike). However, no downgradient detection of these compounds is apparent; therefore, either migration is limited, or some downgradient across-strike influence by the plume capture system is occurring.

Radionuclides

The primary alpha-emitting radionuclides found in the upper EFPC regime during CY 2018 are isotopes of uranium. Exceedances of the drinking water standard for gross alpha (15 pCi/L) have been observed near the S-3 site, the Salvage Yard, and other western source areas; in the central areas near production facilities and the Uranium Oxide Vault; and also in the east end near the former oil skimmer basin at the former inlet to the New Hope Pond, which was capped in 1988. In CY 2018, the maximum occurrence of gross-alpha activity in groundwater in the upper EFPC regime was 351 pCi/L at well GW-154.

The primary beta-emitting radionuclides observed in the upper EFPC regime are ^{99}Tc and isotopes of uranium. Elevated gross-beta activity in groundwater shows a pattern similar to that observed for gross-alpha activity.

Technetium-99 is the primary contaminant exceeding the gross-beta screening level of 50 pCi/L; the source is the S-3 site. The highest gross-beta activity in groundwater was observed during CY 2018 from well GW-108 (9,060 pCi/L).

Exit Pathway and Perimeter Monitoring

In the upper EFPC regime, VOCs have been observed at depths of up to 500 ft below ground surface. The deep fractures and solution channels within the Maynardville Limestone (the primary exit pathway) appear to be well connected and facilitate contaminant migration into Union Valley offsite to the east of Y-12.

Because of the off-site migration of contaminants, a plume capture system (the East End VOC Treatment System [EEVOCTS]) was constructed in and around existing well GW-845 in June 2000 and began continuous operation in October 2000. This system pumps groundwater from the intermediate bedrock 48 to 134 m (157 to 438 ft) below ground surface to mitigate the off-site migration of VOCs. Groundwater is continuously pumped from the Maynardville Limestone at about 95 L/min (25 gal/min), passes through a treatment system to remove the VOCs, and then discharges to upper EFPC.

Monitoring wells near the plume capture system have shown an encouraging response. For example, the Westbay multiport system installed in well GW-722, about 153 m (500 ft) east and downgradient of the system, permits sampling of vertically discrete zones within the Maynardville Limestone between 27 and 130 m (87 and 425 ft) below ground surface (Figure 4.29). This well has been instrumental in characterizing the vertical extent of the east-end plume of VOCs and is critical in the evaluation of the effectiveness of the plume capture system. Monitoring results from well GW-722 indicate reductions in VOCs due to the plume capture system, as shown in sample zone GW-722-17 (385 ft below ground surface) in Figure 4.32. These indicators demonstrate that operation of the plume capture system is decreasing VOC contamination.

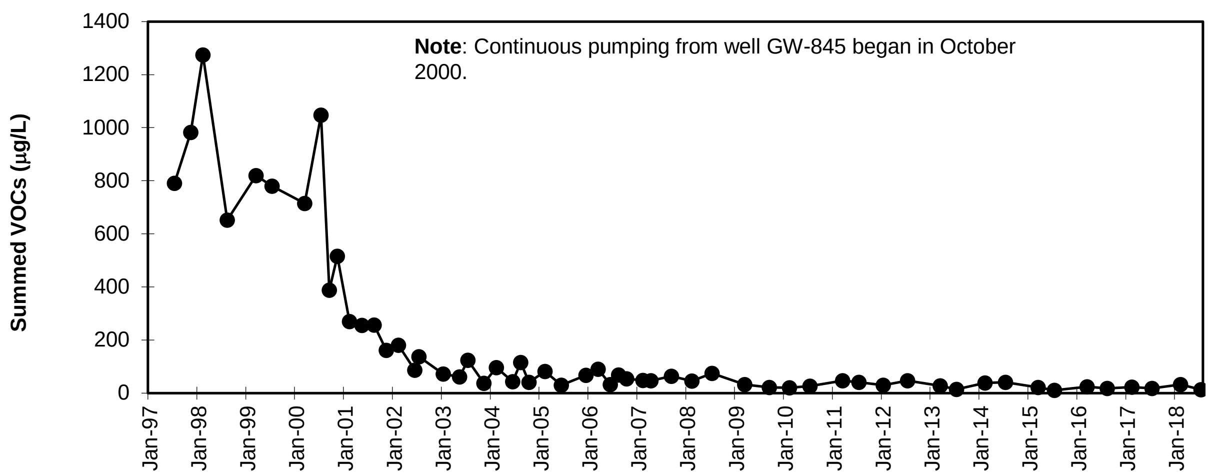


Figure 4.32. Decreasing summed volatile organic compounds observed in exit pathway well GW-722-17 near New Hope Pond, 2018

Five zones in well GW-722 were sampled in CY 2018, with four of the five zones showing summed VOCs greater than 5 µg/L. Only four zones exceeded individual drinking standards (from carbon tetrachloride and PCE, the highest of which was 41 µg/L of carbon tetrachloride).

In addition to the deep system in the eastern portion of upper EFPC, VOCs have also been observed in the shallow groundwater where it flows north-northeast (mimicking the flow of the creek) east of the New Hope Pond site and Lake Reality. In this area, GW-832 has been installed in a distribution channel underdrain associated with the former New Hope Pond. During CY 2018, the observed concentrations of VOCs at the New Hope Pond distribution channel underdrain remained low (30.4 µg/L).

Upper EFPC flows north exiting Y-12 through a gap in Pine Ridge. As mentioned previously, shallow groundwater mimics the creek and also moves through Pine Ridge due to strong upward vertical flow gradients. Monitoring of the wells in this gap has shown no indication of contaminants moving via that exit pathway. One shallow well was monitored in CY 2018, and no groundwater contaminants were detected.

Perimeter sampling locations continue to be monitored north and northwest of Y-12 to evaluate possible contaminant transport, even though those locations are considered unlikely contaminant exit pathways. One of the stations monitored is a tributary that drains the north slope of Pine Ridge and discharges into the adjacent Scarboro Community. One location monitors an upper reach of Mill Branch, which discharges into the residential areas along Wiltshire Drive. The remaining location monitors Gum Hollow Branch as it flows adjacent to the Country Club Estates community. There were no indications that contaminants were being discharged from the ORR into those communities.

Union Valley Monitoring

Groundwater monitoring data obtained during the early 1990s provided the first indication that VOCs were being transported off the ORR through the deep Maynardville Limestone exit pathway. The upper EFPC RI (DOE 1998) discussed the nature and extent of the VOC contamination in Union Valley.

In CY 2018, monitoring of locations in Union Valley continued, showing overall decreasing or low concentration stable trends. Vinyl chloride at 2.1 µg/L (just above the maximum contaminant level of 2 mg/L) was detected at GW-230.

Under the terms of an Interim ROD, administrative controls such as restrictions on potential future groundwater use have been established and maintained. Additionally, the previously discussed EEVOCTS (well GW-845) was installed to mitigate the migration of groundwater contaminated with VOCs into Union Valley (DOE 2018b).

In July 2006, the Agency for Toxic Substances and Diseases Registry, the principal federal public health agency charged with evaluating the human health effects of exposure to hazardous substances in the environment, published a report in which groundwater contamination across the ORR was evaluated (ATSDR 2006). In the report, it was acknowledged that groundwater contamination exists throughout the ORR, but the authors concluded that there is no public health hazard from exposure to contaminated groundwater originating on the ORR. The Y-12 east end VOC groundwater contaminant plume was acknowledged as the only confirmed off-site contaminant plume migrating across the ORR boundary. The report recognized that the institutional and administrative controls established in the ROD do not provide for reduction in toxicity, mobility, or volume of contaminants of concern, but it concluded that the controls are protective of public health to the extent that they limit or prevent community exposure to contaminated groundwater in Union Valley.

4.6.4.2 Bear Creek Hydrogeologic Regime

Located west of Y-12 in Bear Creek Valley, the Bear Creek regime is bounded to the north by Pine Ridge and to the south by Chestnut Ridge. The regime encompasses the portion of Bear Creek Valley extending from the west end of Y-12 to State Highway 95. Descriptions of waste management sites in the Bear

Creek regime and shown on Figure 4.24 have been provided in previous year ASERs and are not repeated this year.

Plume Delineation

The primary contaminants in the Bear Creek regime are nitrate, trace metals, VOCs, and radionuclides. The S-3 site is a source of all four contaminants. The Bear Creek Burial Grounds and the Oil Landfarm waste management areas are sources of uranium, other trace metals, and VOCs. Chlorinated hydrocarbons and PCBs have been observed as deep as 82 m (270 ft) below the Bear Creek Burial Grounds (MMES 1990).

Contaminant plume boundaries are constrained by the bedrock formations (particularly the Nolichucky Shale) that underlie the waste disposal areas in the Bear Creek regime. This fractured aquitard unit is north of and adjacent to the exit pathway unit, the Maynardville Limestone (an aquifer). The elongated shape of the plumes in the Bear Creek regime is the result of preferential transport of the contaminants parallel to strike (parallel to the valley axis) in the Maynardville Limestone, as well as the aquitard.

The plumes in the Bear Creek regime (shown by gray shading on Figures 4.28 through 4.31) represent the average concentrations and radioactivity between CYs 2013 and 2017. The circular icons presented on the figures represent CY 2018 monitoring results.

Nitrate

CY 2018 data indicate that nitrate in groundwater continues to exceed the drinking water standard (10 mg/L) in an area that extends west from the S-3 site. The highest nitrate concentration (2,100 mg/L) was observed at well GW-246 adjacent to the S-3 site at a depth of 19 m (62.5 ft) below ground surface. Historically elevated concentrations of nitrate (>1,000 mg/L) have been detected at greater depths (>700 ft below ground surface) near the S-3 site. In CY 2018 a concentration exceeding the drinking water standard was detected in groundwater as far as 2,438 m (8,000 ft) west of the S-3 site, from spring location SS-4 (17 mg/L).

Trace Metals

During CY 2018, barium, beryllium, cadmium, nickel, and uranium were identified as trace metal contaminants in the Bear Creek regime that exceeded primary drinking water standards. Elevated concentrations of many of the trace metals were observed at shallow depths near the S-3 site. In the Bear Creek regime, where natural geochemical conditions prevail, the trace metals may occur sporadically and in close association with source areas because conditions are typically not favorable for dissolution and migration. Disposal of acidic liquid wastes at the S-3 site reduced the pH of the groundwater, which allows the metals to remain in solution longer and migrate further from the source area.

The most prevalent trace metal contaminant is uranium. Early characterization indicated that the Boneyard-Burnyard site was the primary source of uranium contamination. In 2003, the final remedial actions at the Boneyard-Burnyard were performed. There were decreases in uranium concentration and flux in the surface water tributary downstream of the Boneyard-Burnyard (NT-3), which indicate that the remedial actions were successful. There has been a decrease in uranium in Bear Creek since 1990 (Table 4.20); however, uranium concentrations in the upper reaches of Bear Creek have been stable, indicating that this contaminant still presents an impact in surface water and groundwater.

Other trace metals observed in the Bear Creek regime are arsenic, boron, chromium, copper, lead, mercury, selenium, strontium, thallium, and zinc. Concentrations have commonly exceeded background values near source areas.

Table 4.20. Nitrate and uranium concentrations in Bear Creek

Bear Creek Monitoring station (distance from S-3 site)	Contaminant	Average concentration[a] (mg/L)					
		1990–1994	1995–1999	2000–2004	2005–2009	2010–2014	2015–2018
BCK-11.84 to 11.97	Nitrate	116	65.7	89.5	43.3	53.3	31.8
(approximately 0.5 miles downstream)	Uranium	0.203	0.112	0.129	0.112	0.172	0.186
BCK-09.20 to 09.47	Nitrate	16.1	7.8	12.1	8.4	4.4	5.7
(approximately 2 miles downstream)	Uranium	0.098	0.093	0.135	0.060	0.051	0.071
BCK-04.55	Nitrate	4.7	2.3	3.5	1.1	0.8	0.95
(approximately 5 miles downstream)	Uranium	0.034	0.030	0.033	0.020	0.016	0.018

[a] Excludes results that do not meet data quality objectives.
BCK = Bear Creek kilometer

Volatile Organic Compounds

VOCs are widespread in groundwater in the Bear Creek regime. The primary compounds are PCE; TCE; cis-1,2-DCE; vinyl chloride; and 1,1-dichoroethane. In most areas, they are dissolved in the groundwater and can occur in bedrock at depths up to 92 m (300 ft) below ground surface and can extend 305 m (1,000 ft) laterally from source areas. The highest concentration observed in CY 2018 occurred in the Nolichucky Shale aquitard at the Bear Creek Burial Ground waste management area, with a maximum summed VOC concentration of 7,503 µg/L in well GW-068 (Figure 4.29); cis-1,2-DCE at 3,700 µg/L provides approximately one-half of the summed VOCs.

Near contaminant source areas, such as the Bear Creek Burial Grounds and the Oil Landfarm waste management areas, a variety of concentration trends are observed. These trends are dependent upon proximity to sources and hydrogeologic conditions. Decreasing and stable VOC trends dominate, as observed in wells GW-014 and GW-046 (Figure 4.33).

Increasing trends of VOCs are seen in GW-627 and GW-082 downgradient of the Bear Creek Burial Grounds waste management area (Figure 4.34). These trends indicate the continued presence and migration of a dense nonaqueous-phase source below the Bear Creek Burial Grounds, and a decreasing trend may indicate degradation.

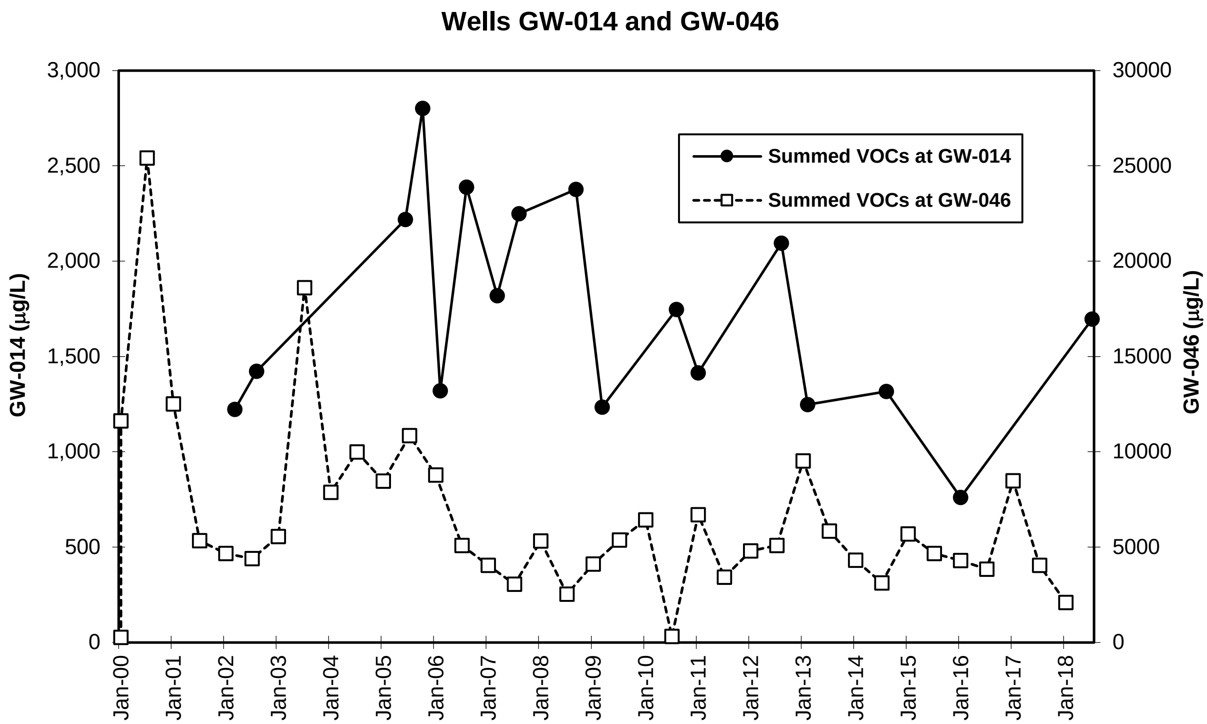


Figure 4.33. Volatile organic compounds in wells GW-014 and GW-046 at the Bear Creek Burial Grounds, 2018

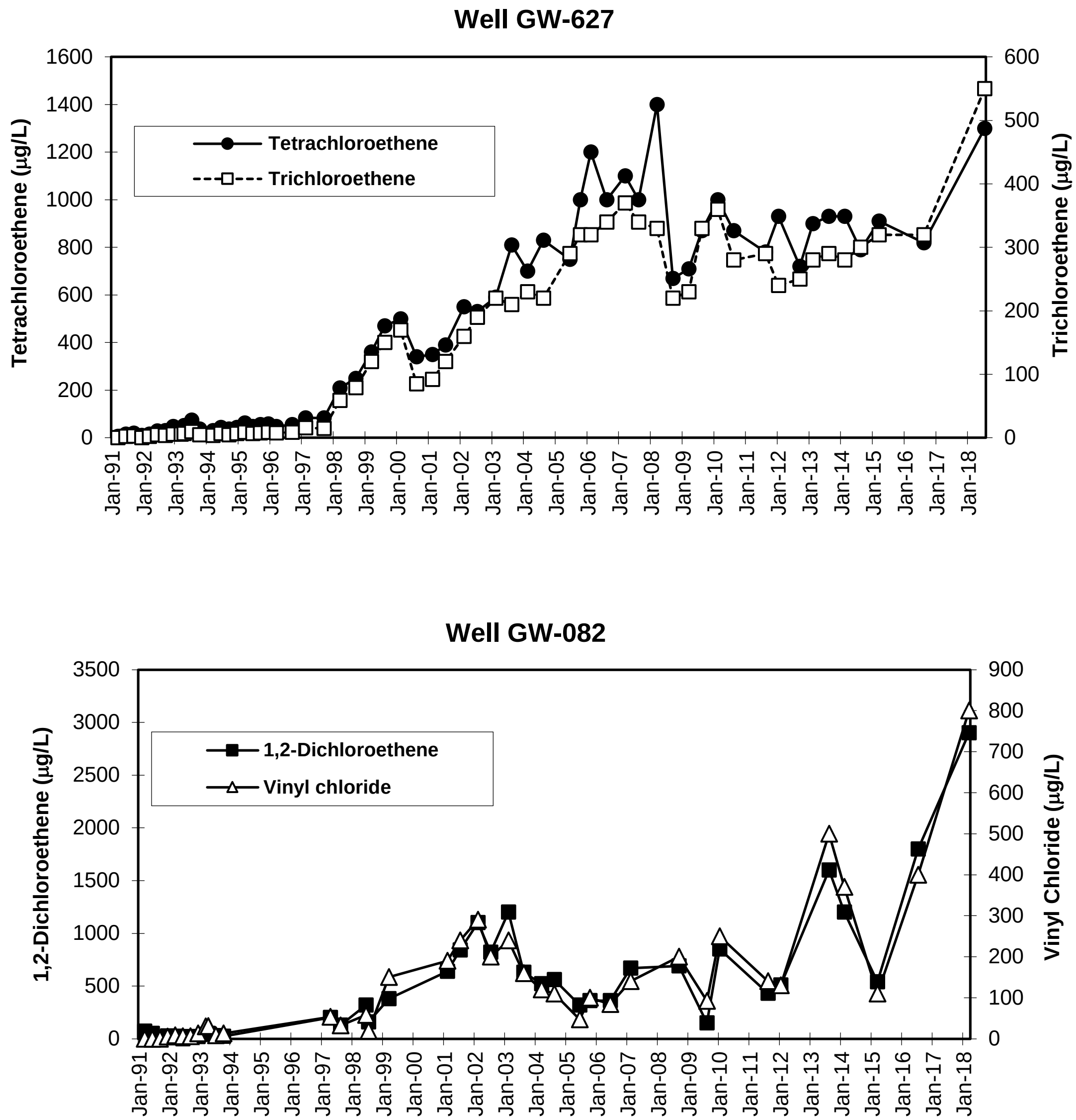


Figure 4.34. Volatile organic compounds in wells GW-627 and GW-082 at the Bear Creek Burial Grounds, 2018

CY 2014 data from well GW-729-44 showed that, in the intermediate-deep groundwater interval (98 m [320 ft] below ground surface), a dissolved plume extends at least 2,591 m (8,500 ft) westward from the S-3 site to just south of the Bear Creek Burial Ground waste management area. In CY 2018, wells at exit pathway transect W (Figure 4.25) showed a trace concentration (0.32 µg/L) of TCE (below drinking water standards), thus indicating migration of contaminants through the Maynardville Limestone a distance of 4,785 m (15,700 ft) from the S-3 Ponds.

Radionuclides

As in the EFPC regime, the primary radionuclides identified in the Bear Creek regime are isotopes of uranium and ^{99}Tc. Neptunium, americium, radium, strontium, thorium, plutonium, and tritium are secondary and less-widespread radionuclides that have been observed historically near the S-3 site.

The extent of radionuclides in groundwater in the Bear Creek regime during CY 2018 was based primarily on measurements of gross-alpha and gross-beta activity. If the gross-alpha activity in a well exceeded 15 pCi/L (the drinking water standard for gross-alpha activity), then one (or more) of the alpha-emitting radionuclides (e.g., uranium) is assumed to be present and, at certain monitoring locations, is evaluated isotopically. A similar rationale is used for gross-beta activity that exceeds 50 pCi/L. Technetium-99, a more volatile radionuclide, is qualitatively screened by gross-beta activity analysis.

Groundwater in the Bear Creek regime with elevated gross-alpha activity occurs near the S-3 site and the Oil Landfarm waste management area. In the bedrock interval, gross-alpha activity has exceeded 15 pCi/L in groundwater in the fractured bedrock of the aquitard units only near source areas (Figure 4.30).

Exit pathway monitoring stations sampled during CY 2018 show that gross-alpha activity in the Maynardville Limestone and in the surface waters of Bear Creek exceeds the drinking water standard for over 3,353 m (11,000 ft) west of the S-3 site (SS-5, 19 pCi/L). The highest gross-alpha activity observed in the Bear Creek regime in groundwater was located adjacent to the S-3 site in CY 2018 (110 pCi/L in well GW-246, Figure 4.30).

In CY 2018, the highest gross-beta activity in groundwater in the Bear Creek regime was also observed at well GW-246 (8,600 pCi/L, Figure 4.31).

Exit Pathway and Perimeter Monitoring

Bear Creek, which flows along the Maynardville Limestone (the primary exit pathway for groundwater) in much of the Bear Creek regime, is the principal exit pathway for surface water. Studies have shown that the surface water in Bear Creek, the springs along the valley floor, and the groundwater in the Maynardville Limestone are hydraulically connected. Surveys have been performed that identify gaining (groundwater discharging into surface waters) and losing (surface water discharging into a groundwater system) reaches of Bear Creek. The western exit pathway well transect (Picket W) serves as the perimeter designation for the Bear Creek regime (Figure 4.25).

Exit pathway monitoring consists of continued monitoring at four well transects (pickets) and selected springs and surface water stations. Data obtained during CY 2018 indicate that groundwater is contaminated above drinking water standards in the Maynardville Limestone between Pickets A and C. Trends continue to be generally stable to decreasing (Figure 4.35).

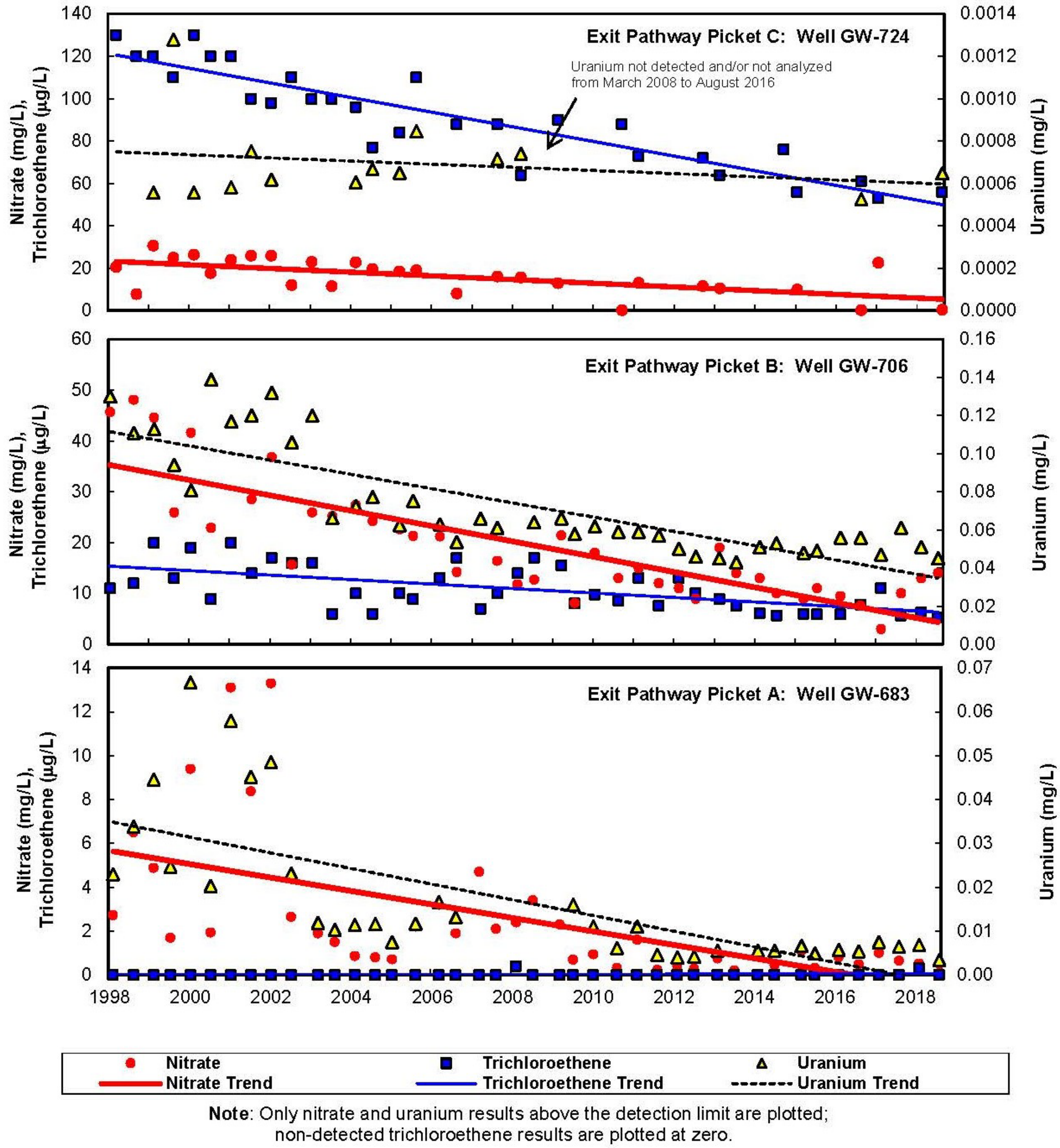


Figure 4.35. Calendar Year 2018 concentrations of selected contaminants in exit pathway monitoring wells in the Bear Creek hydrogeologic regime

Surface water samples collected during CY 2018 indicate that water in Bear Creek contains many of the same compounds found in the groundwater. Uranium concentrations exceeding the drinking water standard have been observed in surface water west of the Burial Grounds as far as Picket W. The concentrations in the creek generally decrease with distance downstream of the waste disposal sites (Table 4.20).

4.6.4.3 Chestnut Ridge Hydrogeologic Regime

The Chestnut Ridge hydrogeologic regime is flanked to the north by Bear Creek Valley and to the south by Bethel Valley Road (Figure 4.25). The regime encompasses the portion of Chestnut Ridge extending from Scarboro Road, east of the complex, to Dunaway Branch, located just west of Industrial Landfill II. Descriptions of waste management sites in the Chestnut Ridge regime and shown on Figure 4.24 have been provided in previous year ASERs and are not repeated this year.

The Chestnut Ridge Security Pits area is the primary source of groundwater contamination in the regime. Contamination from the security pits is distinct and does not mingle with plumes from other sources.

Plume Delineation

The extent of the VOC plume at the Chestnut Ridge Security Pits (CRSP) is reasonably well defined in the water table and shallow bedrock zones. With two exceptions, mentioned in the next paragraph, historical monitoring indicates that the VOC plume from the CRSP has not migrated very far in any direction (<305 m [<1,000 ft]).

Data obtained during CY 2018 indicate that the western lateral extent of the plume of VOCs at the site has not changed significantly. VOC contaminants at a well about 458 m (1,500 ft) southeast and downgradient of the CRSP (well GW-798; Figure 4.29) continue to show that some migration of the eastern plume has occurred. Additionally, previously performed dye tracer test results and the intermittent detection of trace concentrations of VOCs (similar to those found in wells adjacent to the CRSP) and at a natural spring (SCR7.8SP) about 2,745 m (9,000 ft) to the east and along geologic strike may suggest that CRSP contaminants have migrated further than the monitoring well network indicates. No VOCs were detected at SCR7.8SP in 2018.

The CRSP plume in the Chestnut Ridge regime (shown by gray shading on Figure 4.29) represents the average VOC concentrations between CYs 2013 and 2017. The circular icons presented on the figure represent CY 2018 monitoring results.

Nitrate

In CY 2018, nitrate concentrations were below the drinking water standard at all monitoring stations in the Chestnut Ridge regime.

Trace Metals

Concentrations of arsenic were observed in two surface water monitoring locations downstream from the Filled Coal Ash Pond, which is monitored under a CERCLA ROD (DOE 2018b). Under the ROD, migration of contaminated effluent from the Filled Coal Ash Pond is being reduced by a constructed wetland area. During CY 2018, elevated arsenic levels were detected both upgradient (McCoy Branch kilometer [MCK] 2.05) and downgradient (MCK 2.0) of this wetland area (Figure 4.25). The passive wetland treatment area reduced dissolved arsenic by about 50 percent in the wet-season sample, but there was a small increase in total arsenic at the downgradient location. During the dry season, the passive wetland treatment area reduced total arsenic by 35 percent and dissolved arsenic by 60 percent (DOE 2019). A surface water monitoring location (MCK 1.4) about 1,021 m (3,900 ft) downstream from the Filled Coal Ash Pond was also sampled during CY 2018; arsenic was detected below drinking water standards.

Volatile Organic Compounds

Concentrations of VOCs in groundwater at the CRSPs have decreased since 1988. However, stable to increasing trends in VOCs from well GW-798 (Figure 4.29) have been developing since CY 2000. The maximum summed VOC concentration observed at well GW-798 during CY 2018 was 12.33 µg/L. The VOCs detected in well GW-798 continue to be characteristic of the CRSP plume.

In CY 2018, the highest summed VOC in the Chestnut Ridge regime was in another well at the CRSP, GW-322 with 66 µg/L (Figure 4.29).

At Industrial Landfill IV, VOCs have been observed in the groundwater since 1992. Well GW-305, located immediately to the southeast of the facility, continues to exhibit increasing trends in summed VOCs with the CY 2018 summed VOC concentration at 86 µg/L, slightly lower than CY 2017. Because samples from this well exceeded the drinking water standard for 1,1-DCE (7 µg/L), quarterly monitoring was initiated in CY 2 015 to further evaluate the trend. The CY 2015 samples had concentrations of 5.8 to 9.8 µg/L, but in CY 2016, only one quarterly sample exceed the drinking water standard for 1,1-DCE at a concentration of 7.43 µg/L. And again in CY 2017, only one quarterly sample exceeded the drinking water standard for 1,1-DCE at a concentration of 7.17 µg/L. In CY 2018, no sample exceeded the drinking water standard at this well.

Radionuclides

In CY 2018, no gross-alpha or gross-beta activity above the drinking water standard of 15 and 50 pCi/L, respectively, was observed in the Chestnut Ridge hydrogeologic regime.

Exit Pathway and Perimeter Monitoring

Contaminant and groundwater flow paths in the karst bedrock underlying the Chestnut Ridge regime have not been well characterized. Tracer studies have been conducted that show groundwater from Chestnut Ridge discharging into Scarboro Creek and other tributaries that feed into Melton Hill Lake. However, no springs or surface streams that represent discharge points for groundwater have been conclusively correlated to a waste management unit or operation at Y-12 that is a known or potential groundwater contaminant source. Water quality from springs along Scarboro Creek is monitored, and trace concentrations of VOCs are intermittently detected. The detected VOCs are suspected to originate from the CRSP; however, this has not been confirmed. In CY 2018, two springs were sampled with no detected concentrations of VOCs.

Monitoring natural groundwater exit pathways is a basic monitoring strategy in a karst regime such as that of Chestnut Ridge. Perimeter springs and surface water tributaries were monitored to determine whether contaminants are exiting the downgradient (southern) side of the regime. Six springs and four surface water monitoring locations were sampled during CY 2018. No contaminants at any of these monitoring stations were detected at levels above primary drinking water standards.

4.7 Quality Assurance Program

Y-12's QA Program establishes a quality policy and requirements for the overall QA Program for the Y-12 site. Management requirement E-SD-0002, *Quality Assurance Program Description*, details the methods used to carry out work processes safely and securely and in accordance with established procedures (CNS 2017). It also describes mechanisms in place to seek continuous improvements by identifying and correcting findings and preventing recurrences.

Many factors can potentially affect the results of environmental data collection activities, including sampling personnel, methods, and procedures; field conditions; sample handling, preservation, and transport; personnel training; analytical methods; data reporting; and record keeping. QA programs are designed to minimize these sources of variability and to control all phases of the monitoring process.

Field sampling QA encompasses many practices that minimize error and evaluate sampling performance. Some key quality practices include the following:

- Use of work control processes and standard operating procedures for sample collection and analysis.
- Use of chain-of-custody and sample identification procedures.
- Instrument standardization, calibration, and verification.
- Sample technician and laboratory analyst training.
- Sample preservation, handling, and decontamination.
- Use of QC samples, such as field and trip blanks, duplicates, and equipment rinses.

Y-12's Environmental Sampling Services perform field sampling, sample preservation and handling, and chain-of-custody and take field control (QC) samples in accordance with Y-12 Environmental Compliance's internal procedures. Environmental Sampling Services developed a Standards and Calibration Program that conforms to ISO/International Electrotechnical Commission (IEC) 17025, *General Requirements for Competence of Testing and Calibration Laboratories* (ISO 2005), and provides a process for uniform standardization, calibration, and verification of measurement and test equipment. The Standards and Calibration Program ensures measurements are made using appropriate, documented methods; traceable standards; appropriate measurement and test equipment of known accuracy; trained personnel; and technical best practices.

Analytical results may be affected by a large number of factors inherent to the measurement process. Laboratories that support Y-12 environmental monitoring programs use internal QA/QC programs to ensure the early detection of problems that may arise from contamination, inadequate calibrations, calculation errors, or improper procedure performance. Internal laboratory QA/QC programs include routine calibrations of counting instruments; yield determinations; include frequent use of check sources and background counts, replicate and spiked sample analyses, and matrix and reagent blanks; and include maintenance of control charts to indicate analytical deficiencies. These activities are supported by the use of standard materials or reference materials (e.g., materials of known composition that are used in the calibration of instruments, methods standardization, spike additions for recovery tests, and other practices). Certified standards traceable to NIST, DOE sources, or EPA are used (when available) for such work.

Y-12's ACO QA Manual describes QA program elements that are based on Y-12's QA Program; customer-specific requirements; certification program requirements; ISO/IEC 17025, *General Requirements for Competence of Testing and Calibration Laboratories*; federal, state, and local regulations (ISO 2017); and waste acceptance criteria. As a government-owned, contractor-operated laboratory that performs work for DOE, the ACO laboratory operates in accordance with DOE O 414.1D, *Quality Assurance* (DOE 2011d).

Other internal practices used to ensure that laboratory results are representative of actual conditions include training and managing staff; maintaining adequacy of the laboratory environment; safety; controlling the storage, integrity, and identity of samples; record keeping; maintaining and calibrating instruments; and using technically validated and properly documented methods.

Y-12's ACO participated in both Mixed Analyte Performance Evaluation Program studies conducted in 2016 for water, soil, and air filter matrices for metals, organics, and radionuclides. The overall acceptability rating from both studies was greater than 97 percent.

Verification and validation of environmental data are performed as components of the data collection process, which includes planning, sampling, analysis, and data review. Some level of verification and validation of field and analytical data collected for environmental monitoring and restoration programs is necessary to ensure that data conform to applicable regulatory and contractual requirements. Validation of field and analytical data is a technical review performed to compare data with established quality criteria to ensure that data are adequate for the intended use. The extent of project data verification and validation activities is based on project-specific requirements.

For routine environmental effluent monitoring and surveillance monitoring, data verification activities may include processes of checking whether: (1) data have been accurately transcribed and recorded, (2) appropriate procedures have been followed, (3) electronic and hard-copy data show one-to-one correspondence, and (4) data are consistent with expected trends. Typically, routine data verification actions alone are sufficient to document the validity and accuracy of environmental reports. For restoration projects, routine verification activities are more contractually oriented and include checks for data completeness, consistency, and compliance with a predetermined standard or contract.

Certain projects may require a more thorough technical validation of the data, as mandated by the project's data quality objectives. Sampling and analyses conducted as part of an RI to support the CERCLA process may generate data that are needed to evaluate risk to human health and the environment, to document that no further remediation is necessary, or to support a multimillion-dollar construction activity and treatment alternative. In these cases, the data quality objectives of the project may mandate a thorough technical evaluation of the data against rigorous predetermined criteria. The validation process may result in the identification of data that do not meet predetermined QC criteria or in the ultimate rejection of data for their intended use. Typical criteria evaluated in the validation of contract laboratory program data include the percentage of surrogate recoveries, spike recoveries, method blanks, instrument tuning, instrument calibration, continuing calibration verifications, internal standard response, comparison of duplicate samples, and sample holding times.

4.8 Environmental Management and Waste Management Activities

4.8.1 Mercury Technology Development Activities for the Y-12 National Security Complex, East Fork Poplar Creek

Mercury remediation in the Oak Ridge, Tennessee, area is a high priority for DOE. Releases of mercury during Y-12 operations during the 1950s and early 1960s resulted in contamination of surrounding soil, groundwater, and biota. Subsequent transport from the facility resulted in off-site contamination of the lower EFPC. Starting in late 2014, mercury research and technology development activities have been conducted in an effort to develop potential remedial alternatives for lower EFPC.

Research and technology development activities to date have focused on understanding mercury transport and fate in the EFPC system. Monitoring sites from upstream to downstream EFPC were established to measure flow, water chemistry, groundwater, and biota. Field studies have pointed to the importance of bank soil erosion as a source of mercury to the creek, especially in the upstream section. Instream factors such as water chemistry and flow characteristics also influence mercury concentration, including the production of methylmercury. Research studies have also highlighted the importance of methylmercury and its bioaccumulation in the food chain. The early efforts to understand the watershed have added significantly to our understanding of key mercury sources areas and mercury transformations and processes. The watershed-scale mercury information is informing conceptual and dynamic models that can be used for future technology development and remedial decision-making in lower EFPC.

In FY 2018, technology development activities centered on developing strategies and technologies that may influence the major factors controlling mercury bioaccumulation in fish—the amount of mercury to the system, the conversion of inorganic mercury to methylmercury, and the uptake of mercury in the food chain. Field and laboratory studies have focused on narrowing the source zones for mercury and methylmercury flux in the watershed, developing sorbents that might be effective in sequestering mercury, and adding filtering organisms such as mussels that might help change instream chemistry to limit mercury transport on particles or algae. To advance the scale of remediation technology testing beyond the bench scale, preparations are underway to conduct flow-through studies of EFPC water at ORNL's Aquatic Ecology Laboratory.

The multi-year research and technology development effort in lower EFPC is providing detailed and valuable information that will inform remedial alternatives evaluation currently scheduled for the mid-2020s.

Additionally, an analysis of promising technologies and technical approaches to enable the successful completion of Y-12 mercury-use facility demolition and mercury-contaminated waste disposition was completed. The evaluation encompassed techniques for in-situ and ex-situ treatment of debris, mercury measurement techniques, and decontamination methods. The selected technologies and approaches will be evaluated and further refined through the technology development process using bench or pilot-scale studies. The technology development activities and their ultimate outcomes, ideally technologies and methods that can be successfully used at Y-12, will be integrated with the planning for deactivation and demolition. Successful deactivation and demolition of Y-12 mercury-use facilities will ultimately reduce mercury-related ecological risks in EFPC and the overall environment.

4.8.2 Excess Facilities

DOE is preparing to remove five high-risk excess contaminated facilities, known as the Biology, at Y-12. The 350,000-ft^2 area poses asbestos hazards as well as structural deterioration risks. Demolition of these facilities is part of a nationwide effort to eliminate excess contaminated facilities throughout the DOE.

Originally constructed in the 1940s to recover uranium from process streams, the Biology Complex later housed DOE's research on the genetic effects of radiation. The facilities once housed more individuals with doctorates than anywhere in the world. The complex originally consisted of 11 buildings until OREM demolished 4 of them in 2010 as part of the American Recovery and Reinvestment Act of 2009.

Buildings 9743-2 and 9770-2 were demolished in FY 2018, and mobilization started for the demolition of the remaining buildings. The completion of this project will clear land for important future national security missions.

4.8.3 Mercury Treatment Facility

OREM has broken ground on the Outfall 200 Mercury Treatment Facility at Y-12. The facility will reduce mercury in water exiting the site through EFPC. Outfall 200 is the point where the west end of the Y-12 storm drain system creates the headwaters of the upper EFPC.

The mercury treatment facility will help OREM achieve compliance with regulatory criteria for EFPC. It also supports and opens the door for large-scale facility demolition to begin at Y-12 by helping to control potential mercury releases that could occur when disturbing the mercury-contaminated buildings and soil.

In FY 2018, OREM began early site preparation ahead of the planned facility construction. Early site preparation includes construction of the necessary utilities, installation of secant piles, and demolition of existing structures in the area to prepare the site for construction of the mercury treatment facility. OREM anticipates completing early site preparation and beginning construction of the mercury treatment facility in 2019.

4.8.4 Waste Management

4.8.4.1 Comprehensive Environmental Response, Compensation, and Liability Act Waste Disposal

During FY 2018, the Environmental Management Waste Management Facility received 6,305 waste shipments, accounting for 73,510 tons, primarily from soil remediation activities and several smaller cleanup projects at ETTP and Y-12. The Environmental Management Waste Management Facility, an engineered landfill, consists of six disposal cells that only accept low-level radioactive and hazardous CERCLA waste that meets specific waste acceptance criteria. Waste types that qualify for disposal include soil, dried sludge and sediment, solidified waste, stabilized waste, building debris, scrap equipment, personal protective equipment, and classified waste.

4.8.4.2 Solid Waste Disposal

DOE operates and maintains solid waste disposal facilities called the ORR Landfills, three of which are active. In FY 2018, approximately 39,990 yd^3 of waste were disposed in the landfills, which marks a 26-percent decrease from FY 2017 volumes. Clean spoils receipts in FY 2018 were approximately 10,241 yd^3, a 2,315-percent increase from FY 2017. Clean spoils have the potential for being reused and are segregated to avoid taking up valuable landfill space. Several projects will continue to generate large spoils campaigns for FY 2019.

Operation of the ORR Landfills generated approximately 2.7 million gal of leachate that was collected, monitored, and discharged into the Y-12 sanitary sewer system.

4.8.4.3 Wastewater Treatment

NNSA at Y-12 treats wastewater generated from both production activities and environmental cleanup activities. Safe and compliant treatment of more than 127 million gal of wastewater was provided at various facilities during CY 2018:

- The West End Treatment Facility and the Central Pollution Control Facility at Y-12 processed more than 728,000 gal of wastewater, primarily in support of NNSA operational activities.
- The Big Springs Water Treatment System treated more than 109 million gal of mercury-contaminated groundwater. The EEVOCTS treated 12.7 million gal of VOC-contaminated groundwater.
- The Liquid Storage Facility and Groundwater Treatment Facility treated more than 2.7 million gal of leachate from burial grounds and well purge waters from remediation areas.
- The Central Mercury Treatment System treated approximately 1.9 million gal of mercury-contaminated sump waters from the Alpha-4 building.

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5. Oak Ridge National Laboratory

ORNL is the largest DOE science and energy laboratory. Basic and applied research at ORNL delivers transformative solutions to compelling problems in energy and security.

Diverse capabilities at ORNL span a broad range of scientific and engineering disciplines, enabling the exploration of fundamental science challenges and the research needed to accelerate the delivery of solutions to the marketplace. ORNL supports DOE’s national missions of scientific discovery, clean energy, and security through four major areas:

- **Neutrons**—The Spallation Neutron Source and the High Flux Isotope Reactor, two of the world’s leading neutron sources, are operated at ORNL, enabling scientists and engineers to gain new insights into materials and biological systems.
- **Computing**—ORNL programs accelerate scientific discovery through modeling and simulation on powerful supercomputers and advance data-intensive science and US leadership in high-performance computing.
- **Materials**—Basic research and applied research are integrated at ORNL to develop advanced materials for energy applications.
- **Nuclear**—ORNL programs advance the scientific basis for 21st century nuclear fission and fusion technologies and systems and produce isotopes for research, industry, and medicine.

In addition, nine world-class facilities that support ORNL’s research and development activities are also available to users from universities, industry, and other institutions:

- Building Technologies Research and Integration Center
- Carbon Fiber Technology Facility
- Center for Nanophase Materials Sciences
- Center for Structural Molecular Biology
- High Flux Isotope Reactor
- Manufacturing Demonstration Facility
- National Transportation Research Center
- Oak Ridge Leadership Computing Facility
- Spallation Neutron Source

ORNL is managed by UT-Battelle, LLC, a partnership between the University of Tennessee and Battelle Memorial Institute. Other DOE contractors conducting activities at ORNL in 2018 included North Wind Solutions, LLC; URS | CH2M Oak Ridge LLC; and Isotek Systems LLC. During 2018 activities of these contractors were conducted to comply with contractual and regulatory environmental requirements.

Due to different permit reporting requirements and instrument capabilities, this report uses various units of measurement. The lists of units of measure and conversion factors on pages xxvii and xxviii are included to help readers convert numeric values presented herein as needed for specific calculations and comparisons.

5.1 Description of Site, Missions, and Operations

ORNL, which is managed for DOE by UT-Battelle, LLC, a partnership of the University of Tennessee and Battelle Memorial Institute, lies in the southwest corner of ORR (Figure 5.1) and includes facilities in two valleys (Bethel and Melton) and on Chestnut Ridge. ORNL was established in 1943 as part of the secret Manhattan Project to pioneer a method for producing and separating plutonium. During the 1950s and 1960s, and with the creation of DOE in the 1970s, ORNL became an international center for the study of nuclear energy and related research in the physical and life sciences. By the turn of the century, the laboratory supported the nation with a peacetime science and technology mission that was just as important as, but very different from, the work carried out in the days of the Manhattan Project.

ETTP: East Tennessee Technology Park; ORISE: Oak Ridge Institute for Science and Education; Y-12: Y-12 National Security Complex

Figure 5.1. Location of ORNL within ORR and its relationship to other local DOE facilities

The laboratory began as an institution of science, engineering, and collaboration and has continued those traditions through the decades of its history. ORNL celebrated a major event in 2018: its 75th anniversary. Activities that took place for the celebration included “Take Your Child to Work Day” (Figure 5.2); “Lab Day” (Figure 5.3), when the laboratory was open to members of the public who had preregistered; and the installation of IBM Summit (Figure 5.4), the fastest supercomputer in the world. Officially launched during Lab Day, Summit provides unprecedented computing power for research areas such as energy, advanced materials, astrophysics, systems biology, and artificial intelligence.

Figure 5.2. Take Your Child to Work Day featured hands-on activities for the attendees

Figure 5.3. Lab Day gave the public a chance to learn about the work being done at ORNL

Figure 5.4. The Summit supercomputer began operation in 2018

In March 2007, Isotek Systems LLC (Isotek) assumed responsibility for the Building 3019 Complex at ORNL, where the national repository of ^{233}U has been kept since 1962. In 2010, an "alternatives analysis" was conducted to evaluate methods available for ^{233}U disposition, and in 2011, the recommendations in the *Final Draft* ^{233}*U Alternatives Analysis Phase I Report* (DOE 2011b) were endorsed. The Phase I recommendations included (1) transfer of Zero-Power Reactor (ZPR) plate canisters to the National Nuclear Security Administration and disposal of Consolidated Edison Uranium Solidification Project (CEUSP) material canisters and (2) completing a Phase II alternatives analysis for processing the remaining 50 percent of the inventory. The transfer of the ZPR plate canisters was completed in 2012. Disposal of the CEUSP material canisters began in 2015 and was completed in 2017. Plans and preparations for the disposition of the remaining ^{233}U inventory are under way. Building 2026 was transferred from UT-Battelle to Isotek in May of 2017. Preparations are under way for start-up for processing in Building 2026.

UT-Battelle provides air and water quality monitoring support for the Building 3019 complex; results are included in the UT-Battelle air and water monitoring discussions in this chapter.

UCOR is the DOE ORR cleanup contractor. The scope of UCOR activities at ORNL includes long-term surveillance, maintenance, and management of inactive waste disposal sites, structures, and buildings such as former reactors and isotope production facilities. Other activities include groundwater monitoring, transuranic (TRU) waste storage, and operation of the wastewater treatment facility and the waste-processing facility for liquid low-level radioactive waste (LLW).

As of December 11, 2015, North Wind Solutions, LLC, (NWSol) has been the prime contractor for the Transuranic Waste Processing Center (TWPC), which is located on the western boundary of ORNL on about 26 acres of land adjacent to the Melton Valley Storage Tanks along State Route 95. TWPC's mission is to receive TRU wastes for processing, treatment, repackaging, and shipment to designated facilities for final disposal. TWPC consists of the waste-processing facility, the personnel building, and numerous support buildings and storage areas. TWPC began processing supernatant liquid from the Melton Valley Storage Tanks in 2002, contact-handled (CH) debris waste in December 2005, and remotely handled (RH) debris waste in May 2008. Based on the definition of TRU waste, some waste being managed as TRU is later determined to be LLW or mixed LLW. UT-Battelle provides water quality monitoring for operations at the TWPC, and results are included in water-monitoring discussions in this chapter. Air-monitoring data from TWPC are provided to UT-Battelle for inclusion in the ORR National Emission Standards for Hazardous Air Pollutants for Radionuclides (Rad-NESHAPs) annual report and is incorporated into air-monitoring discussions in this chapter.

UT-Battelle manages several facilities located off the main ORNL campus for DOE. The Hardin Valley Campus (HVC) is home to the National Transportation Research Center (NTRC) **here** and the Manufacturing Demonstration Facility (MDF) **here**. HVC is located on a 6 acre site owned by Pellissippi Investors, LLC, and is leased to UT-Battelle and the University of Tennessee. Approximately 152 industry partners work at the HVC to shape America's mobility future. NTRC is DOE's only user facility dedicated to transportation and serves as the gateway to UT-Battelle's comprehensive capabilities for transportation research and development (R&D). Research focuses on fuels and lubricants, engines, emissions, electric drive technologies, lightweight and power-train materials, vehicle systems integration, energy storage and fuel cell technologies, vehicle cyber security, and intelligent transportation systems.

MDF focuses on advanced manufacturing research, including the development of carbon fiber composites and additive manufacturing involving polymers, metal wires, and metal powders. The facility hosts the Institute for Advanced Composites Manufacturing Innovation lab space and an outreach program for local high school students.

The Carbon Fiber Technology Facility (CFTF) **here**, a leased 42,000 ft^2 innovative technology facility located in the Horizon Center Business Park, offers a flexible, highly instrumented carbon fiber line for demonstrating the scalability of advanced carbon fiber technology and for producing market-development volumes of prototypical carbon fibers (Figure 5.5). CFTF is the world's most capable open-access facility for the scale-up of emerging carbon fiber technology. The cost of carbon fiber material remains relatively high, prohibiting widespread adoption of carbon fiber–containing composite materials in the automotive manufacturing industry, which requires lower commodity pricing. The lower-cost carbon fiber produced at ORNL meets the performance criteria prescribed by some automotive manufacturers for carbon fiber materials for use in high-volume vehicle applications.

UT-Battelle also manages several buildings and trailers located at Y-12 and in the city of Oak Ridge.

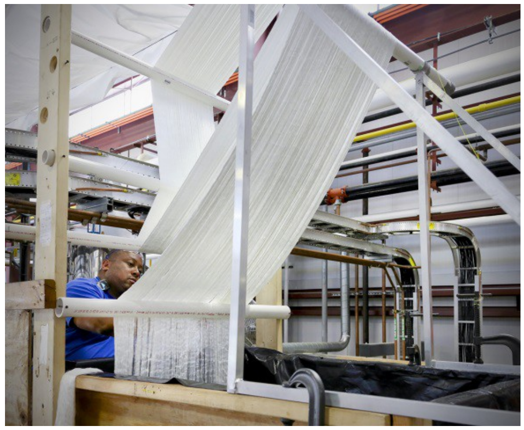


Photo by Jason Richards.

Figure 5.5. Production of lower-cost carbon fiber at the Carbon Fiber Technology Facility

5.2 Environmental Management Systems

Demonstration of environmental excellence through high-level policies that clearly state expectations for continual improvement, pollution prevention, and compliance with regulations and other requirements is a priority at ORNL. In accordance with DOE Order 436.1, *Departmental Sustainability* (DOE 2011), UT-Battelle, NWSol, UCOR, and Isotek have implemented environmental management systems (EMSs), modeled after International Organization for Standardization (ISO) 14001 (ISO 2015), to measure, manage, and control environmental impacts. An EMS is a continuing cycle of planning, implementing, evaluating, and improving processes and actions undertaken to achieve environmental goals.

5.2.1 UT-Battelle Environmental Management System

UT-Battelle's EMS is designed to fully comply with all applicable requirements and to continually improve ORNL's environmental performance. Until August 2018, UT-Battelle was registered to the ISO 14001:2015 standard and had maintained ISO 14001 registration since 2004. In FY 2018 a management decision was made to transition from registration to a declaration of conformance to the ISO 14001:2015. Because of this decision, the external registration audits have been discontinued.

UT-Battelle's EMS is a fully integrated set of environmental management services for UT-Battelle activities and facilities. Services include pollution prevention, waste management, effluent management, regulatory review, reporting, permitting, and other environmental management programs. Through the UT-Battelle Standards-Based Management System (SBMS), the EMS establishes environmental policy and translates environmental laws, applicable DOE orders, and other requirements into laboratory-wide subject area documents (procedures and guidelines). Through environmental protection officers, environmental compliance representatives, and waste services representatives (WSRs), the UT-Battelle EMS assists the line organizations in complying with environmental requirements.

5.2.1.1 Integration with the Integrated Safety Management System

The objective of the UT-Battelle Integrated Safety Management System (ISMS) is to systematically integrate environment, safety, and health (ES&H) requirements and controls into all work activities and to ensure protection of the workers, the environment, and the public. The UT-Battelle EMS and the ISMS are integrated to provide a unified strategy for the management of resources, the control and attenuation of risks, and the establishment and achievement of the organization's ES&H goals. Guided by the ISMS and EMS, UT-Battelle strives for continual improvement through "plan-do-check-act" cycles. Under the ISMS, the term "safety" also encompasses ES&H, including pollution prevention, waste minimization, and resource conservation. Therefore, the guiding principles and core functions in the ISMS apply both to the protection of the environment and to safety. The UT-Battelle EMS is consistent with the ISMS and includes all the elements in the ISO 14001:2015 standard.

5.2.1.2 UT-Battelle Environmental Policy for ORNL

UT-Battelle's Environmental Policy for ORNL **here** clearly states expectations and provides the framework for setting and reviewing environmental objectives.

5.2.1.3 Planning

UT-Battelle Environmental Aspects

Environmental aspects are elements of an organization's activities, products, or services that can interact with the environment. Environmental aspects associated with UT-Battelle activities, products, and services have been identified at both the division level and laboratory level. Activities that are relative to any of the aspects are carefully controlled to minimize or eliminate impacts to the environment. Nine significant environmental aspects (listed **here**) have been identified as potentially having significant environmental impacts.

UT-Battelle Legal and Other Requirements

Legal and other requirements that apply to the environmental aspects identified by UT-Battelle include federal, state, and local laws and regulations; environmental permits; applicable DOE orders; UT-Battelle contract clauses; waste acceptance criteria; and voluntary requirements such as ISO 14001:2015. UT-Battelle has established procedures to ensure that all applicable requirements are reviewed and that changes and updates are communicated to staff and are incorporated into work-planning activities. UT-Battelle's environmental compliance status is discussed in Section 5.3.

UT-Battelle Objectives

To improve environmental performance, UT-Battelle establishes objectives and indicators for monitoring progress for appropriate functions and activities. Laboratory-level environmental objectives are documented in the annual Site Sustainability Plan. Line organization objectives are developed annually, entered into a commitment tracking system, and tracked to completion. In all cases, the objectives and indicators for monitoring progress are consistent with the UT-Battelle Policy for ORNL, are supportive of the laboratory mission, and where practical, they are measurable.

UT-Battelle Programs

UT-Battelle has established an organizational structure to ensure that environmental stewardship practices are integrated into all facets of UT-Battelle's missions at ORNL. Programs led by experts in environmental protection and compliance, energy and resource conservation, pollution prevention, and waste management ensure that laboratory activities are conducted in accordance with the environmental policy (see Section 5.2.1.2). Information on UT-Battelle's 2018 compliance status, activities, and accomplishments is presented in Section 5.3.

The environmental protection and waste management staff provide critical support services in the following areas:

- waste management;
- solid and hazardous waste compliance;
- National Environmental Policy Act (NEPA) compliance;
- air quality compliance;
- water quality compliance;
- US Department of Agriculture (USDA) compliance;
- transportation safety;
- environmental sampling and data evaluation; and
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) interface.

UT-Battelle's staff also include subject matter experts who provide critical waste management, transportation, and disposition support services to research, operations, and support divisions:

- pollution prevention staff, who manage recycling programs, work with staff to reduce waste generation and to promote sustainable acquisition;
- radiological engineering staff, who provide radiological characterization support to generators and WSRs, develop tools to help ensure compliance with facility safety and transportation, and provide packaging support;
- waste acceptance and disposition staff, who review and approve waste characterization methods, accept waste from generator areas into Transportation and Waste Management Division storage areas, review waste disposal paperwork to ensure compliance with the disposal facility's waste acceptance criteria, certify waste packages, and coordinate off-site disposition of UT-Battelle's newly generated waste;
- WSRs, who provide technical support to waste generators to properly manage waste by assisting in identifying, characterizing, packaging, and certifying wastes for disposal;
- the waste-handling team, which performs waste-packing operations and conducts inspections of waste items, areas, and containers;
- the transportation management team, which ensures that both the on-site and off-site packaging and transportation activities are performed in an efficient and compliant manner; and
- the hazardous material spill response team, which is the first line of response to hazardous materials spills at ORNL and controls and contains spills until the situation is stabilized.

5.2.1.4 UT-Battelle Sustainable ORNL

The beginning of 2018 marked a significant transition for energy and water management at ORNL. Originally, the ORNL Sustainable Campus Initiative (SCI) was formally chartered in 2008 during a time when federal governance in efficient and sustainable operations was moving to the forefront in facilities management. ORNL leadership considered the SCI charter to be the logical advancement of a remarkable national lab transformation. Beginning in 2000, through a creative mix of facility development funding, construction, and renovation, ORNL's World War II–era infrastructure became home to state-of-the-art facilities hosting major new research programs in areas such as high-performance computing. Advanced building technologies—many developed, tested, and proven at ORNL—were incorporated into new construction and renovation to further advance the laboratory’s goal of efficient, sustainable operations.

It was recognized that continuous improvements in operational and business processes must be integrated into the fabric of the ORNL culture to maximize the return from the investment made in modernizing facilities and equipment. For 10 years, SCI played a critical role in the advancement of innovations in sustainable and efficient facility operations. In 2018, after 10 years, ORNL recognized that SCI has indeed been successful in utilizing innovation in equipment and processes to advance resource efficiencies and that an integrated, sustainable ORNL had evolved as envisioned (Figure 5.6).

Figure 5.6. Evolution of Sustainable Campus Initiative to Sustainable ORNL

In the evolution to the new Sustainable ORNL, the list of projects covered by Sustainable ORNL was reduced from 25 to 12 vital projects. The 12 projects are greenhouse gas management, clean and renewable energy, intelligent building analytics, high-performance computing, sustainable acquisition, sustainable vehicle fleet, sustainable landscaping and land use, high-performance sustainable buildings, water management, energy efficiency, engagement and recognition, and recycle and reuse. Continuous engagement with ORNL associates and regular status reports to the ORNL Leadership Team are still a measure of success of the program.

FY 2018 Site Sustainability Performance Summary Data for Energy, Water, and Waste

In FY 2018 there was no annual Site Sustainability report; rather, there was a data call from the DOE Headquarters Sustainability Performance Office. The following information is from that data call.

Energy Use Intensity

Executive Order (EO) 13834 (EO 2018), *Efficient Federal Operations*, signed on May 17, 2018, directs federal agencies to manage their buildings, vehicles, and overall operations to optimize energy and environmental performance, reduce waste, and cut costs.

Based on FY 2018 data, energy use in the buildings category at ORNL is 1,295 billion Btu, not including ORNL’s excluded facilities as defined by the Energy Policy Act of 1992. Given an area of 5,199,825 gross square feet (GSF) of energy-consuming buildings, trailers, and other structures and facilities identified in the Facilities Information Management System, the FY 2018 calculated energy use intensity (EUI) is 48,953 Btu/GSF. This results in a cumulative reduction of 31.6 percent since FY 2003.

To maintain steady progress toward EUI reductions, ORNL focuses on energy-efficient and sustainable design in new construction projects as well as smart repurposing of existing facilities and a drive for continuous improvement in facility and utility operations. ORNL continues to modernize by demolishing old, energy-inefficient buildings to make way for the construction of new, high-performance buildings that better serve the ORNL mission.

Water Use Intensity

ORNL procures potable water from the City of Oak Ridge for domestic use (handwashing, flushing), cooling (cooling towers, chillers), heating (steam generation, hot water generation), limited landscape irrigation, laboratories, and special research processes.

ORNL has long been aware of the benefits of effective water management, having already experienced a 61 percent reduction in water use compared with its highest level of water use, experienced in FY 1985. A firmly established aggressive plan continues to be deployed. The numerous strategies that are engaged to reduce water consumption include repairing leaks, replacing old lines in the site water distribution system, and eliminating once-through cooling where possible, resulting in a 20 percent reduction in annual total water use since FY 2007. The cumulative result of these efforts is a water use intensity value of 123 gallons per gross square foot (G/GSF) in FY 2018, which is a reduction of 30 percent from FY 2007.

Waste Diversion

The diversion rate for municipal solid waste at ORNL was 42 percent in FY 2018, slightly less than the DOE goal of 50 percent. The diversion rate for construction and demolition (C&D) materials and debris (80 percent) exceeded the DOE goal of 50 percent.

Pollution Prevention

As part of its source reduction efforts, ORNL increases the use of acceptable nontoxic or less-toxic alternative chemicals and processes while minimizing the acquisition of hazardous chemicals and materials through material substitution; operational assessments; and inventory management, including using the ORNL Chemical Management Center. UT-Battelle implemented 25 new pollution prevention projects and ongoing reuse/recycle projects at ORNL during 2018, eliminating more than 4 million kg of waste. One example implemented in 2018 involved an ORNL researcher who took the initiative to identify a nonhazardous replacement for xylene and to implement its use as a clearing agent in a histology experiment. This success improved safety and reduced hazardous waste and will continue to be shared with other researchers and other labs (Figure 5.7).

Figure 5.7. Postdoctoral researcher Anirban Guha demonstrates his samples prepared with a new, nontoxic agent

Sustainable Vehicle Fleet

During the last 3 years the ORNL Fleet Office has purchased 25 alternative fuel vehicles (AFVs) to replace many diesel-fueled vehicles. During FY 2018, the Fleet replaced larger diesel trucks with, smaller, more suitable E85-fueled AFVs and plug-in hybrid electric vehicles (PHEVs). In the vehicle acquisition planning process with DOE, ORNL fleet management works to maximize the acquisition of

AFVs and PHEVs. As vehicles are retired from service, they will be replaced with models that are more efficient; the number of fleet vehicles is not expected to increase.

Alternative Fuel Use and Infrastructure

ORNL has worked to increase the usage of biodiesel (B20) in equipment and applicable diesel vehicles. Several E85 pumps are located at the closed-campus fueling site (Figure 5.8). In addition, use of E85 is encouraged and marketed for ORNL drivers of fleet vehicles. Sustainable ORNL sponsored a project to provide branding for employee/driver engagement and rebranded the fueling station to demonstrate the commitment to sustainable fuel products.

Figure 5.8. Rebranded fueling station on the ORNL main campus encouraging use of the E85 fuel pumps

High-Performance Sustainable Buildings: Guiding Principles

In FY 2018, ORNL's high-performance sustainable building (HPSB) inventory included a total of 20 buildings that are certified as having attained 100 percent of the HPSB Guiding Principles (GPs) (CEQ 2016). This represents 15 percent of the total applicable site buildings according to the Guiding Principles for Federal Leadership in Sustainable Buildings. This meets the current GP target (15 percent by building count) for DOE Green Buildings, 100 percent GP attainment.

In prior reports, ORNL included three third-party and joint-institute facilities in the HPSB total because they are operated and maintained by ORNL and because they had been grandfathered. The revised HPSB GPs stipulate that contractor-owned leased facilities should not be included in HPSB GP accounting. ORNL's third-party and joint-institute facilities are categorized in the Facilities Information Management System as contractor owned; therefore, they will no longer be included as applicable site buildings or in the total HPSB count.

Employing a systematic approach to identifying HPSB candidates and applying the GPs has been an effective way to ensure continued progress. HPSB candidates have been identified based on building space use, existing metering infrastructure, and known energy conservation opportunities. Action plans for achieving building-specific GPs are developed and executed while laboratory-wide standards are used to fulfill HPSB applicable policies and procedures. Engagement of facility managers, facility engineers, and other technical personnel has been essential to acquiring quality benchmarking data, performing commissioning activities, and implementing energy conservation measures.

One of the ways that ORNL achieved HPSB success was through our long association with the US Green Building Council (USGBC) Leadership in Energy and Environmental Design (LEED) certification program.

In 2018 ORNL achieved USGBC LEED GOLD certification for Building 5200, Research Support Center. During that process ORNL won an Impact Benchmarking Challenge Award for its first completed LEED ARC project. The recognition was for "Most Improved Water" category for USGBC, Tennessee.

ORNL Commuting Options

ORNL is a leader in the region in promoting electric vehicle use and has been actively participating in regional workplace charging efforts, including installation of 47 electric vehicle (EV) supply equipment charging stations at the Spallation Neutron Source (SNS), NTRC, and ORNL's main campus. An ongoing electric vehicle program allows ORNL employees access to charging stations. In 2018 there were 58 members in the ORNL EV Owner's Club with access to more than 40 staff charging station locations. Employees and associates pay an annual fee to join the club; then are allowed to charge their EVs in one of the charging stations during work hours. The funds collected by the club are used to support the cost and maintenance of the EV chargers devoted to the charging of employee-owned vehicles (non-fleet vehicles).

Sustainable ORNL Achievements and Awards

The following ORNL achievements and award were highlighted in the ORNL information submitted to the DOE Sustainability Performance Office in December 2018.

Awards

- 2018 USGBC LEED GOLD certification for the Research Support Center (Building 5200). Presented an Impact Benchmarking Challenge Award for ORNL's first completed LEED ARC project. The recognition was for 'Most Improved Water" category for USGBC, Tennessee.
- Tom Wenning, program manager for Industrial Energy Efficiency, was honored with the Rising Star of Energy Efficiency Award by the Alliance to Save Energy.
- 2018 DOE Honorable Mention for Outstanding Sustainability Program/Project Award for "ORNL's High Performance Computing (HPC) Summit Facility—Designed for Success."
- 2018 Federal Energy Management Program Federal Energy and Water Management Award for Outstanding Program, "ORNL Sustainable Campus Initiative: From Initiation to Integration."
- 2018 Government Green Fleet Award, recognized in 2017 and again in 2018 with improved standing.
- 2018 Tennessee Chamber of Commerce and Industry Environment and Energy Award in the Energy Excellence category for "ORNL's High Performance Computing (HPC) Summit Facility—Designed for Success."

ORNL also received three pollution prevention–related R&D 100 Awards in 2018: High Voltage Electrolytes for Ultracapacitors, TNT Cloning System, and Ambient Reactive Extrusion Additive Manufacturing.

Employee Engagement

The transition to an integrated Sustainable ORNL program is being accomplished through announcements, promotions, and numerous activities, including the following activities during FY 2018:

- Article submissions to *ORNL Today*, a web-based newsletter

- Article submissions to the DOE *Sustainability SPOtlight* Newsletter
- Posting of public relations information on Scala screens throughout the campus
- Launch and promotion of a new web site (here)
- Quarterly workshops with Sustainable ORNL Roadmap owners
- Quarterly updates to the ORNL leadership team
- Planning and delivery of the Earth Day Campaign
- Manage and promote the ORNL Electric Vehicle (EV) Owners Club (for use of EV charging stations)
- Manage and promote bus service between the University of Tennessee (UT), Knoxville; Pellissippi State Community College; and the ORNL main campus

5.2.1.5 Storm Water Management and the Energy Independence and Security Act of 2007

Section 438 of the Energy Independence and Security Act of 2007 (EISA 2007) stipulates the following:

> The sponsor of any development or redevelopment project involving a Federal facility with a footprint that exceeds 5,000 square feet shall use site planning, design, construction, and maintenance strategies for the property to maintain or restore, to the maximum extent technically feasible, the predevelopment hydrology of the property with regard to the temperature, rate, volume, and duration of flow.

For the purposes of this provision, “development or redevelopment” is defined as

> any action that results in the alteration of the landscape during construction of buildings or other infrastructure such as parking lots, roads, etc. (e.g., grading, removal of vegetation, soil compaction) such that the changes affect runoff volumes, rates, temperature, and duration of flow. Examples of projects that would fall under ‘redevelopment’ include structures or other infrastructure that are being reconstructed or replaced and the landscape is altered. Typical patching or resurfacing of parking lots or other travel areas would not fall under this requirement (EISA 2007).

Strategic plans for demolition and renovation of old facilities and construction of new facilities at ORNL incorporate green infrastructure and low-impact development (GI/LID) practices to infiltrate, evapotranspire, and/or harvest and use storm water on site to the maximum extent feasible. GI/LID approaches and technologies have been used to mimic the natural processes of the hydrologic cycle (infiltration, evapotranspiration, and use). GI/LID practices that have been incorporated at ORNL include

- trees and tree boxes,
- rain gardens,
- vegetated swales,
- pocket wetlands,
- infiltration planters,
- porous and permeable pavements,
- vegetated median strips,
- reforestation and revegetation,
- protection of riparian buffers and floodplains,

- retention ponds, and
- water reuse (e.g., tanks in restrooms to collect water for reuse in irrigation).

At ORNL, evaluation occurs to meet the requirements of EISA Section 438. A three-step approach is applied as needed:

- Within the project boundaries if the necessary volume of runoff can be infiltrated or retained on site.
- On land immediately adjacent to the project boundaries if the necessary volume of runoff cannot be infiltrated or retained on site.
- Within the same valley or ridge area (e.g., within Bethel Valley if the project is within Bethel Valley; within Melton Valley if the project is within Melton Valley) if the necessary volume of runoff cannot be infiltrated or retained on land immediately adjacent to the project boundaries.

In addition to GI/LID practices, the projects may remove impervious areas and reestablish pervious areas to allow infiltration or evapotranspiration to occur.

5.2.1.6 Emergency Preparedness and Response

The UT-Battelle Emergency Management Program supplies the resources and capabilities to provide emergency preparedness services and, in the event of an accident, emergency response services. Emergency preparedness personnel perform hazard surveys and hazard assessments to identify potential emergency situations. Procedures and plans have been developed to prepare for and respond to a wide variety of potential emergency situations. Training is provided to ensure appropriate response and performance during emergency events. Frequent exercises and drills are scheduled to ensure the effective performance of the procedures and plans. An environmental subject matter expert is a member of the emergency response team and participates in drills and exercises to ensure that environmental requirements are met and that environmental impacts from an event and the response are mitigated.

5.2.1.7 Checking

Monitoring and Measurement

UT-Battelle has developed monitoring and measurement processes for each operation or activity that can have a significant adverse effect on the environment. Several SBMS subject areas include requirements for managers to establish performance objectives and indicators, conduct performance assessments to collect data and monitor progress, and evaluate the data to identify strengths and weaknesses in performance and areas for improvement.

UT-Battelle Environmental Management System Assessments

UT-Battelle uses several methods to evaluate compliance with legal and other environmental requirements. Most of the compliance evaluation activities are implemented through the EMS or participation in line-organization assessment activities. If a nonconformance were identified, the ORNL issues-management process requires that any regulatory or management system nonconformance be reviewed for cause and that corrective and/or preventive actions be developed. These actions would then be implemented and tracked to completion.

Environmental assessments that cover legal and other requirements are performed periodically. Additionally, management system owners are required to assess management system performance and to address issues identified from customer feedback, staff suggestions, and other assessment activities.

UT-Battelle also uses the results from numerous external compliance inspections conducted by regulators to verify compliance with requirements. In addition to regulatory compliance assessments, internal and external EMS assessments are performed annually to ensure that the UT-Battelle EMS continues to conform to ISO requirements. An independent internal audit conducted in 2018 verified that the EMS conforms to ISO 14001:2015. In addition to verifying conformance, these management system assessments also identify continual improvement opportunities.

5.2.2 Other Environmental Management System Assessments

5.2.2.1 Environmental Management System for the Transuranic Waste Processing Center

The National Sanitation Foundation, International Strategic Registrations, Ltd. (NSF-ISR) registered the TWPC EMS for activities to the ISO 14001:2015 standard (ISO 2015) in May 2017. The EMS is integrated with ISMS to provide a unified strategy for the management of resources, the control and reduction of risks, and the establishment and achievement of the organization’s ES&H goals. The EMS and ISMS are incorporated into the Integrated Safety Management System Description (BJC 2009), and a “plan-do-check-act” cycle is used for continual improvement in both. NSF-ISR conducted a recertification audit in April. No nonconformances or issues were identified, and several significant practices were noted.

The TWPC EMS incorporates applicable environmental laws, DOE orders, and other requirements (i.e., DOE directives and federal, state, and local laws) through NWSol’s *Regulatory Management Plan* (NWSol 2015), which dictates how the various requirements are incorporated into subject area documents (procedures and guidelines). The EMS assists NWSol line organizations in identifying and addressing environmental issues.

Environmental aspects are elements of an organization’s activities, products, or services that can interact with the environment. NWSol has identified environmental aspects associated with TWPC activities, products, and services at both the project and activity level and has identified waste management activities, air emissions, storm water contamination, pollution prevention, habitat alteration, and energy consumption as potentially having significant environmental impacts. Activities that are relative to any of those environmental aspects are carefully controlled to minimize or eliminate impacts to the environment. NWSol has established and implemented objectives and measurable performance indicators for the targets associated with the identified significant impacts.

The pollution prevention programs at TWPC involve waste reduction efforts and implementation of sustainable practices that reduce the environmental impacts of the activities conducted at TWPC. The NWSol EMS establishes annual goals and targets to reduce the impact of TWPC’s environmental aspects.

NWSol has a well-established recycling program at TWPC and continues to identify new material-recycling streams and to expand the types of materials included in the program. Currently, recycle streams at TWPC range from office materials such as paper, aluminum cans, plastic drinking bottles, foam beverage cups, alkaline batteries, and toner cartridges to operations-oriented materials such as cardboard and batteries. The “single stream” recycling program established by NWSol allows the mixing of multiple types of recyclables and thus increases the amount of recyclable items and improves compliance.

“Environmentally preferable purchasing” is a term used to describe an organization’s policy to reduce packaging and to purchase products made with recycled material or biobased materials and other environmentally friendly products. NWSol ensures that environmentally preferable products are purchased by incorporating the "green" procurement requirements in NWSol procurement procedures.

NWSol uses several methods to evaluate compliance with legal and other requirements. Most of these compliance evaluation activities are implemented by internal and external environmental and management assessment activities and by routine reporting and reviews. NWSol also uses the results from numerous external compliance inspections conducted by regulators and contractors to verify compliance with requirements.

5.2.2.2 Environmental Management System for Isotek

Isotek has developed and implemented an EMS for the U-233 Disposition Project that reflects the elements and framework found in the ISO14001:2004 standard (ISO 2004) and that satisfies the applicable requirements of DOE O 450.1A, *Environmental Protection Program* (DOE 2008). The scope of the Isotek EMS is to achieve and demonstrate environmental excellence by identifying, assessing, and controlling the impact of Isotek activities and facilities on the environment. The EMS is designed to ensure compliance with environmental laws, regulations, and other applicable requirements and to improve effectiveness and efficiency, reduce costs, and earn and retain regulator and community trust. The Isotek EMS and ISMS are fully integrated.

Project procedures provide a systematic approach to integrating environmental considerations into all aspects of Isotek's activities at ORNL. The Isotek EMS includes a procedure for identifying environmental aspects associated with the U-233 Disposition Project and for determining whether those aspects can have significant environmental impacts. Isotek has identified radiological air emissions as the only environmental aspect of its operations that has potentially significant environmental impacts and has developed an environmental management plan with measurable objectives and targets to address that aspect. Isotek reviews environmental aspects, potential impacts, objectives, targets, and its environmental management plan at least annually and updates them as necessary.

The U-233 Disposition Project has a well-established recycling program that is implemented at all Isotek-managed facilities and includes Buildings 3017, 3019 Complex, 2026, and 3137 at ORNL and two off-site administrative offices in Oak Ridge. The materials currently recycled by Isotek include paper, cardboard, aluminum cans, plastic bottles, inkjet and toner cartridges, lamps, batteries, scrap metal, circuit boards, aerosol cans, and used oil.

To evaluate compliance with legal and other requirements, Isotek conducts an EMS audit every 3 years, annual management assessments, and periodic surveillances. Compliance with requirements is also evaluated through inspections performed by regulatory agencies. The results of the compliance evaluations are used for continual improvement of the EMS.

5.3 Compliance Programs and Status

During 2018 UT-Battelle, UCOR, NWSol, and Isotek operations were conducted to comply with contractual and regulatory environmental requirements. Table 5.1 presents a summary of environmental audits conducted at ORNL in 2018. The following discussions summarize the major environmental programs and activities carried out at ORNL during 2018 and provide an overview of the compliance status for the year.

Table 5.1. Summary of regulatory environmental audits, evaluations, inspections, and assessments conducted at Oak Ridge National Laboratory, 2018

Date	Reviewer	Subject	Issues
January 8	TDEC	Notice of Termination for Construction Storm Water Permit Coverage	0
January 22	City of Oak Ridge	CFTF Wastewater Inspection	0
March 29	KCDAQM	NTRC CAA Inspection	0
April 10-11	TDEC	Annual RCRA Inspection for ORNL (including TWPC)	0
August 23	City of Oak Ridge	CFTF Waste Water Inspection	0
October 3	TDEC	Annual CAA Inspection for ORNL and CFTF	0

Acronyms
CAA = Clean Air Act
CFTF = Carbon Fiber Technology Facility
KCDAQM = Knox County Department of Air Quality Management
NPDES = National Pollutant Discharge Elimination System
NTRC = National Transportation Research Center
ORNL = Oak Ridge National Laboratory
RCRA = Resource Conservation and Recovery Act
TDEC = Tennessee Department of Environment and Conservation
TWPC = Transuranic Waste Processing Center

5.3.1 Environmental Permits

Table 5.2 contains a list of environmental permits that were in effect in 2018 at ORNL.

Table 5.2. Environmental permits in effect at ORNL in 2018

Regulatory driver	Permit title/description	Permit number	Owner	Operator	Responsible contractor
CAA	Title V Major Source Operating Permit, ORNL	571359	DOE	UT-B	UT-B
CAA	Construction Permit, CFTF facility (located near ETTP)	965013P	DOE	UT-B	UT-B
CAA	Construction Permit, CFTF emergency generator	967180P	DOE	UT-B	UT-B
CAA	Construction Permit, 4501/4505 Area Off Gas System	971441P	DOE	UT-B	UT-B
CAA	Operating Permit, NTRC	17-0941-01	DOE	UT-B	UT-B
CAA	Operating Permit, NWSol	071009P	DOE	NWSol	NWSol
CAA	Construction Permit, 3525 Area Off Gas System	971543P	DOE	UT-B	UT-B
CAA	Operating Permit, NWSol emergency generators	071010P	DOE	NWSol	NWSol
CAA	Title V Major Source Operating Permit, ORNL	569768	DOE	UCOR	UCOR
CAA	Title V Major Source Operating Permit, Isotek	568276	DOE	Isotek	Isotek
CAA	Construction Permit, Modification for 3039 Stack	974744	DOE	UCOR	UCOR
CWA	ORNL NPDES Permit (ORNL sitewide wastewater discharge permit)	TN0002941	DOE	DOE	UT-B, UCOR, NWSol
CWA	Industrial and Commercial User Waste Water Discharge Permit (CFTF)	1-12	UT-B	UT-B	UT-B
CWA	Tennessee Operating Permit, Holding Tank/Haul System for Domestic Wastewater	SOP-07014	UCOR	UCOR	UCOR
CWA	Tennessee Operating Permit (sewage)	SOP-02056	DOE	NWSol	NWSol
CWA	Construction Storm Water Permit – Research Operations Support Center (ROSC) Building	TNR 135617	DOE	UT-B	UT-B
CWA	Construction Storm Water Permit – Leadership Imaging Facility Building	TNR 135602	DOE	UT-B	UT-B
CWA	Aquatic Resources Alteration Permit − Leadership Imaging Facility Building	ARAP - NR1803.153	DOE	UT-B	UT-B
RCRA	Hazardous Waste Transporter Permit	TN1890090003	DOE	DOE	UT-B, UCOR
RCRA	Hazardous Waste Corrective Action Permit	TNHW-164	DOE	DOE/all	DOE/all

Table 5.2 Environmental permits in effect at ORNL in 2018 (continued)

Regulatory driver	Permit title/description	Permit number	Owner	Operator	Responsible contractor
RCRA	Hazardous Waste Container Storage and Treatment Units	TNHW-134	DOE	DOE/UT-B	UT-B
RCRA	Hazardous Waste Container Storage and Treatment Units	TNHW-145	DOE	DOE/ UCOR/ NWSol	UCOR/ NWSol

Acronyms
CAA = Clean Air Act
CFTF = Carbon Fiber Technology Facility
CWA = Clean Water Act
DOE = US Department of Energy

ETTP = East Tennessee Technology Park
Isotek = Isotek Systems LLC
NTRC = National Transportation Research Center
NWSol = North Wind Solutions, LLC
ORNL = Oak Ridge National Laboratory
ROSC = Research Operations Support Center
RCRA = Resource Conservation and Recovery Act
UCOR = URS | CH2M Oak Ridge LLC
UT-B = UT-Battelle

5.3.2 National Environmental Policy Act/National Historic Preservation Act

NEPA provides a means to evaluate the potential environmental impact of proposed federal activities and to examine alternatives to those actions. UT-Battelle, NWSol, and Isotek maintain compliance with NEPA using site-level procedures and program descriptions that establish effective and responsive communications with program managers and project engineers to establish NEPA as a key consideration in the formative stages of project planning. Table 5.3 summarizes NEPA activities conducted at ORNL during 2018.

Table 5.3. National Environmental Policy Act activities, 2018

Types of NEPA documentation	Number of instances
UT-Battelle, LLC	
Approved under general actions or generic CX determinations[a]	89
Project-specific CX determinations[b]	2
North Wind Solutions, LLC	
Approved under general actions[a] or generic CX determinations	0

[a] Projects that were reviewed and documented through the site NEPA compliance coordinator.
[b] Projects that were reviewed and approved through the DOE Site Office and the NEPA compliance officer.

Acronyms
CX = categorical exclusion
DOE = US Department of Energy
NEPA = National Environmental Policy Act

During 2018, UT-Battelle and NWSol continued to operate under site-level procedures that provide requirements for project reviews and NEPA compliance. The procedures call for a review of each proposed project, activity, or facility to determine the potential for impacts to the environment. To streamline the NEPA review and documentation process, the DOE has approved generic categorical exclusion (CX) determinations that cover proposed bench- and pilot-scale research activities and generic CXs that cover proposed nonresearch activities (e.g., maintenance activities, facilities upgrades, personnel safety enhancements). A CX is one of a category of actions defined in 40 CFR 1508.4 that does not individually or cumulatively have a significant effect on the human environment and for which neither an environmental assessment nor an environmental impact statement is normally required.

UT-Battelle uses SBMS as the delivery system for guidance and requirements to manage and control work at ORNL. NEPA is an integral part of SBMS, and a UT-Battelle NEPA coordinator works with principal investigators, environmental compliance representatives, and environmental protection officers within each UT-Battelle division to determine appropriate NEPA decisions.

Compliance with the National Historic Protection Act at ORNL is achieved and maintained in conjunction with NEPA compliance. The scope of proposed actions is reviewed in accordance with the ORR cultural resource management plan (Souza et al. 2001).

5.3.3 Clean Air Act Compliance Status

The Clean Air Act (CAA), passed in 1970 and amended in 1977 and 1990, forms the basis for the national air pollution control effort. This legislation established comprehensive federal and state regulations to limit air emissions. It includes four major regulatory programs: the national ambient air quality standards, state implementation plans, new source performance standards, and NESHAPs. Airborne discharges from DOE Oak Ridge facilities, both radioactive and nonradioactive, are subject to regulation by the US Environmental Protection Agency (EPA) and the Tennessee Department of Environment and Conservation (TDEC) Division of Air Pollution Control. The most recent sitewide UT-Battelle Title V Major Source Operating Permit was issued in October 2018. One administrative amendment request was submitted to TDEC in August 2018. Three minor modifications were submitted in August 2018 and October 2018. The Title V Major Source Operating Permit for the 3039 stack, operated by UCOR, was renewed in 2015. A major modification construction permit was submitted for 3039 stack by UCOR in November 2018. To demonstrate compliance with the Title V Major Source Operating Permits, more than 1,500 data points are collected and reported every year. In addition, nitrogen oxides (NO_x), a family of poisonous, highly reactive gases and defined collectively as a criteria pollutant by the EPA (EPA 2016), are monitored continuously at one location. Samples are collected continuously from 9 major radionuclide sources and periodically from 15 minor radionuclide sources. There are numerous other demonstrations of compliance with generally applicable air quality protection requirements (e.g., asbestos, stratospheric ozone).

NTRC and CFTF are two off-site CAA-regulated facilities maintained and operated by UT-Battelle. A permit was issued by Knox County for an emergency generator located at NTRC in June 2017. The CFTF operates under two construction permits issued by TDEC. A permit application to convert them to a Conditional Major operating air permit was submitted in 2018 after conversations with TDEC and was still pending issuance at the end of 2018.

In summary, there were no UT-Battelle CAA violations and no Isotek, UCOR, or NWSol CAA violations or exceedances in 2018. Section 5.4 provides detailed information on 2018 activities conducted by UT-Battelle in support of the CAA.

5.3.4 Clean Water Act Compliance Status

The objective of the Clean Water Act (CWA) is to restore, maintain, and protect the integrity of the nation's waters. The CWA serves as the basis for comprehensive federal and state programs to protect the nation's waters from pollutants. (See Appendix C for water quality reference standards.) One of the strategies developed to achieve the goals of CWA was the EPA's establishment of limits on specific pollutants allowed to be discharged to US waters by municipal sewage treatment plants (STPs) and industrial facilities. EPA established the National Pollutant Discharge Elimination System (NPDES) permitting program to regulate compliance with pollutant limitations. The program was designed to protect surface waters by limiting effluent discharges into streams, reservoirs, wetlands, and other surface waters. EPA has delegated authority for implementation and enforcement of the NPDES program to the State of Tennessee.

In 2018, compliance with the ORNL NPDES permit was determined by about 2,300 laboratory analyses and field measurements. The NPDES permit limit compliance rate for all discharge points for 2018 was 100 percent.

ORNL submitted an NPDES permit application in 2018 and is planning to receive a renewed permit in 2019.

5.3.5 Safe Drinking Water Act Compliance Status

ORNL's water distribution system is designated as a "nontransient, noncommunity" water system by the TDEC Division of Water Supply. TDEC's Water Supply rules, Chapter 0400-45-01, "Public Water Systems" (TDEC 2012), set limits for biological contaminants and for chemical activities and chemical contaminants. TDEC requires sampling for the following constituents for compliance with state and federal regulations:

- residual chlorine,
- bacteria (total coliform),
- disinfectant by-product (trihalomethanes and haloacetic acids), and
- lead and copper (required once every 3 years).

The City of Oak Ridge supplies potable water to the ORNL water distribution system and meets all regulatory requirements for drinking water. The water treatment plant, located on ORR, north of the Y-12 Complex, is owned and operated by the City of Oak Ridge.

In 2018, sampling results for ORNL's water system residual chlorine levels, bacterial constituents, lead/copper, and disinfectant by-products were all within acceptable limits. Sampling for lead and copper will not be required again until 2021.

5.3.6 Resource Conservation and Recovery Act Compliance Status

The Hazardous Waste Program under the Resource Conservation and Recovery Act (RCRA) establishes a system for regulating hazardous wastes from the initial point of generation through final disposal. In Tennessee, TDEC has been delegated authority by EPA to implement the Hazardous Waste Program; EPA retains an oversight role. In 2018, DOE and its contractors at ORNL were jointly regulated as a "large-quantity generator of hazardous waste" under EPA ID TN1890090003 because, collectively, they generated more than 1,000 kg of hazardous/mixed wastes in at least one calendar month during 2018.

Mixed wastes are both hazardous (under RCRA regulations) and radioactive. Hazardous/mixed wastes are accumulated in satellite accumulation areas or in less-than-90-day accumulation areas and are stored and/or treated in RCRA-permitted units. In addition, hazardous/mixed wastes are shipped off site for treatment and disposal. The RCRA units operate under three permits at ORNL, as shown in Table 5.4. In 2018, UT-Battelle and UCOR were permitted to transport hazardous wastes under the EPA ID number issued for ORNL activities. On September 15, 2015, the ORR Hazardous Waste Corrective Action Permit TNHW-121 was reissued as TNHW-164. TNHW-164 is a set of conditions pertaining to the current status of all solid waste management units (SWMUs) and areas of concern (AOCs) at East Tennessee Technology Park (ETTP), ORNL, and the Y-12 National Security Complex. The corrective action conditions require that the SWMUs and AOCs be investigated and, as necessary, remediated.

Reporting is required for hazardous waste activities on 20 active waste streams at ORNL, some of which are mixed wastes. The quantity of hazardous/mixed waste generated at ORNL in 2018 was 349,811 kg, with mixed wastewater accounting for 311,639 kg. ORNL generators treated 4,734 kg of hazardous/mixed waste by elementary neutralization, silver recovery, and deactivation. The quantity of hazardous/mixed waste treated in RCRA-permitted treatment facilities at ORNL in 2018 was 5,024 kg. This included waste treated by macroencapsulation, size reduction, stabilization/solidification, and wastewater treatment at the Process Waste Treatment Complex (PWTC). In addition, 201,190 kg of liquid mixed waste was treated at the Liquid Low-Level Waste Treatment Facility. The amount of hazardous/mixed waste shipped off site to commercial treatment, storage, and disposal facilities was 207,202 kg in 2018.

In April 2018, TDEC Division of Solid Waste Management conducted a Hazardous Waste Compliance Evaluation inspection of ORNL generator areas; universal waste collection areas; RCRA-permitted treatment, storage, and disposal facilities; hazardous waste training records; site-specific contingency plans; and RCRA records. TDEC also reviewed the Hazardous Waste Transporter Permit; US Department of Transportation (DOT) inspection records for tractors, trailers, and tankers; driver qualification files; hazardous waste manifests; and DOT training records. All records and areas were found to be in compliance with RCRA regulations and the RCRA permits.

Table 5.4. Oak Ridge National Laboratory Resource Conservation and Recovery Act operating permits, 2018

Permit number	Storage and treatment/description
	Oak Ridge National Laboratory
TNHW-134	Building 7651 Container Storage Unit
	Building 7652 Container Storage Unit
	Building 7653 Container Storage Unit
	Building 7654 Container Storage Unit
	Portable Unit 2 Storage and Treatment Unit
TNHW-145	Portable Unit 1
	Building 7572 Contact-Handled Transuranic Waste Storage Facility
	Building 7574 Transuranic Storage Facility
	Building 7823[a] Container Storage Unit
	Building 7855 Remote-Handled Transuranic Retrievable Storage Facility
	Building 7860A Remote-Handled Transuranic Retrievable Storage Facility
	Building 7879 Transuranic /Low Level Waste Storage Facility
	Building 7883 Remote-Handled Transuranic Storage Bunker
	Transuranic Waste Processing Center (TWPC)-1 Contact-Handled Storage Area
	TWPC-2 Waste Processing Building Second Floor
	TWPC-3 Drum Aging Criteria Area
	TWPC-4 Waste Processing Building First Floor
	TWPC-5 Container Storage Area
	TWPC-6 Contact-Handled Marshaling Building
	TWPC-7 Drum-Venting Building
	TWPC-8 Multipurpose Building
	T-1[b] Macroencapsulation Treatment
	T-2[b] Solidification/Stabilization Treatment
	T-3[b] Amalgamation Treatment
	T-4[b] Groundwater Absorption Treatment
	T-5[b] Size Reduction
	T-6[b] Groundwater Filtration Treatment
	Oak Ridge Reservation
TNHW-164[c]	Hazardous Waste Corrective Action Document

[a] Removed from permit in December 2018.
[b] Treatment methodologies within TWPC facilities.
[c] On September 15, 2015, the ORR Hazardous Waste Corrective Action Permit TNHW-121 was reissued as TNHW-164.

In 2018 ORNL requested an EPA ID number for hazardous waste activities at 115A Union Valley Road in Oak Ridge. This is the Oak Ridge National Laboratory's property sales warehouse for excessing and surplus sales. A surplus piece of equipment was determined to have contamination and had to be disposed as hazardous waste. The equipment weighed 1,391 kg, which qualified Property Sales as a large quantity generator for the onetime shipment.

DOE and UT-Battelle operations at NTRC and CFTF were regulated as "conditionally exempt small-quantity generators" in 2018, meaning that less than 100 kg of hazardous waste was generated per month.

In 2018, no hazardous/mixed wastes were generated, accumulated, or shipped by DOE or UT-Battelle at the DOE Office of Scientific and Technical Information, the 1916-T2 warehouse, or the 0800 Area.

ORNL submitted a RCRA permit application in 2018 and is planning to receive a renewed permit in 2019.

5.3.7 ORNL RCRA-CERCLA Coordination

The Federal Facility Agreement for the Oak Ridge Reservation (FFA) (DOE 2014) is intended to coordinate the corrective action processes of RCRA required under the Hazardous and Solid Waste Amendments permit with CERCLA response actions. Annual updates for 2017 for ORNL's SWMUs and AOCs were consolidated with updates for ETTP, the Y-12 Complex, and ORR and were reported to TDEC, DOE, and the EPA Region 4 in January 2018.

Periodic updates of proposed C&D activities and facilities at ORNL have been provided to managers and project personnel from the TDEC Remediation Division and EPA Region 4. A CERCLA screening process is used to identify proposed C&D projects and facilities that warrant CERCLA oversight. The goal is to ensure that modernization efforts do not adversely affect the effectiveness of previously completed CERCLA environmental remediation actions and that they do not adversely affect future CERCLA environmental remediation actions.

ORNL initiated one CERCLA project in 2018 to perform limited environmental remediation in the 3500 Area of the Central Campus to facilitate future brownfield redevelopment. Characterization of the area was completed in August 2018, and data was evaluated against remediation levels defined in the Bethel Valley Interim Record of Decision to identify required clean-up scope. An addendum to the approved Waste Handling Plan was developed and submitted for regulatory approval. Additionally, a technical memorandum will be submitted for regulatory approval as an appendix to the approved Remedial Design Report/Remedial Action Work Plan for Bethel Valley Soils and Sediments to document the proposed remedial actions. Following completion of remedial actions in 2019, a Phased Construction Completion Report will be developed and submitted for regulatory approval to document completed actions, final waste volumes, and waste disposition.

5.3.7.1 Resource Conservation and Recovery Act Underground Storage Tanks

Underground storage tanks (USTs) containing petroleum and hazardous substances are regulated under RCRA Subtitle I (40 CFR 280). TDEC has been granted authority by EPA to regulate USTs containing petroleum under TDEC Rule 400-18-01; however, hazardous-substance USTs are still regulated by EPA.

ORNL has two USTs registered with TDEC under Facility ID 0-730089. These USTs are in service (petroleum) and meet the current UST standards. No audits were performed by TDEC in 2018.

5.3.8 Comprehensive Environmental Response, Compensation, and Liability Act Compliance Status

CERCLA, also known as Superfund, was passed in 1980 and was amended in 1986 by the Superfund Amendments and Reauthorization Act (SARA). Under CERCLA, a site is investigated and remediated if it poses significant risk to health or the environment. The EPA National Priorities List (NPL) is a comprehensive list of sites and facilities that have been found to pose a sufficient threat to human health and/or the environment to warrant cleanup under CERCLA.

In 1989, ORR was placed on the EPA NPL. In 1992, the ORR FFA became effective among EPA, TDEC, and DOE and established the framework and schedule for developing, implementing, and monitoring remedial actions (RAs) on ORR. The on-site CERCLA Environmental Management Waste Management Facility (EMWMF) is operated by UCOR for DOE. Located in Bear Creek Valley, the EMWMF is used for disposal of waste resulting from CERCLA cleanup actions on ORR, including ORNL. The EMWMF is an engineered landfill that accepts low-level radioactive, hazardous, asbestos, and polychlorinated biphenyl (PCB) wastes and combinations of the wastes in accordance with specific waste acceptance criteria under an agreement with state and federal regulators.

5.3.9 Toxic Substances Control Act Compliance Status

PCB uses and waste at ORNL are regulated under the Toxic Substance Control Act (TSCA). PCB waste generation, transportation, and storage at ORNL are reported under EPA ID TN1890090003. In 2018, UT-Battelle operated nine PCB waste storage areas. When longer-term storage was necessary, PCB/radioactive wastes were stored in RCRA-permitted storage buildings at ORNL. One PCB waste storage area was operated at a UT-Battelle facility in the Y-12 Complex. The continued use of authorized PCBs in electrical systems and/or equipment (e.g., transformers, capacitors, rectifiers) is regulated at ORNL. Most of the equipment at ORNL that required regulation under TSCA has been dispositioned. However, some of the ORNL facilities at the Y-12 Complex continue to use (or store for future reuse) PCB equipment.

Because of the age of many of the ORNL facilities and the continued presence of PCBs in gaskets, grease, building construction, and equipment, DOE self-disclosed unauthorized use of PCBs to EPA in the late 1980s. As a result, DOE and ORNL contractors negotiated a compliance agreement with EPA (see Chapter 2, Table 2.1, under Toxic Substances Control Act) to address the compliance issues related to these unauthorized uses and to allow for continued use pending decontamination or disposal. As a result of that agreement, DOE continues to notify EPA when additional unauthorized uses of PCBs, such as PCBs in paint, adhesives, electrical wiring, or floor tile, are identified at ORNL. No new unauthorized uses of PCBs were identified during 2018.

5.3.10 Emergency Planning and Community Right-to-Know Act Compliance Status

The Emergency Planning and Community Right-to-Know Act (EPCRA) and Title III of SARA require that facilities report inventories and releases of certain chemicals that exceed specific release thresholds. The inventory report is submitted to the University of Texas at Dallas (UT-Dallas) Emergency Response Information System (E-Plan), which is an electronic database managed by UT-Dallas and funded by the U.S. Department of Homeland Security. The State of Tennessee Emergency Response Commission has access to ORNL EPCRA data via the E-Plan system.

Table 5.5 describes the main elements of EPCRA. UT-Battelle complied with these requirements in 2018 through the submittal of reports under EPCRA Sections 302, 303, 311, 312, and 313. The reports contain information on all DOE prime contractors and their subcontractors who reported activities at the ORNL site.

Table 5.5. Main elements of the Emergency Planning and Community Right-to-Know Act

Title	Description
Sections 302 and 303, Planning Notification	Requires that local planning committee and state emergency response commission be notified of EPCRA-related planning
Section 304, Extremely Hazardous Substance Release Notification	Addresses reporting to state and local authorities of off-site releases
Sections 311–312, Material Safety Data Sheet/Chemical Inventory	Requires that either safety data sheets or lists of hazardous chemicals for which they are required be provided to state and local authorities for emergency planning. Requires that an inventory of hazardous chemicals maintained in quantities over thresholds be reported annually to EPA
Section 313, Toxic Chemical Release Reporting	Requires that releases of toxic chemicals be reported annually to EPA

Acronyms
EPA = US Environmental Protection Agency
EPCRA = Emergency Planning and Community Right-to-Know Act

ORNL had no releases of extremely hazardous substances, as defined by EPCRA, in 2018. Releases of toxic chemicals that were greater than the Section 313 designated reportable threshold quantities are discussed in Section 5.3.9.2.

5.3.10.1 Safety Data Sheet/Chemical Inventory (Section 312)

Inventories, locations, and associated hazards of hazardous chemicals and/or extremely hazardous substances were submitted in an annual report to the E-Plan as required by the State of Tennessee. In 2018, there were 36 hazardous and/or extremely hazardous substances at ORNL that met EPCRA reporting criteria.

Private-sector lessees were not included in the 2018 submittals. Under the terms of their leases, lessees must evaluate their own inventories of hazardous and extremely hazardous chemicals and must submit information as required by the regulations.

5.3.10.2 Toxic Chemical Release Reporting (EPCRA Section 313)

DOE submits annual toxic release inventory reports to EPA and the Tennessee Emergency Management Agency on or before July 1 of each year. The reports cover the previous calendar year and track the management of certain chemicals that are released to the environment and/or managed through recycling, energy recovery, and treatment. (A “release” of a chemical means that it is emitted to the air or water or that it is placed in some type of land disposal.) Operations involving certain chemicals were compared with regulatory reporting thresholds to determine which chemicals exceeded individual thresholds on amounts manufactured, amounts processed, or amounts otherwise used. Releases and other waste management activities were determined for each chemical that exceeded one or more threshold.

For 2018, ORNL exceeded the reporting threshold and reported on the otherwise use of nitric acid and the manufacture of nitrate compounds. Most of the nitric acid was used in wastewater treatment operations at the PWTC. Nitrate compounds were coincidentally manufactured as by-products of neutralizing the nitric acid waste and as by-products of on-site sewage treatment.

5.3.11 US Department of Agriculture/Tennessee Department of Agriculture

USDA, through Animal and Plant Health Inspection Services, issues permits for the import, transit, and controlled release of regulated animals, animal products, veterinary biologics, plants, plant products, pests, organisms, soil, and genetically engineered organisms. The Tennessee Department of Agriculture issues agreements and jointly regulates domestic soil. In 2018, UT-Battelle personnel had 29 permits and agreements for the receipt, movement, or controlled release of regulated articles.

5.3.12 Wetlands

Wetland delineations of potential project sites are conducted to facilitate compliance with TDEC and US Army Corps of Engineers wetlands protection requirements. Delineation information assists project planners in avoiding or mitigating negative impacts to wetlands. In 2018, the knowledge of previous delineations allowed projects to avoid wetland impacts. One wetland near Building 2519, which was previously delineated in 2012, was reassessed and determined to have the same boundaries.

5.3.13 Radiological Clearance of Property at ORNL

DOE O 458.1, Radiation Protection of the Public and the Environment (DOE 2011c), established standards and requirements for operations of DOE and its contractors with respect to protection of members of the public and the environment against undue risk from radiation. In addition to discharges to the environment, the release of property containing residual radioactive material is a potential contributor to the dose received by the public, and DOE O 458.1 established requirements for clearance of property from DOE control and for public notification of clearance of property.

At ORNL, UT-Battelle uses a graded approach for release of material and equipment for unrestricted public use. Material that may be released to the public has been categorized so that in some cases an administrative release can be accomplished without a radiological survey. Such material originates from nonradiological areas and includes items such as the following:

- documents, mail, diskettes, compact disks, and other office media;
- nonradioactive items or materials received that are immediately (within the same shift) determined to have been delivered in error or damaged;
- personal items or materials;
- paper, plastic products, aluminum beverage cans, toner cartridges, and other items released for recycling;
- office trash;
- housekeeping materials and associated waste;
- breakroom, cafeteria, and medical wastes;
- compressed gas cylinders and fire extinguishers;
- medical and bioassay samples; and
- other items with an approved release plan.

Items that are not in the listed categories and that originate from nonradiological areas within ORNL's controlled areas are surveyed before release to the public, or a process knowledge evaluation is conducted to ensure that the material has not been exposed to radioactive material or beams of radiation capable of creating radioactive material. In some cases, both a radiological survey and a process knowledge evaluation are performed (e.g., a radiological survey is conducted on the outside of the item, and a process knowledge form is signed by the custodian for inaccessible surfaces). A similar approach is used for material released to state-permitted landfills on ORR. The only exception is for items that could be internally contaminated; those items are also sampled by laboratory analysis to ensure that landfill permit criteria are met.

When the process knowledge approach is used, the item's custodian is required to sign a statement that specifies that the history of the item or material is known and that the material is known to be free of contamination. This process knowledge certification is more stringent than what is allowed by DOE O 458.1 (DOE 2011d) in that ORNL requires an individual to take personal responsibility and accountability for knowing the complete history of an item before it can be cleared using process knowledge alone. DOE O 458.1 allows use of procedures for evaluating operational records and operating history to make process knowledge release decisions, but UT-Battelle has chosen to continue to require personal certification of the status of an item. This requirement ensures that each individual certifying the item is aware of the significance of this decision and encourages the individual to obtain a survey of the item if he or she is not confident that the item can be certified as being free of contamination.

A survey and release plan may be developed to direct the radiological survey process for large recycling programs or for clearance of bulk items with low contamination potential. For such projects, survey and release plans are developed based on guidance from the *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM) (NRC 2000) or the *Multi-Agency Radiation Survey and Assessment of Materials and Equipment Manual* (MARSAME) (NRC 2009). MARSSIM and MARSAME allow for statistically based survey protocols that typically require survey measurements for a representative portion of the items being released. The survey protocols are documented in separate survey and release plans, and the measurements from such surveys are documented in radiological release survey reports.

In accordance with DOE Order 458.1 Section k.(6)(f)2 b Pre-Approved Authorized Limits, UT-Battelle continues to use the preapproved authorized limits for surface contamination originally established in Table IV-1 of DOE Order 5400.5 (cancelled in 2011) and the November 17, 1995, Pelletier memorandum (Pelletier 1995) for TRU alpha contamination. UT-Battelle also continues to follow the requirements of the scrap metal suspension. No scrap metal directly released from radiological areas is being recycled. In 2018, UT-Battelle cleared more than 20,000 items through the excess items and property sales processes. A summary of items requested for release through these processes is shown in Table 5.6.

Table 5.6. Excess items requested for release and/or recycling, 2018

Item	Process knowledge	Radiologically surveyed
	Release request totals for 2018	
Totals	18,491	2,149
	Recycling request totals for 2018	
Cardboard (tons)	233	
Scrap metal (nonradiological areas) (tons)	803.85	

5.3.13.1 Authorized Limits Clearance Process for Spallation Neutron Source and High Flux Isotope Reactor Neutron Scattering Experiment Samples

The Spallation Neutron Source (SNS) and High Flux Isotope Reactor (HFIR) facilities provide unique neutron scattering experiment capabilities that allow researchers to explore the properties of various materials by exposing samples to well-characterized neutron beams. Because materials exposed to neutrons can become radioactive, a process has been developed to evaluate and clear samples for release to off-site facilities. DOE regulations and orders governing radiological release of material do not specifically cover items that may have radioactivity distributed throughout the volume of the material. To address sample clearance, activity-based limits were established using the authorized limits process defined in DOE O 458.1 (DOE 2011c) and associated guidance. The sample clearance limits are based on an assessment of potential doses against a threshold of 1 mrem/year to an individual and evaluation of other potentially applicable requirements (e.g., Nuclear Regulatory Commission [NRC]) licensing regulations). Implementation of the clearance limits involves use of unique instrument screening and methods for prediction of sample activity to provide an efficient and defensible process to release neutron scattering experiment samples to researchers without further DOE control.

In 2018 ORNL cleared a total of 107 samples from neutron scattering experiments using the sample authorized limits process. Of these, 61 samples were from SNS and 46 were from HFIR.

5.4 Air Quality Program

5.4.1 Construction and Operating Permits

Permits issued by the State of Tennessee convey the clean air requirements that are applicable to ORNL. New projects are governed by construction permits until the projects are converted to operating status. The sitewide Title V Major Source Operating Permits include requirements that are generally applicable to large operations such as national laboratories (e.g., asbestos and stratospheric ozone) as well as specific requirements directly applicable to individual air emission sources. Source-specific requirements include Rad-NESHAPs (see Section 5.4.3), requirements applicable to sources of ambient air criteria pollutants, and requirements applicable to sources of other hazardous (nonradiological) air pollutants. In August 2017, the State of Tennessee issued Title V Major Source Operating Permit 571359 to DOE and UT-Battelle operations at ORNL. In January 2015, TDEC also issued two construction permits for the Building 3525 and the 4501/4505 Off Gas System new radionuclide emission sources. DOE and UT-Battelle also maintained a valid minor source operating permit with the Knox County Department of Air Quality Management Division for NTRC facilities located in Knox County.

In 2012 and in 2014 UT-Battelle applied for and received, construction permit numbers 965013P and 967180P, respectively, for the construction of CFTF, located off site at the Horizon Center Business Park in Oak Ridge, Tennessee. The initial start-up of CFTF occurred in March 2013. A Conditional Major Source Operating Permit for the facility and its emergency generator is anticipated to be issued in FY 2020.

DOE/NWSol has two non-Title V Major Source Operating Permits for one emission source and two emergency generators at TWPC. During 2018 no permit limits were exceeded. Isotek has a Title V Major Source Operating Permit 568276 for the Radiochemical Development Facility (Building 3019 complex). During 2018 no permit limits were exceeded. UCOR was issued a Title V Major Source Operating Permit 569768 on September 18, 2015, for the 3039 stack and Construction Permit 974744 was issued on November 19, 2018 to implement several proposed modifications to the Title V Air Permit. No permit limits were exceeded for these sources in 2018.

5.4.2 National Emission Standards for Hazardous Air Pollutants—Asbestos

Numerous facilities, structures, and facility components and various pieces of equipment at ORNL contain asbestos-containing material (ACM). UT-Battelle's Asbestos Management Program manages the compliance of work activities involving the removal and disposal of ACM, which include notifications to

TDEC for all demolition activities and required renovation activities, approval of asbestos work authorization requests, current use of engineering controls and work practices, inspections, air monitoring, and waste tracking of asbestos-contaminated waste material. During 2018 there were no deviations or releases of reportable quantities of ACM.

5.4.3 Oak Ridge National Laboratory Radiological Airborne Effluent Monitoring

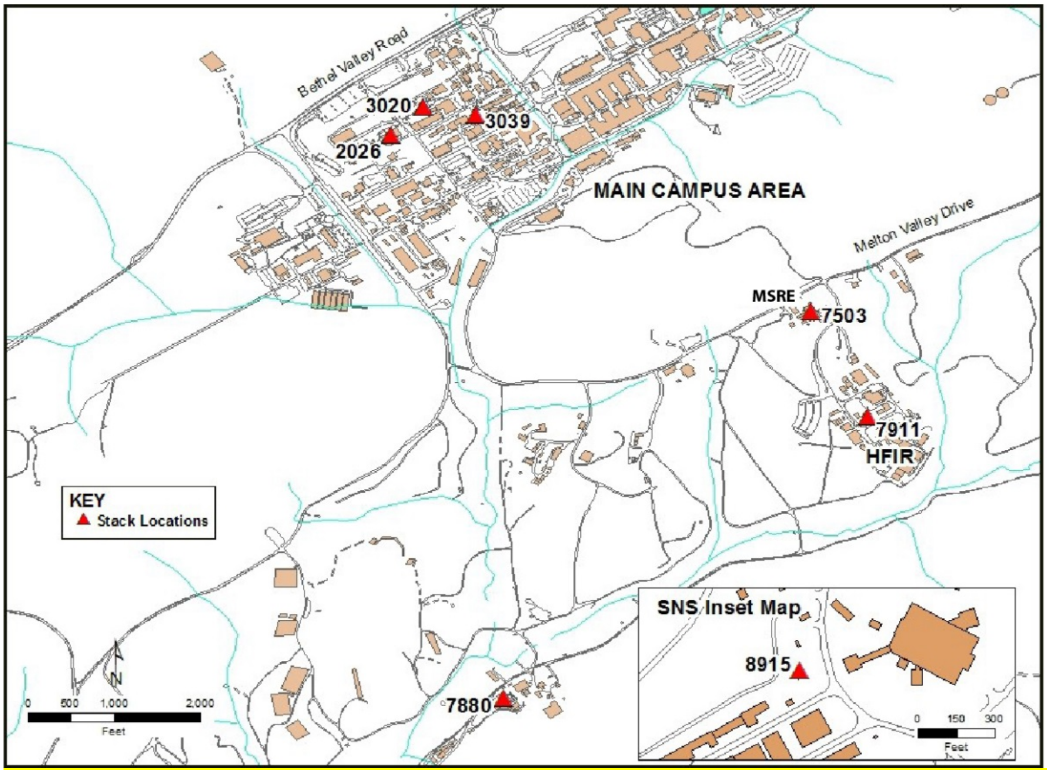
Radioactive airborne discharges at ORNL are subject to Rad-NESHAP and consist primarily of ventilation air from radioactively contaminated or potentially contaminated areas, vents from tanks and processes, and ventilation for hot cell operations and reactor facilities. The airborne emissions are treated and then filtered with high- efficiency particulate air filters and/or charcoal filters before discharge. Radiological airborne emissions from ORNL consist of solid particulates, tritium, adsorbable gases (e.g., iodine), and nonadsorbable gases (e.g., noble gases).

The major radiological emission point sources for ORNL consist of the following seven stacks. Six are located in Bethel and Melton Valleys, and one, the SNS Central Exhaust Facility stack, is located on Chestnut Ridge (Figure 5.9):

- 2026 Radioactive Materials Analytical Laboratory
- 3020 Radiochemical Development Facility
- 3039 central off-gas and scrubber system, which includes the 3500 cell ventilation system, isotope solid-state ventilation system, 3025 area cell ventilation system, 3042 ventilation system, and 3092 central off-gas system
- 7503 Molten Salt Reactor Experiment Facility
- 7880 TWPC
- 7911 Melton Valley complex, which includes HFIR and the Radiochemical Engineering Development Center
- 8915 SNS Central Exhaust Facility stack

In 2018 there were 12 minor point/group sources, and emission calculations/estimates were made for each of them.

ORNL 2018-G00383/mhr



HFIR = High Flux Isotope Reactor, MSRE = Molten Salt Reactor Experiment, and SNS = Spallation Neutron Source

Figure 5.9. Locations of major radiological emission points at Oak Ridge National Laboratory, 2018

5.4.3.1 Sample Collection and Analytical Procedure

Four of the major point sources (stacks 2026, 3020, 3039, and 7503) are equipped with in-stack source-sampling systems that comply with criteria in the American National Standards Institute (ANSI) standard ANSI N 13.1-1969R (ANSI 1969). The sampling systems generally consist of a multipoint in-stack sampling probe, a sample transport line, a particulate filter, activated charcoal cartridges, a silica gel cartridge (if required), flow-measurement and totalizing instruments, a sampling pump, and a return line to the stack. The 7911 (Melton Valley complex) and 7880 (TWPC) stacks are equipped with in-stack source-sampling systems that comply with criteria in the ANSI–Health Physics Society standard ANSI/HPS N13.1-1999 (ANSI 1999).

The 7911 sampling system has the same components as the ANSI 1969 sampling systems but uses a stainless-steel-shrouded probe instead of a multipoint in-stack sampling probe. The sampling system also consists of a high-purity germanium detector with an analog-to-digital converter and ORTEC GammaVision software, which allows for continuous isotopic identification and quantification of radioactive noble gases (e.g., ^{41}Ar) in the effluent stream. The 7880 sampling system consists of a stainless-steel-shrouded probe, an in-line filter-cartridge holder placed at the probe to minimize line losses, a particulate filter, a sample transport line, a rotary vane vacuum pump, and a return line to the stack. The sample probes from both the ANSI 1969 and ANSI 1999 stack-sampling systems are removed, inspected, and cleaned annually. The SNS Central Exhaust Facility (8915) stack is equipped with an in-stack radiation detector that complies with criteria in ANSI/HPS N13.1-1999 (ANSI 1999). The detector monitors radioactive gases flowing through the exhaust stack and provides a continual readout of activity detected by a scintillator probe. The detector is calibrated to correlate with isotopic emissions.

Velocity profiles are performed quarterly at major sources (except for the 3039 stack) and at some minor sources; the criteria in EPA Method 2 (EPA 2010) are followed. The profiles provide accurate stack flow data for subsequent emission-rate calculations. An annual leak-check program is carried out to verify the integrity of the sample transport system. An annual comparison is performed for the 7880 stack between the effluent flow rate totalizer and EPA Method 2. The response of the stack effluent-flow-rate monitoring system is checked quarterly with the manufacturer's instrument test procedures. The stack sampler rotameter is calibrated at least quarterly in comparison with a secondary (transfer) standard. Only a certified secondary standard is used for all rotameter tests.

Starting in 2017, the 3039 emissions are calculated using a fixed stack flow rate. A fixed stack flow rate is used because the stack velocity at the sampling level is at or below the sensitivity of standard methods for measuring the velocity and therefore stack flow rates can no longer be determined. Low effluent velocity measurements are due to stack flow reductions resulting from the removal of facilities exhausting through the stack. The EPA Region 4 office approved a request to use an alternative fixed stack flow for emission calculations for the 3039 stack in a letter dated April 27, 2017 (V. Anne Heard, Acting Regional Administrator, United States Environmental Protection Agency Region 4 to Raymond J. Skwarek, Environmental Safety, Health and Quality Assurance Manager, UCOR, April 27, 2017).

In addition to the major sources, ORNL has a number of minor sources that have the potential to emit radionuclides to the atmosphere. A minor source is defined as any ventilation system or component such as a vent, laboratory hood, room exhaust, or stack that does not meet the approved regulatory criteria for a major source but that is located in or vents from a radiological control area as defined by Radiological Support Services of the UT-Battelle Nuclear and Radiological Protection Division. Various methods are used to determine the emissions from the various minor sources. Methods used for calculations of minor source emissions comply with EPA criteria. The minor sources are evaluated on a 1 to 5 year basis. Major and minor emissions are compiled annually to determine the overall ORNL source term and associated dose.

The charcoal cartridges, particulate filters, and silica-gel traps are collected weekly to biweekly. The use of charcoal cartridges is a standard method for capturing and quantifying radioactive iodine in airborne emissions. Gamma spectrometric analysis of the charcoal samples quantifies the adsorbable gases. Analyses are performed weekly to biweekly. Particulate filters are held for 8 days before a weekly gross alpha and gross beta analysis to minimize the contribution from short-lived isotopes such as ^{220}Rn and its daughter products. At stack 7911, a weekly gamma scan is conducted to better detect short-lived gamma isotopes. The filters are then composited quarterly or semiannually and are analyzed for alpha-, beta-, and gamma-emitting isotopes. At stack 7880, the filters are composited monthly and analyzed for alpha-, beta-, and gamma-emitting isotopes. The sampling system on stack 7880 requires no other type of radionuclide collection media. Compositing provides a better opportunity for quantification of the low-concentration isotopes. Silica-gel traps are used to capture water vapor that may contain tritium. Analysis is performed weekly to biweekly. At the end of the year, the sample probes for all of the stacks are rinsed, except for the 8915 and 7880 probes, and the rinsate is collected and submitted for isotopic analysis identical to that performed on the particulate filters. A probe-cleaning program has been determined unnecessary for 8915 because the sample probe is a scintillator probe used to detect radiation and not to extract a sample of stack exhaust emissions. It is not anticipated that contaminant deposits would collect on the scintillator probe. A probe-cleaning program for 7880 has established that rinse analysis historically showed no detectable contamination. Therefore, the frequency of probe rinse collection and analysis is no more often than every 3 years unless there is an increase in particulate emissions, an increase in detectable radionuclides in the sample media, or process modifications.

The data from the charcoal cartridges, silica gel, probe wash, and filter composites are compiled to give the annual emissions for each major source and some minor sources.

5.4.3.2 Results

Annual radioactive airborne emissions for ORNL in 2018 are presented in Table 5.7. All data presented were determined to be statistically different from zero at the 95 percent confidence level. Any number not statistically different from zero was not included in the emission calculation. Because measuring a radionuclide requires counting random radioactive emissions from a sample, the same result may not be obtained if the sample is analyzed repeatedly. This deviation is referred to as the "counting uncertainty." Statistical significance at the 95 percent confidence level means that there is a 5 percent chance that the results could be erroneous.

Historical trends for tritium (^{3}H) and ^{131}I are presented in Figures 5.10 and 5.11. For 2018, tritium emissions totaled about 814 Ci (Figure 5.10), comparable to what was seen in 2017; ^{131}I emissions totaled 0.06 Ci (Figure 5.11), a significant decrease from 2017 but comparable to what was seen in 2016. For 2018, of the 436 radionuclides (excluding radionuclides with multiple solubility type) released from ORNL operations and evaluated, the isotopes that contributed 10 percent or more to the off-site dose from ORNL included ^{212}Pb, which contributed about 54 percent; ^{138}Cs, which contributed about 21 percent; and ^{41}Ar, which contributed about 14 percent to the total ORNL dose. Emissions of ^{212}Pb result from research activities and from the radiation decay of legacy material stored on site and areas containing isotopes of ^{228}Th, ^{232}Th, and ^{232}U. Emissions of ^{212}Pb were from the following stacks: 2026, 3020, 3039, 4501, 7503, 7856, 7911, and the 4000 area laboratory hoods. Cesium-138 and ^{41}Ar emissions result from Radiochemical Engineering Development Center research activities and HFIR operations. For 2018, ^{212}Pb emissions totaled 5.54 Ci, ^{138}Cs emissions totaled 859 Ci, and ^{41}Ar emissions totaled 1,194 Ci (see Figure 5.12).

The calculated radiation dose to the maximally exposed individual (MEI) from all radiological airborne release points at ORR during 2018 was 0.2 mrem. The dose contribution to the MEI from all ORNL radiological airborne release points was 19 percent of the ORR dose. This dose is well below the NESHAPs standard of 10 mrem and is equal to approximately 0.07 percent of the roughly 300 mrem that the average individual receives from natural sources of radiation. (See Section 7.1.2 for an explanation of how the airborne radionuclide dose was determined.)

Table 5.7. Radiological airborne emissions from all sources at ORNL, 2018 (Ci)[a]

Isotope	Inhalation Form[b]	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total Minor Source	ORNL Total
^{223}Ac	B	unspecified								3.97E-13	3.97E-13
^{225}Ac	M	particulate								6.93E-06	6.93E-06
^{226}Ac	M	particulate								2.5E-06	2.5E-06
^{227}Ac	M	particulate								2.07E-08	2.07E-08
^{228}Ac	M	particulate								7.82E-21	7.82E-21
^{106}Ag	M	particulate								2.78E-22	2.78E-22
^{108}Ag	B	unspecified								1.82E-18	1.82E-18
^{108m}Ag	M	particulate								1.91E-17	1.91E-17
^{109m}Ag	B	unspecified								3.E-16	3.E-16
^{110}Ag	B	unspecified								1.39E-09	1.39E-09
^{110}Ag	M	particulate								5.29E-29	5.29E-29
^{110m}Ag	M	particulate								1.25E-09	1.25E-09
^{111}Ag	M	particulate								2.94E-05	2.94E-05
^{112}Ag	M	particulate								6.15E-08	6.15E-08
^{115}Ag	M	particulate								1.05E-10	1.05E-10
^{26}Al	M	particulate								2.68E-17	2.68E-17
^{239}Am	M	particulate								1.57E-19	1.57E-19
^{240}Am	M	particulate								1.21E-16	1.21E-16
^{241}Am	F	particulate			8.65E-08	5.58E-09	2.44E-07			3.17E-09	3.39E-07
^{241}Am	M	particulate	2.23E-08	3.8E-07				9.3E-09		2.87E-07	6.98E-07
^{242}Am	M	particulate								3.74E-10	3.74E-10
^{242m}Am	M	particulate								1.13E-13	1.13E-13
^{243}Am	M	particulate								7.08E-09	7.08E-09
^{244}Am	M	particulate								2.77E-10	2.77E-10
^{244m}Am	M	particulate								1.53E-10	1.53E-10
^{245}Am	M	particulate								3.04E-15	3.04E-15
^{246}Am	M	particulate								7.32E-19	7.32E-19
^{37}Ar	B	unspecified								6.65E-10	6.65E-10
^{39}Ar	B	unspecified								4.82E-05	4.82E-05
^{41}Ar	B	unspecified						1.18E+03	1.4E+01		1.19E+03
^{74}As	M	particulate								3.63E-33	3.63E-33

Table 5.7 Radiological airborne emissions from all sources at ORNL, 2018 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total Minor Source	ORNL Total
^{76}As	M	particulate								4.93E-13	4.93E-13
^{77}As	M	particulate								5.16E-11	5.16E-11
^{78}As	M	particulate								1.13E-10	1.13E-10
^{217}At	B	unspecified								4.8E-11	4.8E-11
^{131}Ba	M	particulate								2.15E-06	2.15E-06
^{133}Ba	M	particulate								2.65E-05	2.65E-05
^{135m}Ba	M	particulate								7.04E-13	7.04E-13
^{137m}Ba	B	unspecified								7.29E-09	7.29E-09
^{139}Ba	M	particulate						2.85E-01		3.47E-08	2.85E-01
^{140}Ba	M	particulate						5.69E-04		6.51E-06	5.76E-04
^{141}Ba	M	particulate								3.19E-08	3.19E-08
^{142}Ba	M	particulate								3.12E-08	3.12E-08
^{7}Be	M	particulate	1.64E-07							3.14E-06	3.31E-06
^{7}Be	S	particulate			4.17E-06	8.87E-08				1.01E-06	5.27E-06
^{10}Be	M	particulate								3.47E-16	3.47E-16
^{206}Bi	M	particulate								2.62E-07	2.62E-07
^{207}Bi	M	particulate								6.E-16	6.E-16
^{208}Bi	B	unspecified								8.67E-17	8.67E-17
^{210}Bi	M	particulate								7.6E-25	7.6E-25
^{210m}Bi	M	particulate								4.04E-17	4.04E-17
^{211}Bi	B	unspecified								5.82E-11	5.82E-11
^{212}Bi	M	particulate								1.7E-07	1.7E-07
^{213}Bi	M	particulate								4.77E-11	4.77E-11
^{249}Bk	M	particulate								7.E-11	7.E-11
^{250}Bk	M	particulate								1.65E-19	1.65E-19
^{80}Br	M	particulate								1.02E-14	1.02E-14
^{80m}Br	M	particulate								6.2E-15	6.2E-15
^{82}Br	M	particulate								7.96E-07	7.96E-07

Table 5.7 Radiological airborne emissions from all sources at ORNL, 2018 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total Minor Source	ORNL Total
^{83}Br	M	particulate								2.59E-09	2.59E-09
^{84}Br	M	particulate								4.7E-09	4.7E-09
^{11}C	G	dioxide							9.07E+03		9.07E+03
^{14}C	M	particulate								2.48E-08	2.48E-08
^{41}Ca	M	particulate								7.04E-09	7.04E-09
^{45}Ca	M	particulate								3.6E-06	3.6E-06
^{47}Ca	M	particulate								2.04E-10	2.04E-10
^{109}Cd	M	particulate								7.63E-11	7.63E-11
^{113m}Cd	M	particulate								5.24E-12	5.24E-12
^{115}Cd	M	particulate								3.13E-05	3.13E-05
^{115m}Cd	M	particulate								2.08E-11	2.08E-11
^{117}Cd	M	particulate								8.41E-11	8.41E-11
^{117m}Cd	M	particulate								4.58E-11	4.58E-11
^{139}Ce	M	particulate								5.76E-08	5.76E-08
^{141}Ce	M	particulate						2.88E-07		4.39E-06	4.68E-06
^{143}Ce	M	particulate								5.9E-06	5.9E-06
^{144}Ce	M	particulate								5.14E-07	5.14E-07
^{249}Cf	M	particulate								1.E-11	1.E-11
^{250}Cf	M	particulate								1.41E-16	1.41E-16
^{251}Cf	M	particulate								3.54E-24	3.54E-24
^{252}Cf	M	particulate	6.56E-10	2.23E-10			3.91E-06			1.6E-08	3.93E-06
^{253}Cf	M	particulate								6.E-24	6.E-24
^{254}Cf	M	particulate								2.53E-26	2.53E-26
^{36}Cl	M	particulate								1.E-10	1.E-10
^{241}Cm	M	particulate								9.76E-18	9.76E-18
^{242}Cm	M	particulate								5.24E-10	5.24E-10
^{243}Cm	F	particulate			5.95E-09	9.35E-09	2.5E-07			6.13E-11	2.65E-07
^{243}Cm	M	particulate	2.76E-08					2.74E-08		4.73E-09	5.97E-08
^{244}Cm	F	particulate			5.95E-09	9.35E-09	2.5E-07			6.13E-11	2.65E-07
^{244}Cm	M	particulate	2.76E-08	9.36E-09				2.74E-08		3.68E-06	3.74E-06
^{245}Cm	M	particulate								1.93E-09	1.93E-09

Table 5.7 Radiological airborne emissions from all sources at ORNL, 2018 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total Minor Source	ORNL Total
^{246}Cm	M	particulate								1.75E-09	1.75E-09
^{247}Cm	M	particulate								2.39E-09	2.39E-09
^{247}Cm	M	particulate								1.16E-19	1.16E-19
^{248}Cm	M	particulate								1.72E-09	1.72E-09
^{249}Cm	M	particulate								9.48E-19	9.48E-19
^{57}Co	M	particulate								2.83E-11	2.83E-11
^{58}Co	M	particulate								4.14E-05	4.14E-05
^{60}Co	S	particulate					8.67E-07				8.67E-07
^{60}Co	M	particulate								1.06E-04	1.06E-04
^{60m}Co	M	particulate								8.15E-23	8.15E-23
^{51}Cr	M	particulate								5.36E-04	5.36E-04
^{131}Cs	F	particulate								2.2E-06	2.2E-06
^{132}Cs	F	particulate								1.04E-07	1.04E-07
^{134}Cs	S	particulate					1.16E-06				1.16E-06
^{134}Cs	F	particulate								4.54E-06	4.54E-06
^{134m}Cs	F	particulate								9.27E-10	9.27E-10
^{135}Cs	F	particulate								9.37E-14	9.37E-14
^{135}Cs	M	particulate								1.57E-28	1.57E-28
^{135m}Cs	F	particulate								1.82E-10	1.82E-10
^{136}Cs	F	particulate								4.42E-06	4.42E-06
^{137}Cs	S	particulate			3.22E-05					1.43E-07	3.23E-05
^{137}Cs	F	particulate	4.02E-07	2.61E-06				6.07E-06		2.68E-04	2.77E-04
^{138}Cs	F	particulate						8.59E+02		3.6E-08	8.59E+02
^{64}Cu	M	particulate								3.23E-05	3.23E-05
^{67}Cu	M	particulate								1.6E-08	1.6E-08
^{159}Dy	M	particulate								7.33E-16	7.33E-16
^{165}Dy	M	particulate								3.12E-12	3.12E-12
^{166}Dy	M	particulate								2.41E-13	2.41E-13
^{169}Er	M	particulate								5.63E-14	5.63E-14

Table 5.7 Radiological airborne emissions from all sources at ORNL, 2018 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total Minor Source	ORNL Total
^{171}Er	M	particulate								1.39E-22	1.39E-22
^{253}Es	M	particulate								2.86E-24	2.86E-24
^{254}Es	M	particulate								1.86E-26	1.86E-26
^{254m}Es	M	particulate								1.89E-25	1.89E-25
^{150}Eu	M	particulate								1.52E-20	1.52E-20
^{152}Eu	M	particulate								2.34E-07	2.34E-07
^{152m}Eu	M	particulate								1.18E-13	1.18E-13
^{154}Eu	M	particulate								1.99E-07	1.99E-07
^{155}Eu	M	particulate								4.06E-08	4.06E-08
^{156}Eu	M	particulate								8.62E-10	8.62E-10
^{157}Eu	M	particulate								2.04E-10	2.04E-10
^{158}Eu	M	particulate								1.01E-10	1.01E-10
^{55}Fe	M	particulate								1.94E-04	1.94E-04
^{59}Fe	M	particulate								8.06E-06	8.06E-06
^{221}Fr	B	unspecified								4.08E-11	4.08E-11
^{72}Ga	M	particulate								1.19E-11	1.19E-11
^{73}Ga	M	particulate								1.49E-12	1.49E-12
^{151}Gd	M	particulate								5.8E-12	5.8E-12
^{152}Gd	M	particulate								1.19E-28	1.19E-28
^{153}Gd	M	particulate								7.75E-06	7.75E-06
^{159}Gd	M	particulate								6.32E-11	6.32E-11
^{71}Ge	M	particulate								2.01E-09	2.01E-09
^{75}Ge	M	particulate								8.34E-12	8.34E-12
^{77}Ge	M	particulate								1.85E-11	1.85E-11
^{78}Ge	M	particulate								1.11E-10	1.11E-10
^{3}H	V	vapor	3.68E-03		2.69E+00	5.32E-01		1.7E+02	6.41E+02	2.31E-01	8.14E+02
^{175}Hf	M	particulate								3.E-06	3.E-06
^{178m}Hf	M	particulate								6.05E-12	6.05E-12

Table 5.7 Radiological airborne emissions from all sources at ORNL, 2018 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total Minor Source	ORNL Total
^{179m}Hf	M	particulate								1.47E-08	1.47E-08
^{181}Hf	M	particulate								7.47E-05	7.47E-05
^{182}Hf	M	particulate								2.77E-12	2.77E-12
^{203}Hg	M	inorganic								1.5E-14	1.5E-14
^{163}Ho	B	unspecified								6.41E-14	6.41E-14
^{166}Ho	M	particulate								7.58E-13	7.58E-13
^{166m}Ho	M	particulate								1.94E-12	1.94E-12
^{124}I	F	particulate								8.92E-07	8.92E-07
^{126}I	F	particulate								6.3E-07	6.3E-07
^{128}I	F	particulate								1.03E-10	1.03E-10
^{129}I	F	particulate					2.06E-06			1.99E-05	2.2E-05
^{130}I	F	particulate								3.22E-07	3.22E-07
^{131}I	F	particulate						5.73E-02		3.77E-03	6.11E-02
^{132}I	F	particulate						5.67E-01		3.23E-03	5.7E-01
^{133}I	F	particulate			1.01E-05			2.76E-01		4.26E-07	2.76E-01
^{134}I	F	particulate						4.99E-01		4.19E-08	4.99E-01
^{135}I	F	particulate						9.37E-01		3.52E-08	9.37E-01
^{113m}In	M	particulate								2.6E-06	2.6E-06
^{114}In	B	unspecified								1.37E-07	1.37E-07
^{114m}In	M	particulate								1.43E-07	1.43E-07
^{115}In	M	particulate								1.39E-25	1.39E-25
^{115m}In	M	particulate								1.42E-10	1.42E-10
^{116m}In	M	particulate								5.94E-11	5.94E-11
^{117}In	M	particulate								7.77E-11	7.77E-11
^{117m}In	M	particulate								9.83E-11	9.83E-11
^{119m}In	M	particulate								1.E-10	1.E-10
^{191m}Ir	B	unspecified								1.25E-11	1.25E-11
^{192}Ir	M	particulate								3.09E-09	3.09E-09

Table 5.7 Radiological airborne emissions from all sources at ORNL, 2018 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total Minor Source	ORNL Total
^{192m}Ir	M	particulate								2.36E-17	2.36E-17
^{40}K	M	particulate								3.7E-07	3.7E-07
^{79}Kr	B	unspecified								1.37E-21	1.37E-21
^{81}Kr	B	unspecified								2.7E-11	2.7E-11
^{83m}Kr	B	unspecified								2.59E-09	2.59E-09
^{85}Kr	B	unspecified						1.34E+03		3.08E+02	1.65E+03
^{85m}Kr	B	unspecified						1.32E+01		5.88E-09	1.32E+01
^{87}Kr	B	unspecified						9.4E+01	1.9E+01	1.17E-08	1.13E+02
^{88}Kr	B	unspecified						6.25E+01	1.E+01	1.64E-08	7.25E+01
^{89}Kr	B	unspecified						3.86E+01			3.86E+01
^{137}La	M	particulate								1.16E-19	1.16E-19
^{138}La	M	particulate								2.22E-24	2.22E-24
^{140}La	M	particulate								2.97E-06	2.97E-06
^{141}La	M	particulate								3.17E-08	3.17E-08
^{142}La	M	particulate								3.11E-08	3.11E-08
^{143}La	M	particulate								3.09E-08	3.09E-08
^{173}Lu	M	particulate								2.21E-11	2.21E-11
^{174}Lu	M	particulate								7.82E-11	7.82E-11
^{174m}Lu	M	particulate								2.16E-11	2.16E-11
^{176}Lu	M	particulate								3.29E-18	3.29E-18
^{176m}Lu	M	particulate								3.39E-13	3.39E-13
^{177}Lu	M	particulate								1.2E-04	1.2E-04
^{177m}Lu	M	particulate								7.81E-10	7.81E-10
^{28}Mg	M	particulate								2.19E-22	2.19E-22
^{53}Mn	M	particulate								1.07E-17	1.07E-17
^{54}Mn	M	particulate								2.25E-05	2.25E-05
^{56}Mn	M	particulate								5.33E-12	5.33E-12
^{101}Mo	M	particulate								3.03E-08	3.03E-08

Table 5.7 Radiological airborne emissions from all sources at ORNL, 2018 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total Minor Source	ORNL Total
^{93}Mo	M	particulate								1.78E-10	1.78E-10
^{99}Mo	M	particulate								2.74E-05	2.74E-05
^{13}N	B	unspecified							1.95E+02		1.95E+02
^{24}Na	M	particulate								4.33E-06	4.33E-06
^{91}Nb	B	unspecified								6.7E-14	6.7E-14
^{91m}Nb	B	unspecified								7.26E-10	7.26E-10
^{92}Nb	B	unspecified								4.65E-15	4.65E-15
^{92m}Nb	B	unspecified								5.79E-09	5.79E-09
^{93m}Nb	M	particulate								5.2E-07	5.2E-07
^{94}Nb	M	particulate								4.94E-08	4.94E-08
^{95}Nb	M	particulate								1.83E-04	1.83E-04
^{95m}Nb	M	particulate								1.41E-06	1.41E-06
^{96}Nb	M	particulate								3.29E-07	3.29E-07
^{97}Nb	M	particulate								3.91E-08	3.91E-08
^{98m}Nb	B	unspecified								4.02E-08	4.02E-08
^{147}Nd	M	particulate								2.83E-06	2.83E-06
^{149}Nd	M	particulate								6.56E-09	6.56E-09
^{151}Nd	M	particulate								3.06E-09	3.06E-09
^{59}Ni	M	particulate								1.92E-07	1.92E-07
^{63}Ni	M	particulate								1.66E-03	1.66E-03
^{235}Np	M	particulate								1.13E-17	1.13E-17
^{236}Np	M	particulate								3.13E-20	3.13E-20
^{237}Np	M	particulate								9.71E-08	9.71E-08
^{238}Np	M	particulate								4.39E-09	4.39E-09
^{239}Np	M	particulate								2.23E-07	2.23E-07
^{240}Np	M	particulate								1.67E-10	1.67E-10
^{240m}Np	B	unspecified								1.93E-23	1.93E-23
^{185}Os	M	particulate								1.62E-09	1.62E-09
^{191}Os	M	particulate								9.73E-12	9.73E-12
^{32}P	M	particulate								2.32E-07	2.32E-07

Table 5.7 Radiological airborne emissions from all sources at ORNL, 2018 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total Minor Source	ORNL Total
^{33}P	M	particulate								1.32E-10	1.32E-10
^{228}Pa	M	particulate								7.8E-07	7.8E-07
^{230}Pa	M	particulate								3.49E-06	3.49E-06
^{231}Pa	M	particulate								1.42E-16	1.42E-16
^{232}Pa	M	particulate								5.79E-07	5.79E-07
^{233}Pa	M	particulate								2.92E-06	2.92E-06
^{234}Pa	M	particulate								3.87E-16	3.87E-16
^{234m}Pa	B	unspecified								2.52E-11	2.52E-11
^{205}Pb	M	particulate								1.83E-17	1.83E-17
^{209}Pb	M	particulate								4.64E-11	4.64E-11
^{210}Pb	M	particulate								8.05E-25	8.05E-25
^{211}Pb	M	particulate								5.22E-22	5.22E-22
^{212}Pb	S	particulate			4.52E+00	6.97E-02				5.8E-02	4.65E+00
^{212}Pb	M	particulate	4.43E-01	4.21E-01				2.11E-02		3.59E-03	8.89E-01
^{214}Pb	M	particulate			2.83E-01					1.18E-03	2.84E-01
^{103}Pd	M	particulate								2.77E-32	2.77E-32
^{107}Pd	M	particulate								1.25E-14	1.25E-14
^{109}Pd	M	particulate								3.21E-09	3.21E-09
^{112}Pd	B	unspecified								7.08E-06	7.08E-06
^{146}Pm	M	particulate								8.35E-15	8.35E-15
^{147}Pm	M	particulate								1.23E-08	1.23E-08
^{148}Pm	M	particulate								6.31E-09	6.31E-09
^{148m}Pm	M	particulate								4.55E-08	4.55E-08
^{149}Pm	M	particulate								8.3E-09	8.3E-09
^{150}Pm	M	particulate								2.73E-10	2.73E-10
^{151}Pm	M	particulate								2.99E-09	2.99E-09
^{210}Po	B	inorganic								2.83E-11	2.83E-11
^{213}Po	B	unspecified								4.67E-11	4.67E-11

Table 5.7 Radiological airborne emissions from all sources at ORNL, 2018 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total Minor Source	ORNL Total
^{216}Po	B	unspecified								1.06E-18	1.06E-18
^{142}Pr	M	particulate								5.82E-10	5.82E-10
^{142m}Pr	M	particulate								1.26E-10	1.26E-10
^{143}Pr	M	particulate								3.58E-08	3.58E-08
^{144}Pr	M	particulate								4.33E-08	4.33E-08
^{144m}Pr	B	unspecified								4.08E-10	4.08E-10
^{145}Pr	M	particulate								2.04E-08	2.04E-08
^{147}Pr	M	particulate								1.25E-08	1.25E-08
^{193}Pt	M	particulate								8.26E-15	8.26E-15
^{236}Pu	M	particulate								7.58E-15	7.58E-15
^{237}Pu	M	particulate								4.79E-15	4.79E-15
^{238}Pu	F	particulate			5.21E-08		5.8E-07			9.2E-09	6.41E-07
^{238}Pu	M	particulate								9.22E-07	9.22E-07
^{239}Pu	F	particulate			1.54E-07	3.91E-09	1.57E-07			2.47E-09	3.17E-07
^{239}Pu	M	particulate	1.08E-08	3.01E-07				2.06E-08		1.7E-07	5.02E-07
^{240}Pu	F	particulate			1.54E-07	3.91E-09	1.57E-07			2.47E-09	3.17E-07
^{240}Pu	M	particulate	1.08E-08					2.06E-08		6.36E-08	9.5E-08
^{241}Pu	M	particulate								5.04E-07	5.04E-07
^{242}Pu	M	particulate								7.21E-09	7.21E-09
^{243}Pu	M	particulate								1.33E-09	1.33E-09
^{244}Pu	M	particulate								9.75E-12	9.75E-12
^{245}Pu	M	particulate								3.04E-15	3.04E-15
^{223}Ra	M	particulate								1.99E-06	1.99E-06
^{224}Ra	M	particulate								9.E-07	9.E-07
^{225}Ra	M	particulate								9.36E-08	9.36E-08
^{226}Ra	M	particulate								1.E-07	1.E-07
^{228}Ra	M	particulate								6.41E-10	6.41E-10
^{83}Rb	M	particulate								1.2E-13	1.2E-13

Table 5.7 Radiological airborne emissions from all sources at ORNL, 2018 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total Minor Source	ORNL Total
^{84}Rb	M	particulate								8.09E-14	8.09E-14
^{86}Rb	M	particulate								6.64E-11	6.64E-11
^{87}Rb	M	particulate								1.88E-17	1.88E-17
^{88}Rb	M	particulate								1.66E-08	1.66E-08
^{89}Rb	M	particulate								2.16E-08	2.16E-08
^{184}Re	M	particulate								3.35E-09	3.35E-09
^{184m}Re	M	particulate								3.27E-09	3.27E-09
^{186}Re	M	particulate								3.39E-05	3.39E-05
^{186m}Re	M	particulate								2.48E-12	2.48E-12
^{187}Re	M	particulate								1.68E-18	1.68E-18
^{188}Re	M	particulate								1.52E-04	1.52E-04
^{102}Rh	M	particulate								1.46E-14	1.46E-14
^{102m}Rh	M	particulate								2.22E-15	2.22E-15
^{103m}Rh	M	particulate								2.42E-08	2.42E-08
^{105}Rh	M	particulate								2.56E-05	2.56E-05
^{106}Rh	B	unspecified								1.73E-08	1.73E-08
^{106m}Rh	M	particulate								1.17E-10	1.17E-10
^{107}Rh	M	particulate								6.61E-09	6.61E-09
^{219}Rn	B	unspecified								3.8E-11	3.8E-11
^{220}Rn	B	unspecified								1.7E-07	1.7E-07
^{222}Rn	B	unspecified								5.74E-10	5.74E-10
^{103}Ru	M	particulate								8.24E-06	8.24E-06
^{105}Ru	M	particulate								1.29E-08	1.29E-08
^{106}Ru	M	particulate								8.88E-07	8.88E-07
^{35}S	M	particulate								2.22E-07	2.22E-07
^{120m}Sb	M	particulate								2.65E-07	2.65E-07
^{122}Sb	M	particulate								3.71E-06	3.71E-06
^{124}Sb	M	particulate								1.36E-05	1.36E-05

Table 5.7 Radiological airborne emissions from all sources at ORNL, 2018 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total Minor Source	ORNL Total
^{124}Sb	S	particulate			1.02E-06						1.02E-06
^{124m}Sb	B	unspecified								1.55E-13	1.55E-13
^{125}Sb	M	particulate						9.52E-09		5.98E-06	5.99E-06
^{126}Sb	M	particulate								5.14E-06	5.14E-06
^{126m}Sb	M	particulate								6.32E-12	6.32E-12
^{127}Sb	M	particulate								5.92E-06	5.92E-06
^{128}Sb	M	particulate								3.53E-08	3.53E-08
^{129}Sb	M	particulate								4.8E-09	4.8E-09
^{130}Sb	M	particulate								1.62E-09	1.62E-09
^{131}Sb	M	particulate								1.48E-08	1.48E-08
^{46}Sc	M	particulate								2.69E-07	2.69E-07
^{47}Sc	M	particulate								1.26E-07	1.26E-07
^{48}Sc	M	particulate								3.28E-07	3.28E-07
^{75}Se	F	particulate								2.29E-05	2.29E-05
^{75}Se	S	particulate			2.17E-03						2.17E-03
^{79}Se	F	particulate								2.22E-14	2.22E-14
^{79}Se	M	particulate								6.22E-29	6.22E-29
^{81}Se	F	particulate								1.08E-09	1.08E-09
^{81m}Se	F	particulate								3.36E-11	3.36E-11
^{83}Se	F	particulate								9.95E-10	9.95E-10
^{31}Si	M	particulate								9.07E-11	9.07E-11
^{32}Si	M	particulate								6.84E-13	6.84E-13
^{145}Sm	M	particulate								2.91E-10	2.91E-10
^{146}Sm	M	particulate								7.29E-23	7.29E-23
^{147}Sm	M	particulate								2.38E-20	2.38E-20
^{151}Sm	M	particulate								1.39E-09	1.39E-09
^{153}Sm	M	particulate								7.02E-09	7.02E-09
^{155}Sm	M	particulate								4.65E-10	4.65E-10
^{156}Sm	M	particulate								2.7E-10	2.7E-10
^{113}Sn	M	particulate								2.6E-06	2.6E-06

Table 5.7 Radiological airborne emissions from all sources at ORNL, 2018 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total Minor Source	ORNL Total
^{117m}Sn	M	particulate								4.22E-07	4.22E-07
^{119m}Sn	M	particulate								2.47E-07	2.47E-07
^{121}Sn	M	particulate								3.33E-09	3.33E-09
^{121m}Sn	M	particulate								4.06E-09	4.06E-09
^{123}Sn	M	particulate								3.85E-09	3.85E-09
^{123m}Sn	M	particulate								1.33E-10	1.33E-10
^{125}Sn	M	particulate								4.8E-06	4.8E-06
^{126}Sn	M	particulate								3.53E-14	3.53E-14
^{127}Sn	M	particulate								8.33E-10	8.33E-10
^{128}Sn	M	particulate								2.42E-09	2.42E-09
^{85}Sr	M	particulate								1.51E-07	1.51E-07
^{87m}Sr	M	particulate								4.03E-14	4.03E-14
^{89}Sr	S	particulate			8.1E-06	4.19E-09				2.61E-08	8.13E-06
^{89}Sr	M	particulate	3.49E-08	1.07E-06				6.6E-06		1.34E-04	1.42E-04
^{90}Sr	S	particulate			8.1E-06	4.19E-09	2.83E-06			2.61E-08	1.1E-05
^{90}Sr	M	particulate	3.49E-08	1.07E-06				6.6E-06		1.15E-04	1.23E-04
^{91}Sr	M	particulate								2.7E-08	2.7E-08
^{92}Sr	M	particulate								2.83E-08	2.83E-08
^{179}Ta	M	particulate								1.08E-11	1.08E-11
^{182}Ta	M	particulate								1.36E-05	1.36E-05
^{182m}Ta	M	particulate								9.E-11	9.E-11
^{183}Ta	M	particulate								8.34E-06	8.34E-06
^{158}Tb	M	particulate								6.46E-13	6.46E-13
^{160}Tb	M	particulate								3.67E-10	3.67E-10
^{161}Tb	M	particulate								1.17E-11	1.17E-11
^{101}Tc	M	particulate								2.98E-08	2.98E-08
^{104}Tc	M	particulate								1.74E-08	1.74E-08
^{96}Tc	M	particulate								1.57E-08	1.57E-08
^{98}Tc	M	particulate								3.7E-19	3.7E-19
^{99}Tc	S	particulate					5.44E-06				5.44E-06
^{99}Tc	M	particulate								2.54E-05	2.54E-05

Table 5.7 Radiological airborne emissions from all sources at ORNL, 2018 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total Minor Source	ORNL Total
^{99m}Tc	M	particulate								1.15E-07	1.15E-07
^{121}Te	M	particulate								1.06E-07	1.06E-07
^{121m}Te	M	particulate								4.1E-09	4.1E-09
^{123}Te	M	particulate								5.66E-27	5.66E-27
^{123m}Te	M	particulate								1.89E-08	1.89E-08
^{125m}Te	M	particulate								7.34E-07	7.34E-07
^{127}Te	M	particulate								1.43E-09	1.43E-09
^{127m}Te	M	particulate								2.64E-10	2.64E-10
^{129}Te	M	particulate								4.77E-09	4.77E-09
^{129m}Te	M	particulate								7.67E-10	7.67E-10
^{131}Te	M	particulate								1.53E-08	1.53E-08
^{131m}Te	M	particulate								3.34E-06	3.34E-06
^{132}Te	M	particulate								6.68E-06	6.68E-06
^{133}Te	M	particulate								2.19E-08	2.19E-08
^{133m}Te	M	particulate								1.52E-08	1.52E-08
^{134}Te	M	particulate								3.41E-08	3.41E-08
^{226}Th	S	particulate								5.55E-23	5.55E-23
^{227}Th	S	particulate								1.43E-05	1.43E-05
^{228}Th	S	particulate	1.32E-08	2.93E-08	1.21E-07	3.98E-10		3.64E-08		3.95E-07	5.96E-07
^{229}Th	S	particulate								4.32E-08	4.32E-08
^{230}Th	S	particulate	1.23E-09	6.67E-09				1.62E-08		2.03E-08	4.44E-08
^{230}Th	F	particulate			2.89E-08	4.3E-10				1.89E-09	3.12E-08
^{231}Th	S	particulate								7.E-11	7.E-11
^{232}Th	F	particulate			1.28E-08	3.18E-10				1.22E-09	1.43E-08
^{232}Th	S	particulate	8.23E-10	7.2E-09				8.67E-09		7.41E-08	9.08E-08
^{234}Th	S	particulate								2.58E-11	2.58E-11
^{202}Tl	M	particulate								3.86E-10	3.86E-10
^{204}Tl	M	particulate								9.77E-15	9.77E-15

Table 5.7 Radiological airborne emissions from all sources at ORNL, 2018 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total Minor Source	ORNL Total
^{208}Tl	B	unspecified								1.7E-07	1.7E-07
^{209}Tl	B	unspecified								1.03E-12	1.03E-12
^{168}Tm	B	unspecified								1.31E-14	1.31E-14
^{170}Tm	M	particulate								1.34E-09	1.34E-09
^{171}Tm	M	particulate								6.37E-10	6.37E-10
^{172}Tm	M	particulate								2.14E-20	2.14E-20
^{230}U	M	particulate								5.55E-23	5.55E-23
^{231}U	M	particulate								1.39E-20	1.39E-20
^{232}U	M	particulate								1.7E-07	1.7E-07
^{233}U	S	particulate			7.7E-08	8.35E-09	7.75E-07			1.22E-08	8.73E-07
^{233}U	M	particulate	3.28E-08					4.09E-08		1.99E-08	9.35E-08
^{234}U	S	particulate			7.7E-08	8.35E-09	7.75E-07			1.22E-08	8.73E-07
^{234}U	M	particulate	3.28E-08	2.83E-07				4.09E-08		3.71E-07	7.27E-07
^{235}U	S	particulate			1.66E-08	1.04E-09	8.42E-07			4.12E-09	8.64E-07
^{235}U	M	particulate	3.21E-09	1.22E-08				8.34E-09		7.09E-06	7.11E-06
^{236}U	M	particulate								6.01E-10	6.01E-10
^{237}U	M	particulate								1.34E-08	1.34E-08
^{238}U	S	particulate			7.93E-08	3.66E-09	1.22E-06			9.48E-09	1.31E-06
^{238}U	M	particulate	1.36E-08	2.58E-08				2.16E-08		2.02E-05	2.03E-05
^{239}U	M	particulate								1.71E-07	1.71E-07
^{240}U	M	particulate								3.76E-13	3.76E-13
^{48}V	M	particulate								3.68E-11	3.68E-11
^{49}V	M	particulate								6.E-09	6.E-09
^{181}W	M	particulate								4.24E-05	4.24E-05
^{185}W	M	particulate								3.06E-03	3.06E-03
^{187}W	M	particulate								3.13E-03	3.13E-03
^{188}W	M	particulate								1.84E-04	1.84E-04
^{127}Xe	B	unspecified							5.9E+01	2.77E-16	5.9E+01
^{129m}Xe	B	unspecified								4.5E-13	4.5E-13

Table 5.7 Radiological airborne emissions from all sources at ORNL, 2018 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total Minor Source	ORNL Total
^{131m}Xe	B	unspecified						1.44E+02		2.18E-10	1.44E+02
^{133}Xe	B	unspecified						1.24E+01		4.35E-08	1.24E+01
^{133m}Xe	B	unspecified						2.96E+01		1.15E-09	2.96E+01
^{135}Xe	B	unspecified						8.24E+01		3.13E-09	8.24E+01
^{135m}Xe	B	unspecified						3.06E+01		6.96E-09	3.06E+01
^{137}Xe	B	unspecified						8.12E+01			8.12E+01
^{138}Xe	B	unspecified						2.05E+02		3.34E-08	2.05E+02
^{87}Y	M	particulate								1.16E-07	1.16E-07
^{88}Y	M	particulate					9.62E-07			9.42E-10	9.63E-07
^{89m}Y	B	unspecified								1.96E-17	1.96E-17
^{90}Y	M	particulate								3.62E-08	3.62E-08
^{135}Xe	B	unspecified						8.24E+01		3.13E-09	8.24E+01
^{135m}Xe	B	unspecified						3.06E+01		6.96E-09	3.06E+01
^{137}Xe	B	unspecified						8.12E+01			8.12E+01
^{138}Xe	B	unspecified						2.05E+02		3.34E-08	2.05E+02
^{87}Y	M	particulate								1.16E-07	1.16E-07
^{88}Y	M	particulate					9.62E-07			9.42E-10	9.63E-07
^{89m}Y	B	unspecified								1.96E-17	1.96E-17
^{90}Y	M	particulate								3.62E-08	3.62E-08
^{90m}Y	M	particulate								1.95E-13	1.95E-13
^{91}Y	M	particulate								1.65E-07	1.65E-07
^{91m}Y	M	particulate								1.56E-08	1.56E-08
^{92}Y	M	particulate								2.84E-08	2.84E-08
^{93}Y	M	particulate								3.15E-08	3.15E-08
^{94}Y	M	particulate								3.14E-08	3.14E-08
^{95}Y	M	particulate								3.31E-08	3.31E-08
^{169}Yb	M	particulate								2.67E-08	2.67E-08
^{175}Yb	M	particulate								1.48E-05	1.48E-05

Table 5.7 Radiological airborne emissions from all sources at ORNL, 2018 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total Minor Source	ORNL Total
^{65}Zn	M	particulate								3.22E-05	3.22E-05
^{69}Zn	M	particulate								1.04E-06	1.04E-06
^{69m}Zn	M	particulate								9.71E-07	9.71E-07
^{72}Zn	M	particulate								5.51E-13	5.51E-13
^{93}Zr	M	particulate								7.62E-10	7.62E-10
^{95}Zr	M	particulate								1.24E-04	1.24E-04
^{97}Zr	M	particulate								3.59E-06	3.59E-06
Totals			**4.47E-01**	**4.21E-01**	**7.5E+00**	**6.02E-01**	**2.25E-05**	**4.35E+03**	**1.E+04**	**3.08E+02**	**1.47E+04**

[a] Emissions given in curies (Ci). 1 Ci = 3.7E+10 Bq

[b] The designation of F, M, and S refers to the lung clearance type—Fast (F), Moderate (M), and Slow (S) for the given radionuclide. G stands for gaseous, V stands for vapor, and B stands for blank, unspecified form.

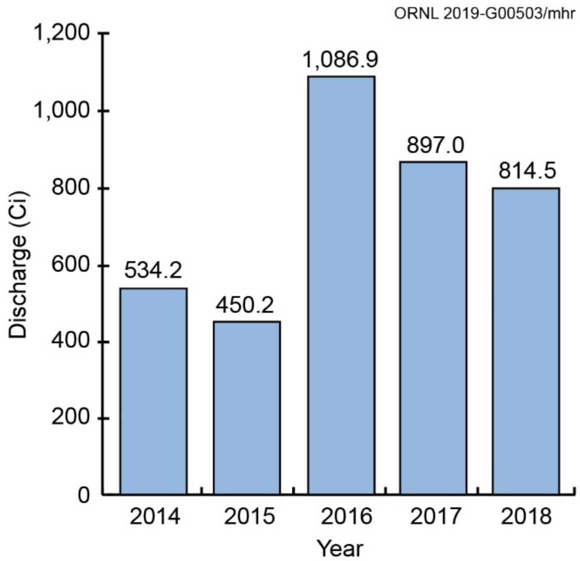


Figure 5.10. Total curies of tritium discharged from Oak Ridge National Laboratory to the atmosphere, 2014–2018

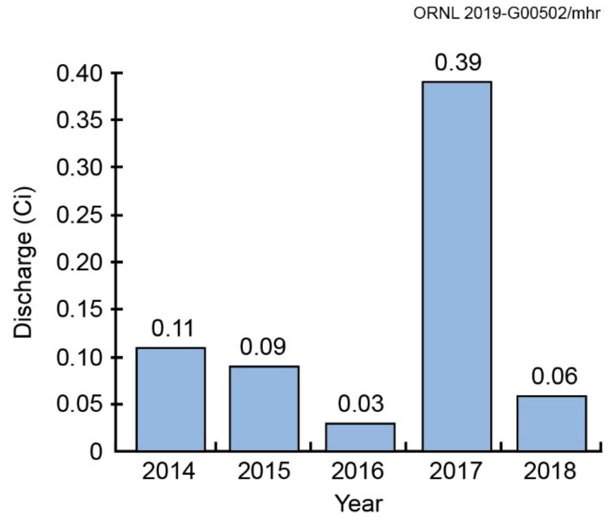


Figure 5.11. Total curies of ^{131}I discharged from Oak Ridge National Laboratory to the atmosphere, 2014–2018

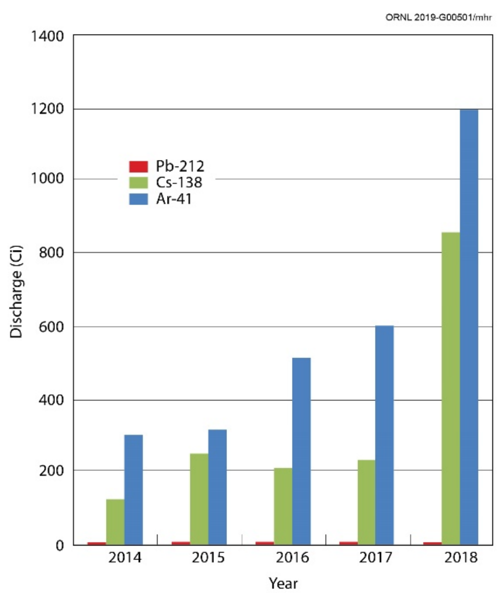


Figure 5.12. Total curies of ^{41}Ar, ^{138}Cs, and ^{212}Pb discharged from Oak Ridge National Laboratory to the atmosphere, 2014–2018

5.4.4 Stratospheric Ozone Protection

As required by the CAA Title VI Amendments of 1990 and in accordance with 40 CFR Part 82, actions have been implemented to comply with the prohibition against intentionally releasing ozone-depleting substances (ODSs) during maintenance activities performed on refrigeration equipment. In 2017, EPA enacted major revisions to the Stratospheric Ozone rules to include the regulation of non-ODS substitutes as part of 40 CFR 82 Subpart F. These revisions were effective January 1, 2018, for disposal of small appliances and January 1, 2019, for the leak rate provisions for large appliances. Necessary changes to the Stratospheric Ozone Protection compliance program were implemented to comply with the requirements of the new rule. Service requirements for refrigeration systems (including motor vehicle air conditioners), technician certification requirements, record-keeping requirements, and labeling requirements were implemented in accordance with 40 CFR 82 Subpart F.

5.4.5 Ambient Air

Station 7 in the ORNL 7000 maintenance area is the site-specific ambient air monitoring location. During 2018, the sampling system at Station 7 was used to quantify levels of tritium; uranium; and gross alpha-, beta-, and gamma-emitting radionuclides. A low-volume air sampler was used for particulate collection. The 47 mm glass-fiber filters were collected biweekly and were composited annually for laboratory analysis. A silica-gel column was used for collection of tritium as tritiated water. The silica gel was collected biweekly or weekly, depending on ambient humidity, and was composited quarterly for tritium analysis. Station 7 sampling data (Table 5.8) are compared with derived concentration standards (DCSs) for air established by DOE as guidelines for controlling exposure to members of the public (DOE 2011a). During 2018 average radionuclide concentrations at Station 7 were less than 1 percent of the applicable DCS in all cases.

Table 5.8. Radionuclide concentrations measured at Oak Ridge National Laboratory air monitoring Station 7, 2018

Parameter	Concentration (pCi/mL)[a]
Alpha	5.73E-09
^{7}Be	1.87E-08
Beta	1.21E-08
^{40}K	-1.26E-09[b]
Tritium	2.13E-06
^{234}U	8.40E-12
^{235}U	8.26E-13
^{238}U	1.12E-11
Total U	2.04E-11

[a] 1 pCi = 3.7×10^{-2} Bq.
[b] At very low sample activity levels, close to the instrument background, it is possible to obtain a sample result that is less than the background. When the background activity is subtracted from the sample activity to obtain a net value, a negative value results.

5.5 Oak Ridge National Laboratory Water Quality Program

NPDES permit TN 0002941, issued to DOE for the ORNL site and renewed by the State of Tennessee in 2014, includes requirements for discharging wastewaters from the two ORNL on-site wastewater treatment facilities and from more than 150 category outfalls (outfalls with nonprocess wastewaters such as cooling water, condensate, groundwater, and storm water), and for the development and implementation of a water quality protection plan (WQPP). The permit calls for a WQPP to "establish better linkages between water quality monitoring and detecting and abating water quality and ecological impact." Rather than prescribing rigid monitoring schedules, the ORNL WQPP is flexible and focuses on significant findings. It is implemented utilizing an adaptive management approach (Figure 5.13) whereby results of investigations are routinely evaluated and strategies for achieving goals are modified based on those evaluations. The goals established for the WQPP are to meet the requirements of the NPDES permit, improve the quality of aquatic resources on the ORNL site, prevent further impacts to aquatic resources from current activities, identify the stressors that contribute to impairment of aquatic resources, use available resources efficiently, and communicate outcomes with decision makers and stakeholders.

The ORNL WQPP was developed by UT-Battelle and was approved by TDEC in 2008, and the WQPP monitoring was initiated in 2009. Revisions to the WQPP are submitted to TDEC for review and comment. The WQPP incorporated several control plans that were required under the previous NPDES permit, including a biological monitoring and abatement plan (BMAP), a chlorine control strategy, a storm water pollution prevention plan, a non-storm water best management practices plan, and an NPDES radiological monitoring plan.

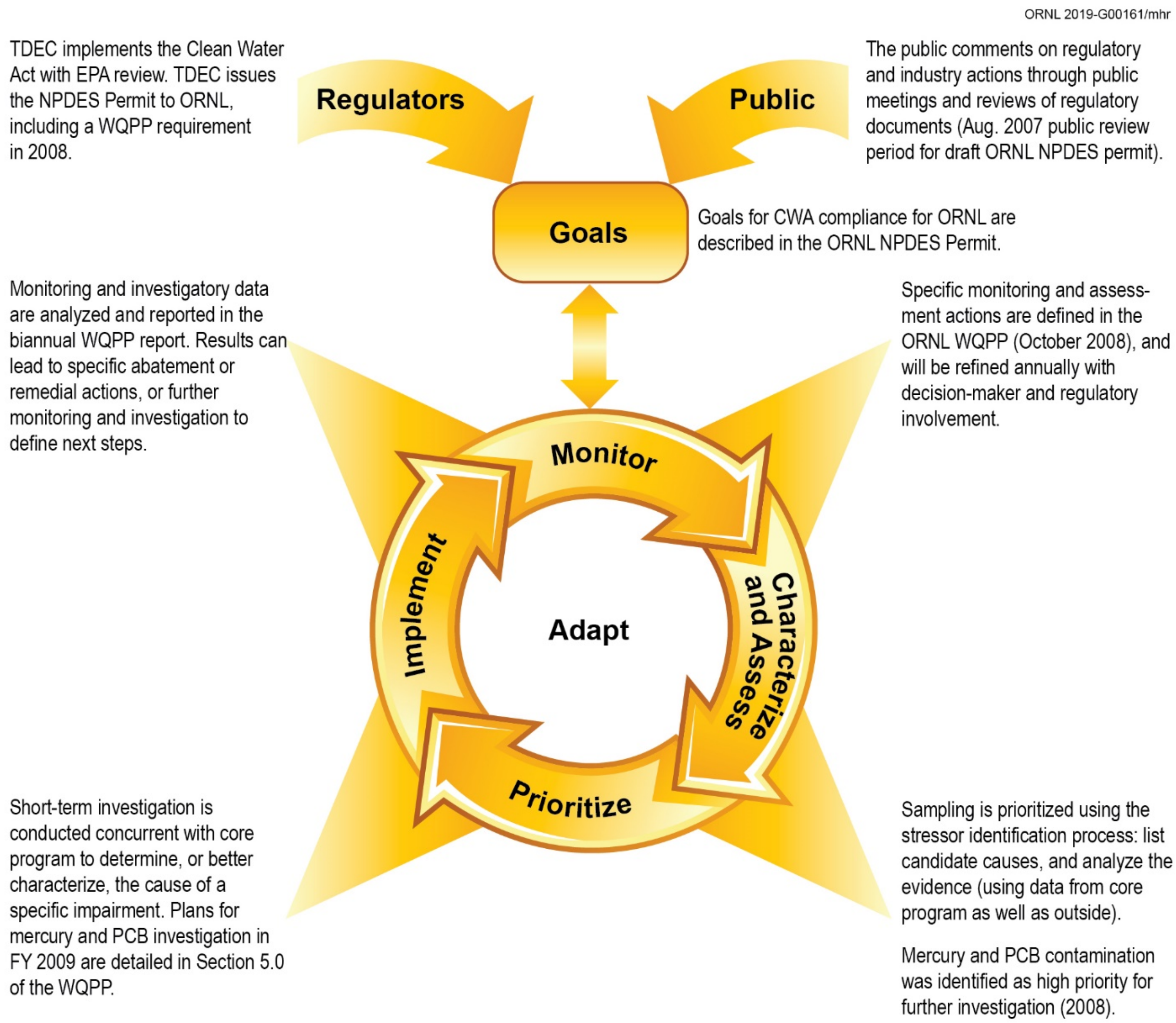
To prioritize the stressors and/or contaminant sources that may be of greatest concern to water quality and to define conceptual models that would guide any special investigations, the WQPP strategy was defined using EPA's Stressor Identification Guidance Document (EPA 2000). Figure 5.14 summarizes that process. The process involves three major steps for identifying the cause of any impairment:

1. list candidate causes of impairment (based on historical data and a working conceptual model),
2. analyze the evidence (using both case study and outside data), and
3. characterize the causes.

The first two steps of the stressor identification process were initiated in 2009, focusing first on mercury impairment (Figure 5.14) and then on PCB impairment because mercury and PCB concentrations in fish from White Oak Creek (WOC) are at or near human health risk thresholds (e.g., EPA ambient water quality criteria [AWQCs] and TDEC fish advisory limits). Some of the major sources of mercury to biota in the WOC watershed are known, providing a good basis from which to define an appropriate conceptual model for mercury contamination in WOC. A list of potential causes of PCB contamination was also developed.

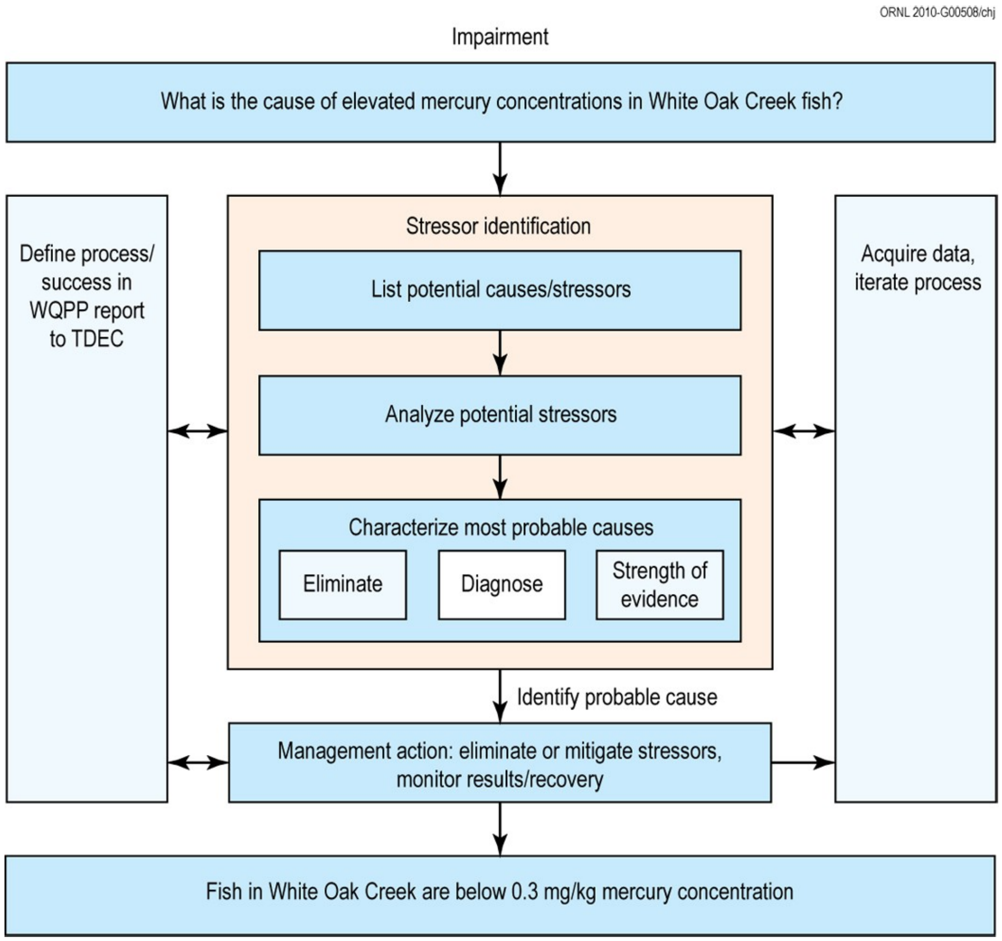
After potential causes were listed and the available evidence of mercury and PCB contamination in the WOC watershed was analyzed, it was clear that additional investigation was needed to characterize the causes. Special investigations were designed to identify specific source areas and to revise the conceptual model of the major causes of contamination in the WOC watershed.

Monitoring and investigation data collected under the ORNL WQPP are analyzed, interpreted, reported, and compared with past results at least annually. The significant findings are reported in the Annual Site Environmental Report, and a more comprehensive report of findings is submitted to TDEC on a biannual basis. This information provides an assessment of the status of ORNL's receiving-stream watersheds and the impact of ongoing efforts to protect and restore those watersheds and will guide efforts to improve the water quality in the watershed.



Adapted from the US Environmental Protection Agency (EPA) stressor guidance document (EPA 2000).
CWA = Clean Water Act, NPDES = National Pollutant Discharge Elimination System, ORNL = Oak Ridge National Laboratory, PCB = polychlorinated biphenyl, TDEC = Tennessee Department of Environment and Conservation, WQPP = Water Quality Protection Plan

Figure 5.13. Diagram of the adaptive management framework with step-wise planning specific to the Oak Ridge National Laboratory Water Quality Protection Plan (WQPP)



Modified from Figure 1-1 in the US Environmental Protection Agency stressor guidance document (EPA 2000).
TDEC = Tennessee Department of Environment and Conservation, WQPP = water quality protection plan

Figure 5.14. Application of stressor identification guidance to address mercury impairment in the White Oak Creek watershed

5.5.1 Treatment Facility Discharges

Two on-site wastewater treatment systems were operated at ORNL in 2018 to provide appropriate treatment of the various R&D, operational, and domestic wastewaters generated by site staff and activities. Both were permitted to discharge treated wastewater and were monitored under NPDES Permit TN0002941, issued by TDEC to DOE for the ORNL site. These are the ORNL STP (Outfall X01) and the ORNL PWTC (Outfall X12). The ORNL NPDES permit requirements include monitoring the two ORNL wastewater treatment facility effluents for conventional, water-quality-based, and radiological constituents and for effluent toxicity, with numeric parameter-specific compliance limits established by TDEC as determined to be necessary. The ORNL NPDES permit was last renewed by TDEC in March 2014. The results of field measurements and laboratory analyses to assess compliance for the parameters required by the NPDES permit and rates of compliance with numeric limits established in the permit are provided in Table 5.9. ORNL wastewater treatment facilities achieved 100 percent compliance with permit limits and conditions in 2018.

Table 5.9. National Pollutant Discharge Elimination System compliance at Oak Ridge National Laboratory, January through December 2018

Effluent parameters[a]	Permit limits					Permit compliance		
	Monthly average (lb/day)	Daily max. (lb/day)	Monthly average (mg/L)	Daily max. (mg/L)	Daily min. (mg/L)	Number of noncompliances	Number of samples	Percentage of compliance[b]
				X01 (ORNL Sewage Treatment Plant)				
LC_{50} for *Ceriodaphnia* (%)					100	0	1	100
LC_{50} for fathead minnows (%)					100	0	1	100
Ammonia, as N (summer)	6.26	9.39	2.5	3.75		0	27	100
Ammonia, as N (winter)	13.14	19.78	5.25	7.9		0	25	100
Carbonaceous biological oxygen demand	19.2	28.8	10	15		0	52	100
Dissolved oxygen					6	0	52	100
Escherichia coliform (col/100 mL)			941	126		0	50	100
Oil and grease				15		0	1	100
pH (standard units)				9	6	0	52	100
Total suspended solids	57.5	86.3	30	45		0	52	100
				X12 (Process Waste Treatment Complex)				
LC_{50} for *Ceriodaphnia* (%)					100	0	1	100
LC_{50} for fathead minnows (%)					100	0	1	100
Arsenic, total				0.014		0	4	100
Chromium, total				0.44		0	4	100
Copper, total				0.11		0	4	100
Cyanide, total				0.046		0	2	100
Lead, total				0.69		0	4	100
Oil and grease				15		0	12	100
pH (standard units)				9.0	6.0	0	52	100
Temperature (°C)				30.5		0	52	100
				Instream chlorine monitoring points				
Total residual oxidant			0.011	0.019		0	288	100

[a] The ORNL NPDES Permit was modified in October 2018 to include monitoring to evaluate effectiveness of the new peracetic acid disinfection system being installed at the STP. It is anticipated that this new system will become operational in the summer of 2019. The associated new monitoring requirements will not begin until the system becomes operational. Therefore, these requirements have not been included in the 2018 data.

[b] Percentage compliance = 100 – [(number of noncompliances/number of samples) × 100].

Acronyms

LC_{50} = lethal concentration; the concentration (as a percentage of full-strength wastewater) that kills 50 percent of the test species in 48 h.

ORNL = Oak Ridge National Laboratory

Toxicity testing provides an assessment of any harmful effects that could occur from the total combined constituents in discharges from ORNL wastewater treatment facilities. Effluents from the STP have been required to be tested for toxicity to aquatic species under the NPDES permit every year since 1986, and effluents from PWTC have been tested since it went into operation in 1990. Test species have been *Ceriodaphnia dubia* (*C. dubia*), an aquatic invertebrate, and fathead minnow (*Pimephales promelas*) larvae. Tests have been conducted using EPA chronic or acute test protocols at frequencies ranging from one to four times per year. Test results have been excellent. PWTC effluent has always been shown to be nontoxic. The STP has shown isolated indications of effluent toxicity, none recent, but confirmatory tests conducted as required by the permit have shown that either the result of the routine test was an anomaly or that the condition of toxicity that existed at the time of the routine test was temporary and of short duration.

Toxicity test requirements under the current NPDES permit include annual testing for acute toxicity from the ORNL STP and PWTC. Both test species are tested on a series of four aliquots of effluent, collected at 6 h intervals over a 24 h period. In 2018, toxicity test results for the ORNL wastewater treatment facilities were once again favorable, with no indication of toxicity in any of the tests that were conducted (Table 5.9).

5.5.2 Residual Bromine and Chlorine Monitoring

ORNL receives its water supply from the City of Oak Ridge Water Treatment Plant which uses chlorine as a disinfectant. On the ORNL site, this supply water is used for drinking, sanitary and housekeeping purposes as well as for research and in cooling systems. Water-cooled air conditioning systems used to be a common source of chlorinated discharge. However as of 2018 on the ORNL site, all but one of these units have been replaced with air cooled systems. Additional chlorine and bromine are used in cooling towers to control bacterial growth. When chlorine and bromine do not evaporate or are not consumed, they are residual in a discharge. As the cooling towers lose water via evaporation, higher conductivity triggers blowdown that may contain residual oxidants from the towers. These residuals can be toxic to fish and other aquatic life. ORNL uses 92 percent sodium sulfite tablets or in some cases 38-40 percent liquid sodium bisulfite drip proportionate to the flow to neutralize/dechlorinate these discharges. The total residual oxidant (TRO) is monitored routinely where there are any discharges of once-through cooling water or cooling tower blowdown/discharge. The TDEC NPDES permit action level is 1.2 g/day TRO at any outfall. If TRO is found above detection (>0.05 mg/L), steps are taken to improve dechlorination. Cooling tower blowdown and any once through cooling water discharges are monitored twice a month to check the effectiveness of dechlorination systems. Less frequent monitoring is done at outfalls with seasonal cooling discharges, or where infrastructure leaks have been found and fixed in the past.

In 2018, 23 outfalls were monitored for TRO on a semiannual, quarterly, monthly, or semimonthly basis if flow was present. Table 5.10 shows that in 2018 there was an increase over past years in discharges that exceeded the TRO permit action level. The exceedance at Outfall 210 in late November was related to faulty heat strips on liquid sodium bisulfite supply lines for the building dechlorination system and the exceedance at Outfall 082 in October was due to bad tablets in the dechlorinator for the 7503 water-cooled air conditioning system. Outfall 211 has a weir in which two dechlorinator boxes are mounted. Chlorinated water was leaking under the plate; the leak was repaired in May. When creek water rises, dechlorinator boxes located at the creek appear to have wet tablets swell and prevent adequate circulation and dosing. This occurred at Outfall 211 and possibly at Outfall 227.

With respect to cooling towers, Outfall 231 had one incident of a TRO exceedance in both 2016 and 2017, but there were three incidents in 2018. Outfall 231 receives cooling tower blowdown from Building 5800 where blowdown passes through a sodium sulfite tablet feeder prior to discharge. In 2017, after inspection of this tablet feeder and all other tablet feeder boxes, eight of the boxes were repaired or replaced to keep tablets dry between flows, and to improve contact with sodium sulfite tablets. After dechlorination box improvement, excess oxidant continued to be sporadically present in discharges from 5800 Towers (Outfall 231), 4510/4521 Towers (Outfall 014), 5300/5309 Towers (Outfall 363), and 5600/5511 Towers (Outfall 227). Secondary dechlorination has remained in place at Outfall 227 and 363 but there was an instance in October 2018 when oxidant bypassed the secondary dechlorination at the tower and elevated oxidant levels were found present at Outfall 227. Beginning in November 2018, the target range for oxidant used in cooling towers was modified from 1.5 mg/L to 1.0 mg/L. It is hoped that lower levels of oxidant use in the main plant area will eliminate TRO discharges from those cooling towers.

Table 5.10. Outfalls exceeding total residual oxidant NPDES permit action level in 2018

Sample date	Outfall	TRO[a] concentration (mg/L)	Flow (gpm)	Load (g/day)	Receiving stream	Downstream integration point	Instream TRO point	TRO Source
7/26/2018	014	0.4	20	43.63	WOC	WCK 4.4	X23	4510/4521 CT
10/4/2018	082	0.63	1	3.44	MB	MEK 0.6	X27	7503 AC
11/26/2018	210	0.7	8	30.55	WOC	WCK 4.1	X25	4508 CW
4/19/2018	211	0.4	25	54.55	WOC	WCK 4.4	X22	CW
6/19/2018	211	0.3	18	29.45	WOC	WCK 4.4	X22	CW
7/26/2018	211	0.1	0.1	10.91	WOC	WCK 4.4	X22	CW
10/15/2018	227	0.6	10	32.73	WOC	WCK 4.4	X25	5600 CT
4/2/2018	231	0.3	25	136.36	WOC	WCK 4.4	X25	5800 CT
10/1/2018	231	0.4	15	32.73	WOC	WCK 4.4	X25	5800 CT
10/15/2018	231	0.3	12	19.64	WOC	WCK 4.4	X25	5800 CT

[a] The NPDES action level is 1.2 g/day.

Acronyms
AC = water-cooled air conditioning unit
CT = cooling tower
CW = once-through cooling water
MB = Melton Branch
MEK = Melton Branch kilometer
NPDES = National Pollutant Discharge Elimination System
TRO = total residual oxidant
WCK = White Oak Creek kilometer
WOC = White Oak Creek

5.5.3 Radiological Monitoring

At ORNL, monitoring of liquid effluents and selected instream locations for radioactivity is conducted under the WQPP. Table 5.11 details the analyses performed on samples collected in 2018 at two treatment facility outfalls, three instream monitoring locations, and 20 category outfalls (outfalls that are categorized into groups with similar effluent characteristics for the purposes of setting monitoring and reporting requirements in the site NPDES permit). Dry-weather discharges from category outfalls are primarily cooling water, groundwater, and condensate. Low levels of radioactivity can be discharged from category outfalls in areas where groundwater contamination exists and where contaminated groundwater enters category outfall collection systems by direct infiltration and from building sumps, facility sumps, and building footer drains. In 2018, dry-weather grab samples were collected at 18 of the 20 category outfalls targeted for sampling. Two category outfalls (205 and 241) were not sampled because there was no discharge present during sampling attempts.

The two ORNL treatment facility outfalls that were monitored for radioactivity in 2018 were the STP outfall (Outfall X01) and the PWTC outfall (Outfall X12). The three instream locations that were monitored were X13 on Melton Branch, X14 on WOC, and X15 at White Oak Dam (WOD) (Figure 5.15). At each treatment facility and instream monitoring location, monthly flow-proportional composite samples were collected using dedicated automatic water samplers.

For each radioisotope, a DCS is published in DOE directives and is used to evaluate discharges of radioactivity from DOE facilities (DOE 2011a). DCSs were developed for evaluating effluent discharges and are not intended to be applied to instream values, but the comparisons can provide a useful frame of reference. Four percent of the DCS is used as a comparison point. Although comparisons are made, neither ORNL effluents nor ambient surface waters are direct sources of drinking water. The annual average concentration of at least one radionuclide exceeded 4 percent of the relevant DCS concentration in dry-weather discharges from NPDES Outfalls 080, 085, 203, 204, 302, 304, X01, and X12 and at instream sampling locations on WOC (X14) and at WOD (X15) (Figure 5.16).

In 2018, one outfall (304) had an annual mean radioactivity concentration greater than 100 percent of a DCS. Outfall 304 had an average total radioactive strontium ($^{89/90}$Sr) concentration that exceeded the DCS for ^{90}Sr (it is reasonable, for an ORNL environmental sample, to assume that $^{89/90}$Sr activity is comparable to ^{90}Sr activity due to the relatively short half-life of ^{89}Sr—50.55 days). The concentration of $^{89/90}$Sr was 130 percent of the DCS at Outfall 304. Consequently, concentrations of radioactivity in the discharge from Outfall 304 was also greater than the DCS level on a sum-of-fractions basis (i.e., the summation of DCS percentages of multiple radiological parameters); the sum of the fractions was 135 percent.

Levels of radioactivity in discharges from Outfall 304 have been elevated since 2014 because of two unrelated infrastructure issues. In 2014, a pump failed in a groundwater suppression sump at the DOE Office of Environmental Management (OREM) WOC-9 (WC-9) Low Level Liquid Waste Tank Farm, a CERCLA soil and groundwater contamination area. Without groundwater suppression in the tank farm area, contaminated groundwater enters the Outfall 304 storm drain system. A second infrastructure issue, which had an even greater influence on Outfall 304 radiological concentrations, occurred in 2015. A leak developed in a pipe leading from Pump Station #2 in the Process Waste Collection System to a downstream diversion box. A dye tracer test confirmed a hydraulic connection between the pipe and the storm water collection system that discharges through Outfall 304, and the pipe was subsequently bypassed and taken out of service. Before the leaky pipe was bypassed, the $^{89/90}$Sr concentration at Outfall 304 peaked at 29,000 pCi/L (August and September 2015). Since the bypass was implemented, $^{89/90}$Sr levels in the outfall effluent have trended downward, but they remained above DCS levels in 2018. No additional infrastructure issues affecting Outfall 304 have been discovered, and it is believed that concentrations of radioactivity at the outfall will slowly decline as concentrations of radioactivity in the groundwater surrounding the outfall pipe decline by means of normal hydrologic processes.

Table 5.11. Radiological monitoring conducted under the Oak Ridge National Laboratory Water Quality Protection Plan, 2018

Location	Frequency	Gross alpha/beta	Gamma scan	^{3}H	^{14}C	$^{89/90}Sr$	Isotopic uranium	Isotopic plutonium	^{241}Am	$^{243/244}Cm$
Outfall 001	Annual	X								
Outfall 080	Monthly	X	X	X		X			X[a]	X
Outfall 081	Annual	X								
Outfall 085	Quarterly	X	X	X		X				
Outfall 203	Annual	X	X			X				
Outfall 204	Semiannual	X	X			X				
Outfall 205[b]	Annual									
Outfall 207	Quarterly	X								
Outfall 211	Annual	X								
Outfall 234	Annual	X								
Outfall 241[b]	Quarterly									
Outfall 265	Annual	X								
Outfall 281	Quarterly	X		X						
Outfall 282	Quarterly	X								
Outfall 302	Monthly	X	X	X		X	X[a]	X[a]	X[a]	X[a]
Outfall 304	Monthly	X	X	X		X	X[a]	X[a]	X[a]	X[a]
Outfall 365	Semiannual	X								
Outfall 368	Annual	X								
Outfall 383	Annual	X		X						
Outfall 484	Annual	X								
STP (X01)	Monthly	X	X	X	X	X				
PWTC (X12)	Monthly	X	X	X		X	X			
Melton Branch (X13)	Monthly	X	X	X		X				
WOC (X14)	Monthly	X	X	X		X				
WOD (X15)	Monthly	X	X	X		X				

[a] The Water Quality Protection Plan does not require this parameter for this location, and therefore it may have been monitored on a frequency less than indicated in the table. Additional analyses are sometimes performed on samples, the most common reason being that gross alpha and gross beta activities exceeded a screening criterion (as described in the May 2012 update to the Water Quality Protection Plan).
[b] The outfall was included in the monitoring plan, but samples were not collected because no discharge was present during sampling attempts.

Acronyms
PWTC = Process Waste Treatment Complex, STP = Sewage Treatment Plant, WOC = White Oak Creek, WOD = White Oak Dam

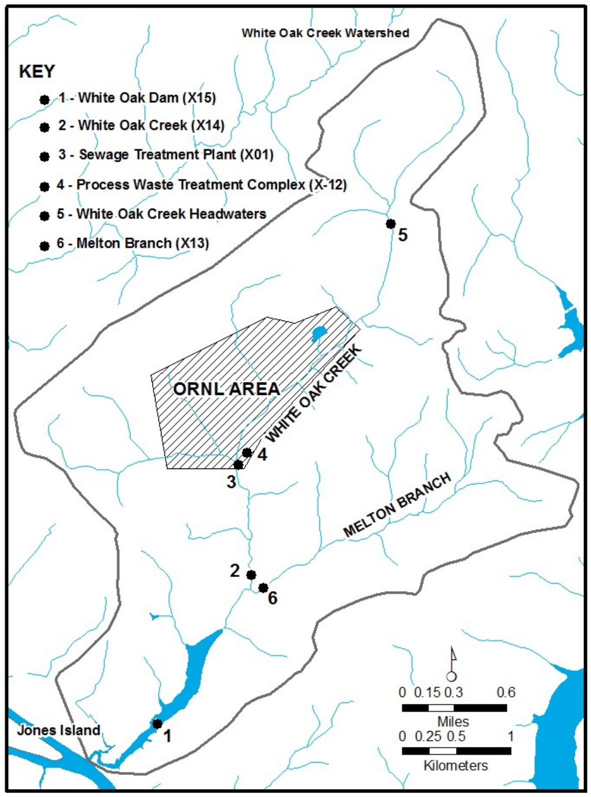


Figure 5.15. Selected surface water, National Pollutant Discharge Elimination System, and reference sampling locations at Oak Ridge National Laboratory, 2018

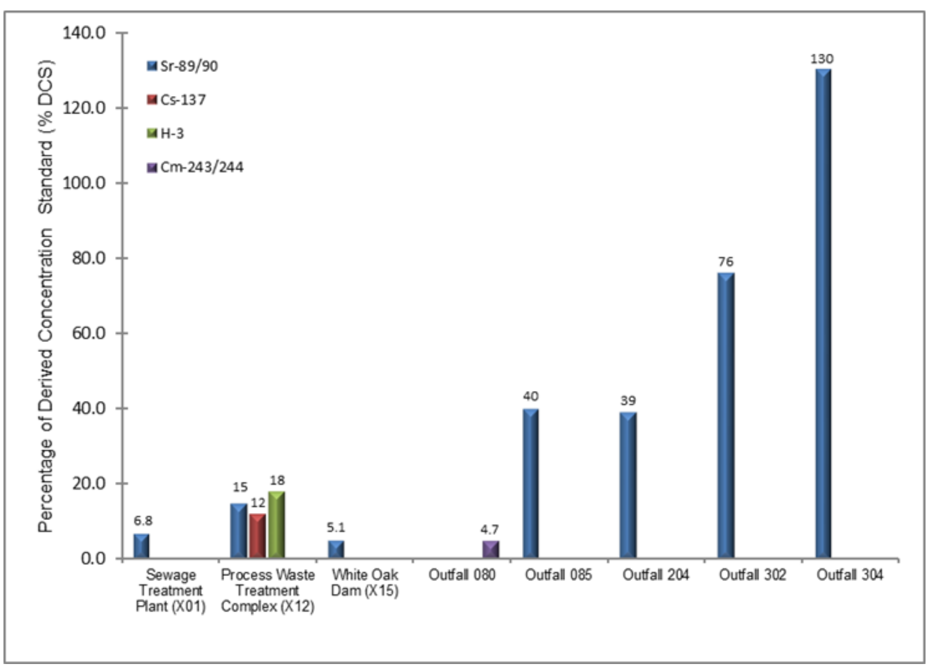


Figure 5.16. Outfalls and instream locations at Oak Ridge National Laboratory with average radionuclide concentrations greater than 4 percent of the relevant derived concentration standards in 2018

The total annual discharges (or amounts) of radioactivity measured in stream water at WOD, the final monitoring point on WOC before the stream flow leaves ORNL, were calculated from concentration and flow. Results of those calculations for each of the past 5 years are shown in Figures 5.17 through 5.21. Because discharges of radioactivity are somewhat correlated to stream flow, annual flow volumes measured at the WOD monitoring station are given in Figure 5.22. Discharges of radioactivity at WOD in 2018 were similar to discharges during other recent years, particularly when differences in annual flow volume are taken into account and continue to be generally lower than in the years preceding completion of the waste area caps in Melton Valley (substantially complete by 2006).

Radiological monitoring at category outfalls in 2018 also included monitoring during storm runoff conditions. Seven storm water outfalls were monitored. Storm water samples were analyzed for gross alpha, gross beta, $^{89/90}Sr$, and tritium activities. A gamma scan analysis was also performed. The monitoring plan calls for additional analyses to be added when sufficient gross alpha and/or beta activity is present in a sample to indicate that levels of radioactivity may exceed DCS levels, but in 2018 no additional analyses were required for storm water samples.

Concentrations of radioactivity in storm water discharges were compared with DCSs if a DCS existed for that parameter (there are no DCSs for gross alpha or gross beta activities) and if a concentration was greater than or equal to the minimum detectable activity for the measurement. In 2018, none of the outfalls had a radionuclide concentration in storm water that was greater than 4 percent of a DCS level.

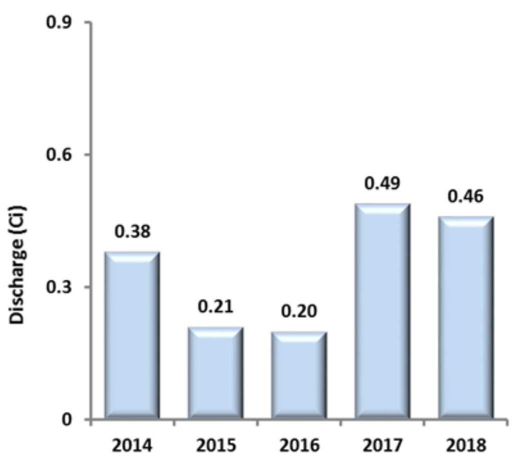


Figure 5.17. Cesium-137 discharges at White Oak Dam, 2014−2018

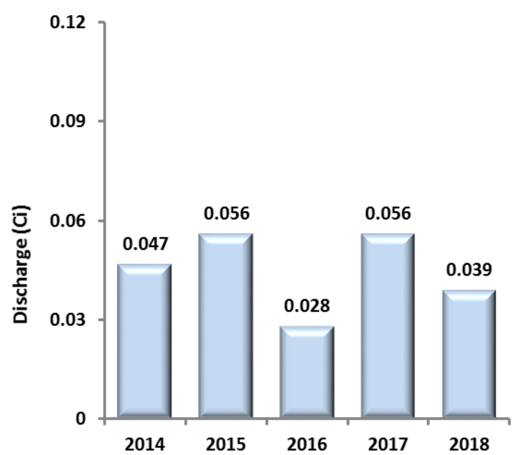


Figure 5.18. Gross alpha discharges at White Oak Dam, 2014−2018

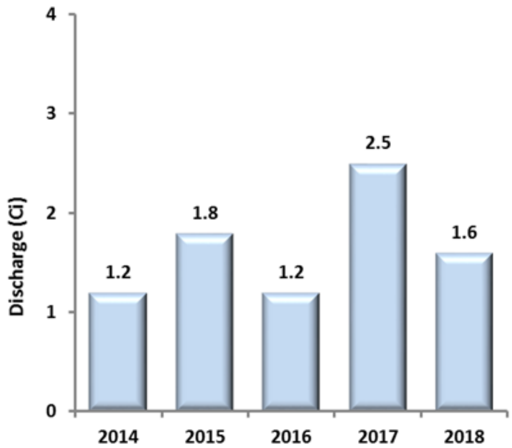


Figure 5.19. Gross beta discharges at White Oak Dam, 2014−2018

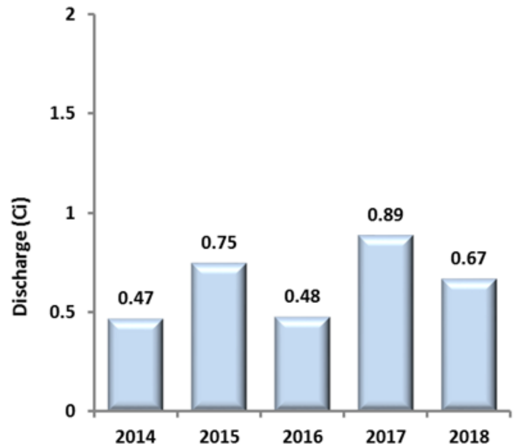


Figure 5.20. Total radioactive strontium discharges at White Oak Dam, 2014−2018

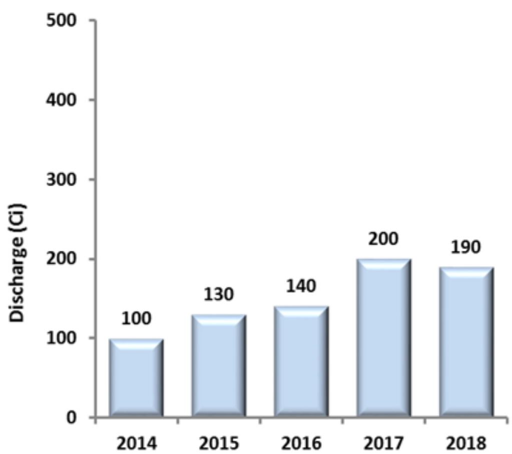


Figure 5.21. Tritium discharges at White Oak Dam, 2014−2018

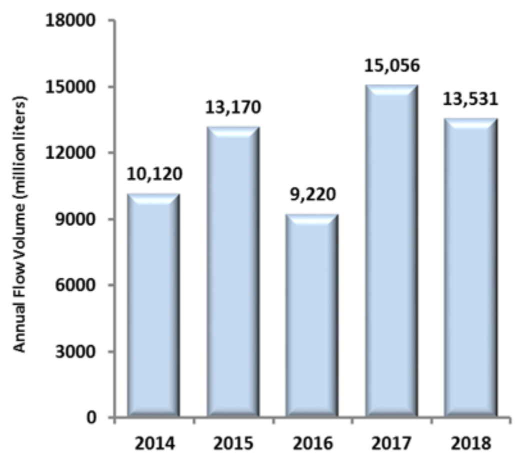


Figure 5.22. Annual flow volume at White Oak Dam, 2014−2018

5.5.4 Mercury in the White Oak Creek Watershed

Due to the persistence of elemental mercury, its volatility, and the complexity of its interactions in soil, mercury continues to be a contaminant associated with groundwater and storm water runoff in and around the facilities and associated piping where it was used. During the 1950s, mercury was used in a number of ORNL facilities (e.g., pilot-scale isotope separation work in Buildings 4501, 4505, and 3592 and in spent-fuel reprocessing in Building 3503). Legacy mercury contamination exists in those facilities and in infrastructure connected to them. Mercury is also present in process wastewater piping north of the intersection of Fifth Street and Central Avenue. The largest releases are known to be associated with Buildings 4501 and 4505, located east of Fifth Creek, where most of the building foundation sumps and storm drains were historically routed south to Outfall 211 on WOC (Figure 5.23). Buildings 3592 and

3503 were removed under the CERCLA remedial process in 2011 and 2012, respectively; however, their footprints and associated storm water drains remain in the Outfall 207 storm water drainage system.

ORNL 2018-G00384/mhr

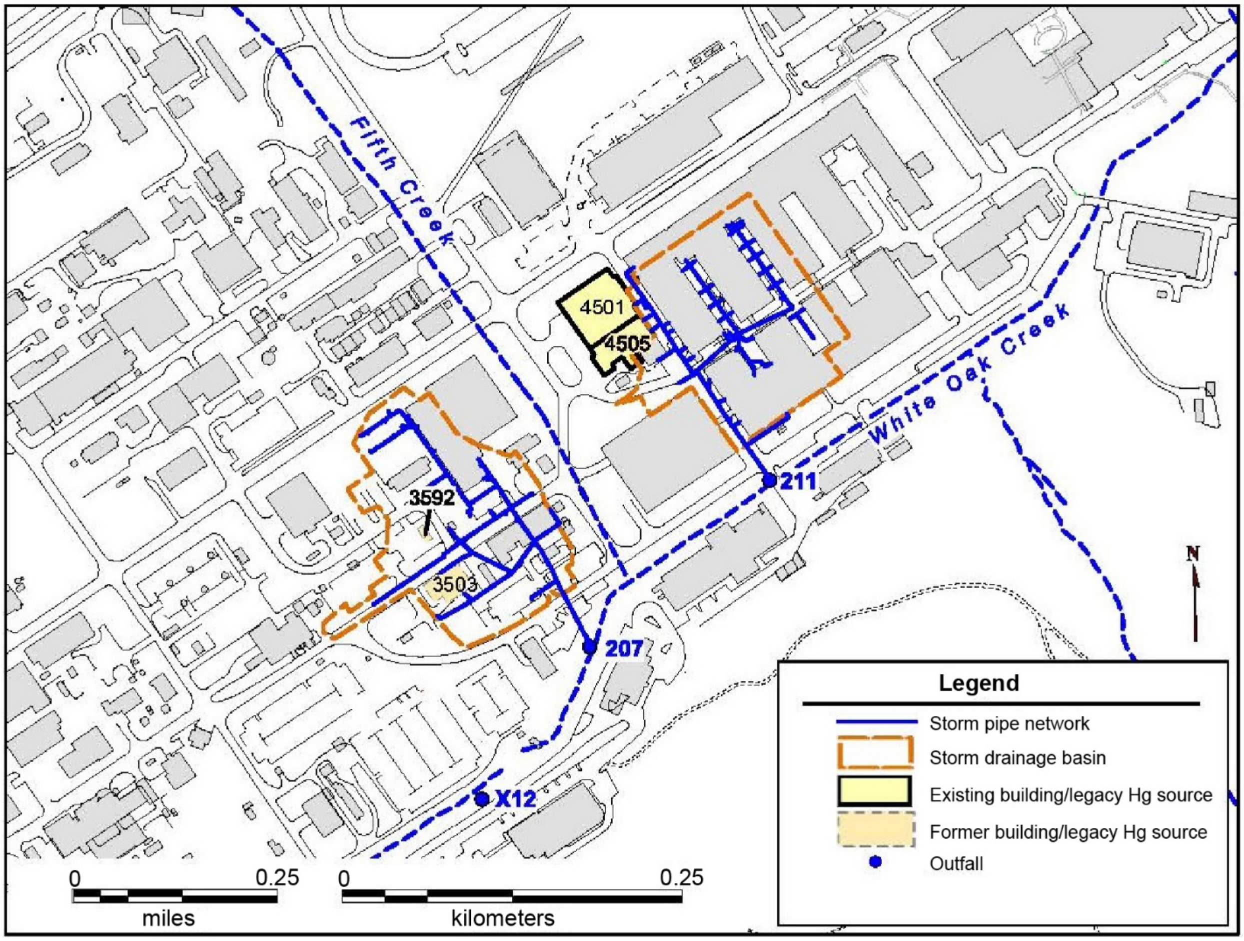


Figure 5.23. Outfalls with known historic mercury sources to White Oak Creek, 2018

5.5.4.1 Ambient Mercury in Water

In continuation of a monitoring effort initiated in 1997, bimonthly water samples were collected from WOC at four sites in 2018 (WCK 1.5, WCK 3.4, WCK 4.1, and WCK 6.8) (Figure 5.24). Stream conditions were selected to be representative of seasonal base-flow conditions (dry-weather, clear flow) based on historical results that indicate higher mercury concentrations under those conditions. The concentration of mercury in WOC upstream from ORNL (White Oak Creek kilometer [WCK] 6.8) was less than 10 ng/L in 2018. Long-term trends in waterborne mercury in the WOC system downstream of ORNL are shown in Figure 5.25. Waterborne mercury downstream of ORNL declined abruptly in 2008 and remained low through 2017 as a result of actions including the rerouting of mercury-contaminated sump water in Building 4501 from Outfall 211 to the PWTC in December 2007 and the October 22, 2009 installation of mercury pretreatment at a sump in Building 4501. In general, concentrations remained low since that time, with the exception of a significant spike in mercury concentrations in the samples taken at WCK 3.4 in September 2018 (Figure 5.25). Both filtered and unfiltered samples taken on this date were >100 ng/L, suggesting that most of the mercury was dissolved rather than particulate. The filtered and unfiltered samples taken at WCK 4.1 (downstream of Fifth Creek and Outfall 211) on this date were low, and comparable to recent years. The mean total mercury concentration at WCK 4.1 was 17.17 ± 9.88 ng/L in 2018 compared with 108 ± 33 ng/L in 2007. Including the September grab sample in the annual average brings the mean mercury concentration seen at WCK 3.4 in 2018 to levels seen prior to the sump re-route, with mean concentrations at WCK 3.4 of 55.49 ± 76.05 ng/L in 2018 vs. 49 ± 23 ng/L in 2007. This average is driven by the one outlier data point; note the deviation around the mean. Given this was a grab sample and subsequent sampling at this site has shown that levels have not remained elevated but have dropped back to typical concentrations (<20 ng/L) since the September sampling event, this average is likely not representative of the average annual concentrations in the creek at this site, but does highlight how issues with water quality may lead to intermittent spikes in aqueous mercury concentrations. There is no evidence in the 2018 fish bioaccumulation data that there was a longer term increase in aqueous mercury concentrations (see Section 5.5.6), but fish typically take 1-2 years to respond to increases in aqueous mercury concentrations. The average aqueous mercury concentration at WOD (WCK 1.5) was 52.55 ± 27.59 ng/L in 2018, higher than concentrations at other sites, and slightly higher than the average concentration seen at this site in 2017. This average is above the Recreational Water Quality Criteria for Water and Organisms of 51 ng/L (Figure 5.25).

ORNL 2019-G00162/mhr

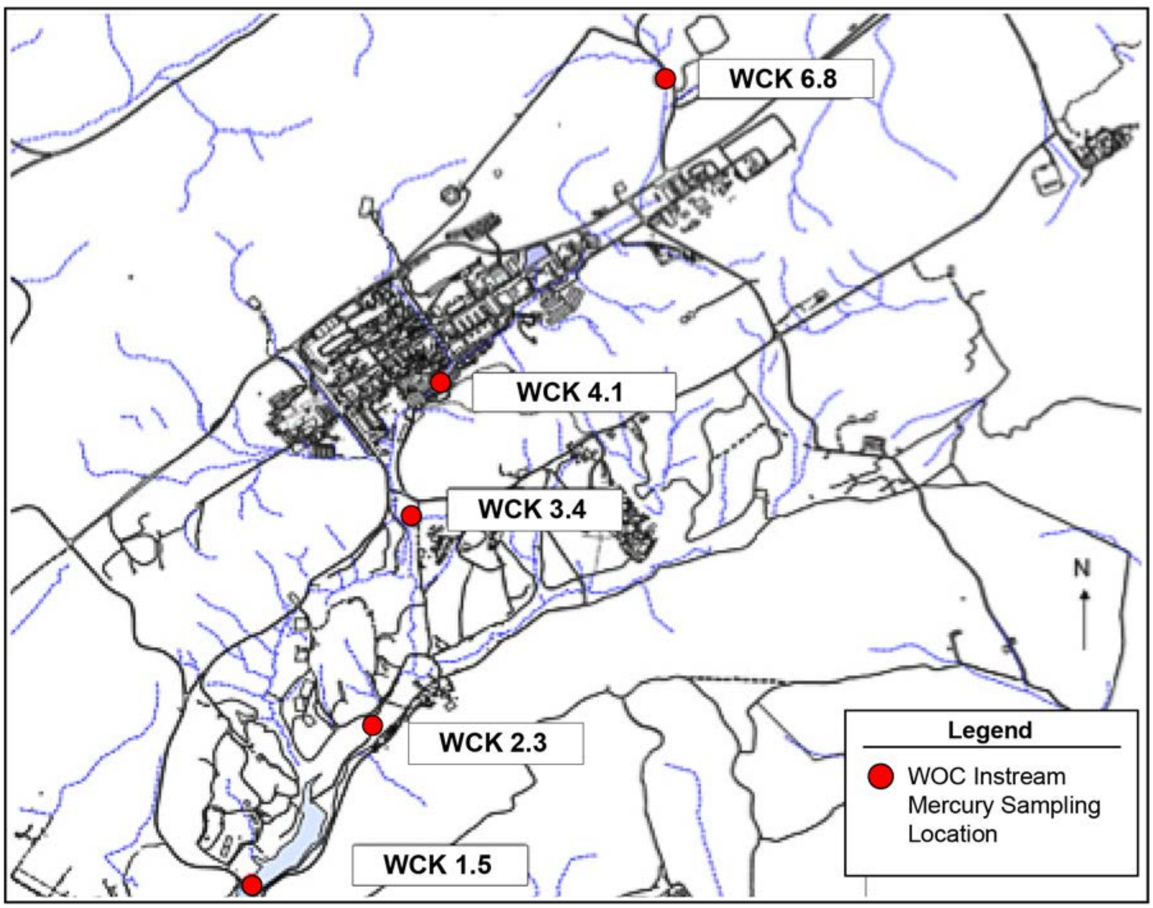
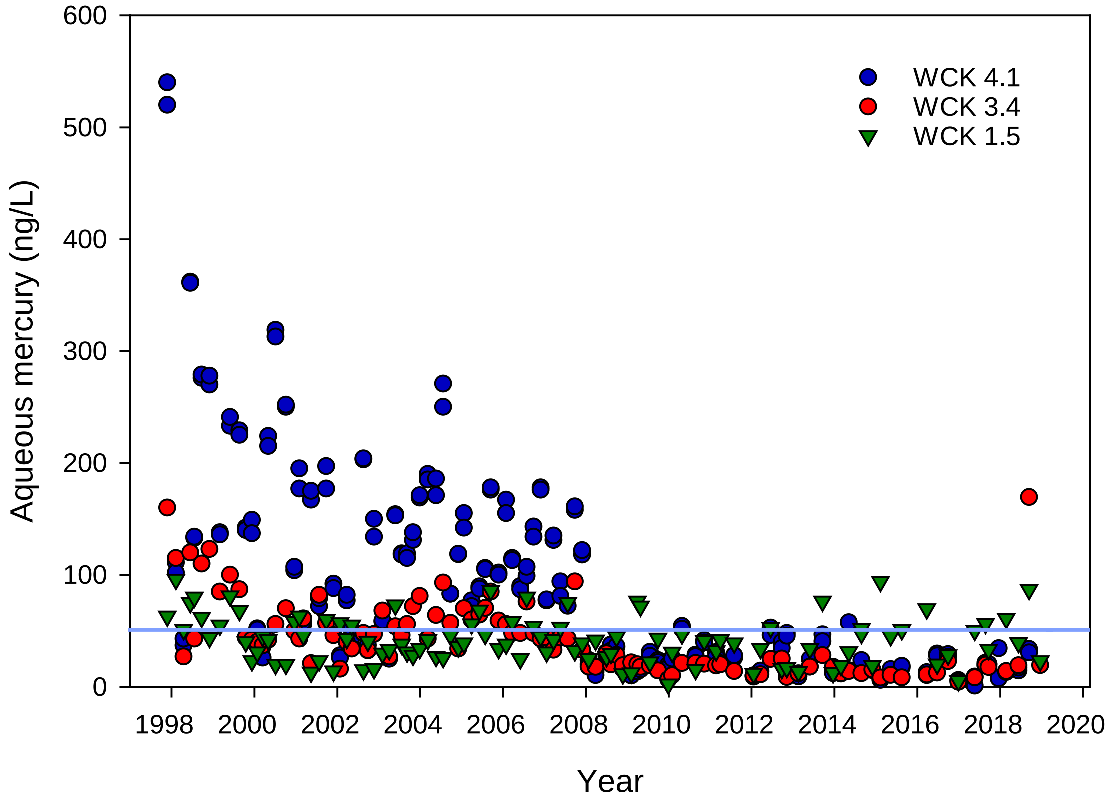


Figure 5.24. Instream mercury monitoring and data locations, 2018



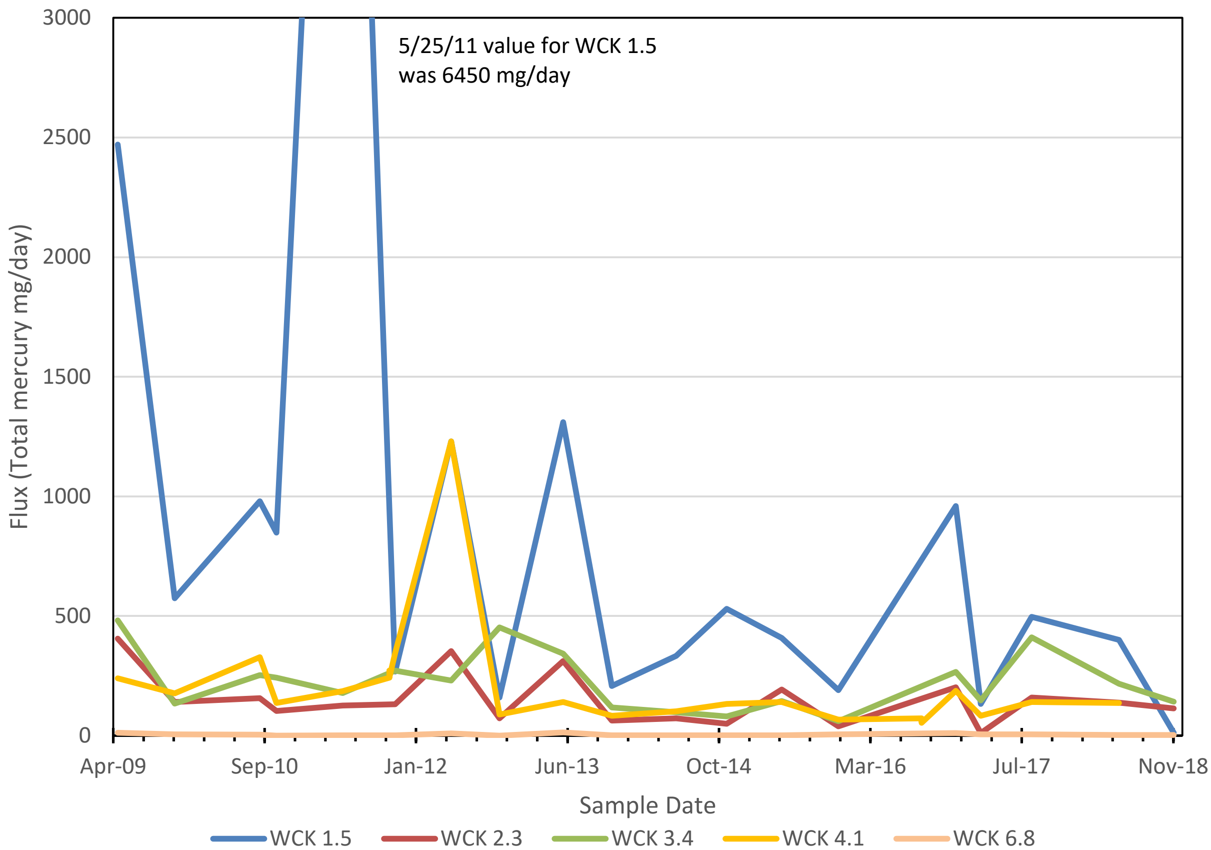
The blue line at 51 ng/L shows the Recreational Water Quality Criteria for Water and Organisms.
WCK = White Oak Creek kilometer

Figure 5.25. Total aqueous mercury concentrations at sites in White Oak Creek downstream from Oak Ridge National Laboratory, 1998–2018

Water Quality Protection Plan Mercury Investigation

Twice a year, instream samples for mercury concentration are collected and stream flows are recorded so that mercury fluxes (i.e., the amount of a substance per unit time in flowing water) can be calculated at these points. Data for flux calculations is collected during dry weather in winter and summer at the WOC instream points shown in Figure 5.26.

Figure 5.26 shows mercury flux (in milligrams per day) since 2009. The figure compares trends from WCK 6.8 (upstream of ORNL campus) downstream to WCK 1.5 at WOD and shows that there may be a downward trend in flux at WOD since 2009. The November 2018 result at WCK 1.5 was an order of magnitude lower than any recorded previously. Future monitoring will determine if this is a true reduction in concentration, or an outlier in the data.



WCK = White Oak Creek kilometer

Figure 5.26. Historic (2009–2018) mercury fluxes (mg/day) at White Oak Creek instream monitoring locations WCK 1.5, 2.3, 3.4, 4.1, and 6.8

Outfall Source Investigation

Individual outfalls that contribute mercury are investigated as part of the WQPP to better delineate mercury sources and to prioritize future abatement actions. Between 2007 and 2011, three sumps that receive foundation groundwater from Buildings 4501 and 4500N were redirected to PWTC treatment for mercury removal; in addition, during 2009 a mercury pretreatment system was installed on the main sump in Building 4501. At the PWTC facility, one of the granular activated carbon filter columns was also upgraded in 2014 to a sulfur-impregnated carbon that is optimized for mercury removal. Figure 5.25 shows that after 2008, legacy mercury release was significantly reduced by these actions that directed foundation water away from the storm drain system and improved treatment plant removal capabilities.

Historically, dry- and wet-weather samples taken at storm Outfalls 211 and 207, have contained the highest concentrations of total mercury. At Outfall 207, flows during dry weather are less than 1 gpm. Therefore, even the highest dry-weather concentration (1830 ng/L), which was measured in 2018 along with a flow of 0.25 gpm, had a calculated flux of 0.997 mg Hg/day. During larger storm flows, Outfall 207 can deliver higher mercury fluxes to WOC, so attempts have been made to sample those larger storms. Figure 5.27 shows those storm results. The highest flux shown, in February 2017 (261 mg/day) was due to a mercury concentration of 956 ng/L and a flow of 50 gpm. The highest 2018 storm flux monitored was in September (171 mg/day) due to a 100 gpm flow moving through the storm pipe network and contributing a concentration of 314 ng/L total mercury. Most mercury in storm flow appears to be associated with particulates; dissolved mercury flux has not exceeded 30 mg/day, and highs are not aligned with the largest storm flows.

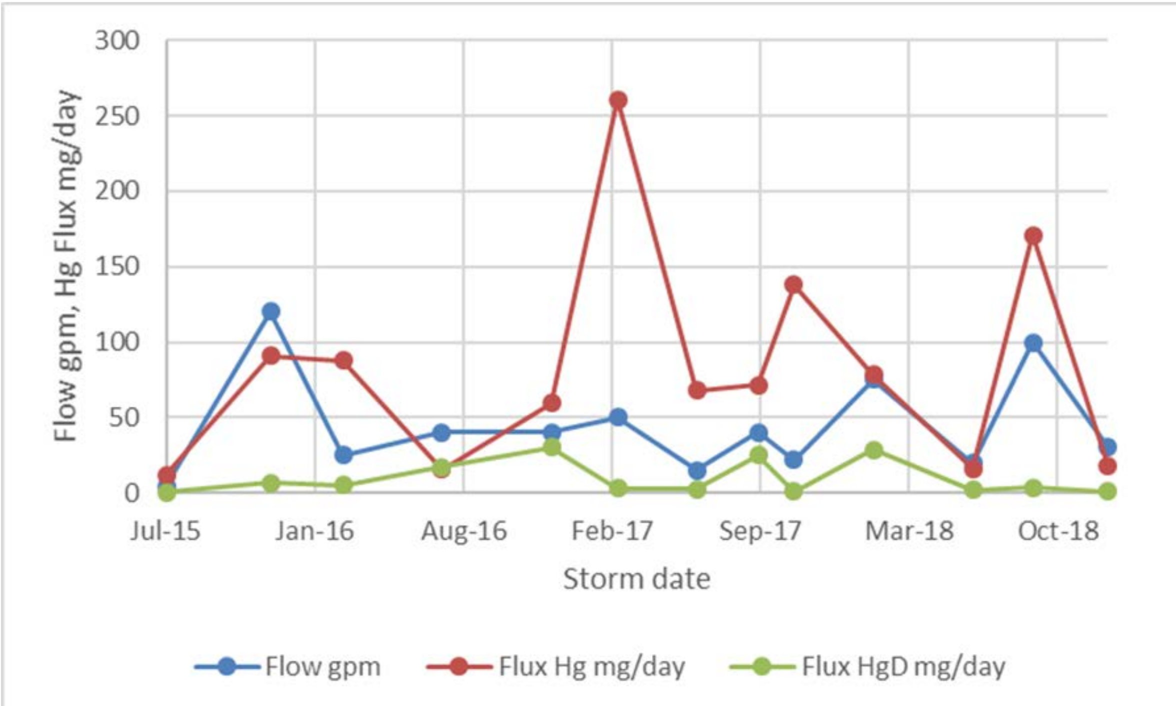


Figure 5.27. Outfall 207 storm flow and flux of total and dissolved mercury, 2018

The volume of dry-weather flows at Outfall 211 have dropped by about half since 2013 when water conservation efforts were made to recirculate once through cooling water rather than discharge it. However, Figure 5.28 shows that mercury concentrations in dry-weather discharges to Outfall 211 have not decreased.

At the terminus of the Outfall 211 pipe, a weir plate directs flow through two sodium sulfite tablet dechlorination boxes. Sediment deposited by the creek and by the storm pipe network during storms, accumulates behind the weir on either side of the pipe. An environmental action was tried in 2017-2018 to remove this sediment quarterly; it was thought sediment removal might decrease mercury discharges, especially during storms when water backs up into this area. Future sampling results will help to confirm if sediment removal had any impact on dry-weather mercury concentrations from Outfall 211.

Storm data collected at Outfall 211 in years through 2018 (Figure 5.29) continue to show much higher fluxes of total mercury than are seen at Outfall 207. Although dry-weather flows have declined, the Outfall 211 piping system still experiences large storm flow rates(estimated at 50 to 225 gpm). In 2018 mercury fluxes were found to be slightly lower than those in 2017. The maximum flux found was 1,070 mg/day. During storms, the highest total mercury fluxes were not always correlated with the highest dissolved mercury flux, implying the contribution of mercury associated with particulates. It is not clear whether sediment removal was partly responsible for lower mercury storm fluxes.

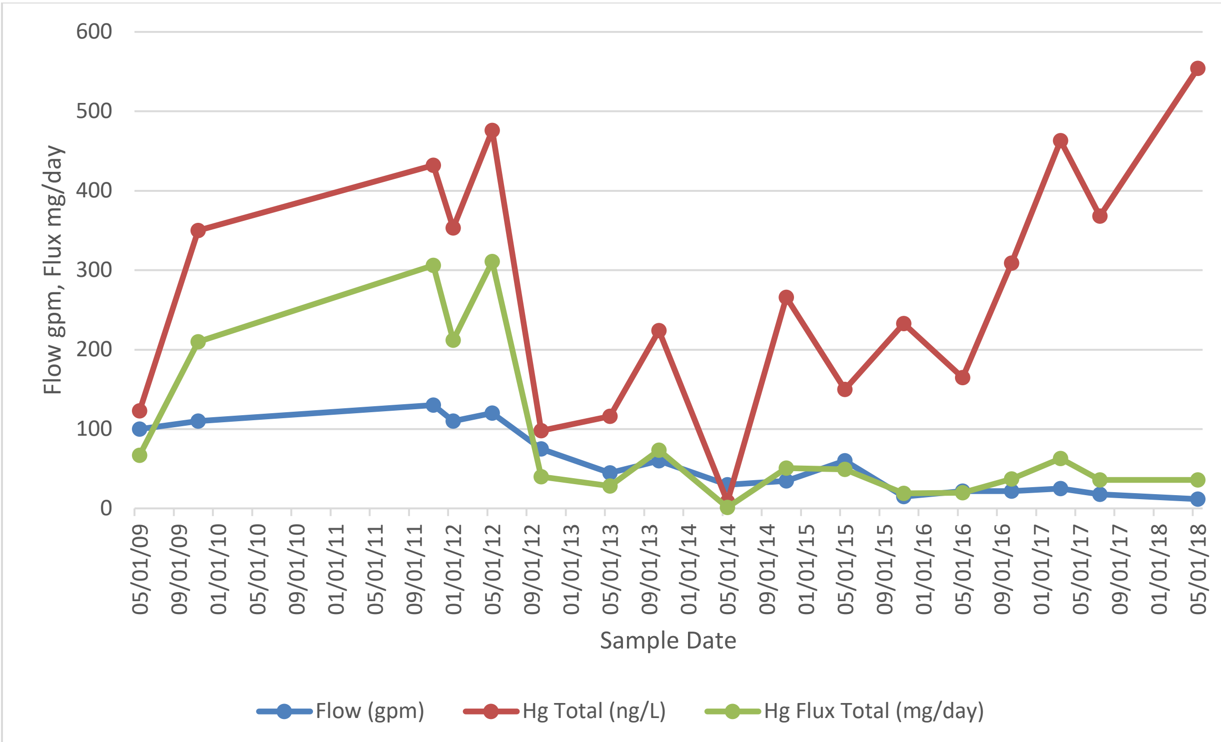


Figure 5.28. Outfall 211 dry-weather flow, total mercury concentrations, and total mercury flux, 2009−2018

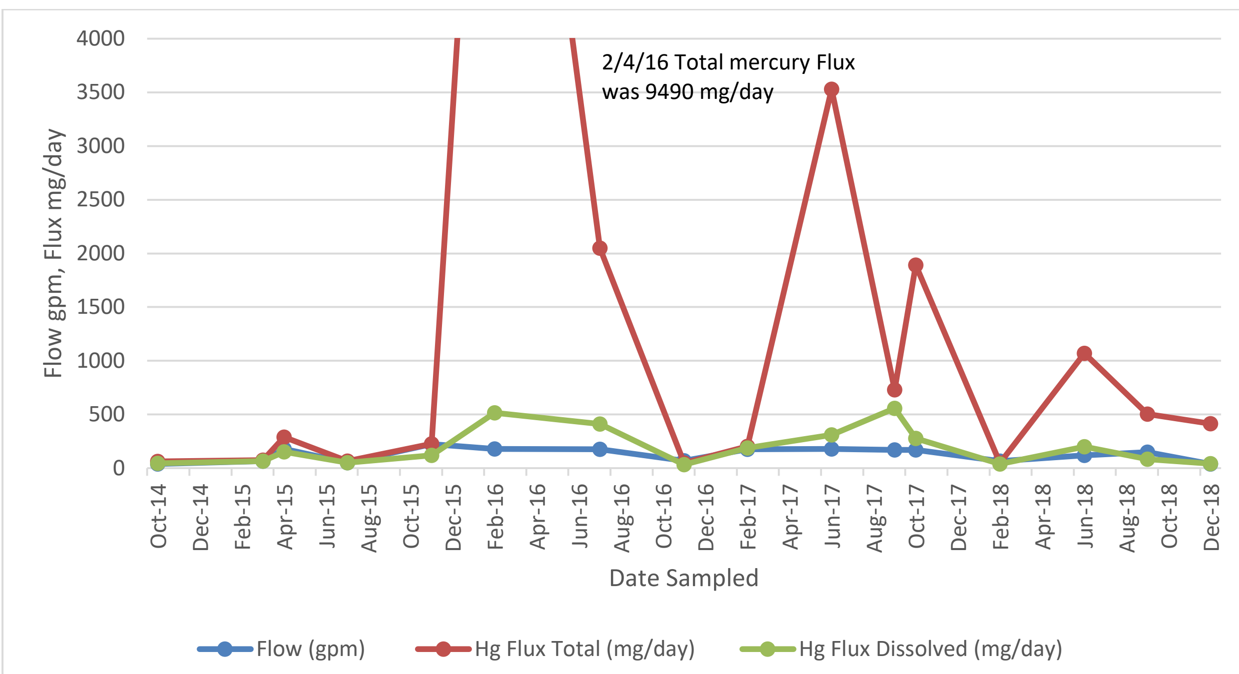


Figure 5.29. Outfall 211 storm flow and flux of total and dissolved mercury, 2014–2018

5.5.5 Storm Water Surveillances and Construction Activities

Storm water drainage areas at ORNL are inspected twice per year as directed in the WQPP. Land use within drainage areas is typical of office/industrial/research settings with surface features that include laboratories, support facilities, paved areas, and grassy lawns. Outdoor material storage is dynamic in many places but is most prevalent in the 7000 area on the east end of the main ORNL facility, where most of the craft and maintenance shops are located. Smaller outdoor storage areas are located throughout the facility in and around loading docks and material delivery areas at laboratory and office buildings. The types of materials stored outside, as noted in field inspections, include finished metal items (pipes and parts); equipment awaiting use, disposal, or repair; aging (rusting) infrastructure; and construction equipment and material. A site visit to active construction sites also occurs twice per year to evaluate the overall effectiveness of the best management practices in use. In general, no long-term environmental impacts have been noted. While sites that are covered by a Tennessee construction general permit are considered to have more significant potential for runoff impacts, inspections and controls required by an approved Storm Water Pollution Prevention Plan have proven effective at minimizing short-term and long-term impacts to nearby streams and waterways from construction sites.

Some construction activities are performed on third-party-funded construction projects on ORR under agreements with federal agencies other than DOE and with local and state agencies. There are mechanisms in place for ensuring effective storm water controls at the third-party sites, one of which includes staff from UT-Battelle acting as points of contact for communication interface on environmental conditions, erosion and sedimentation controls, spill/emergency responses, and other key issues.

5.5.6 Biological Monitoring

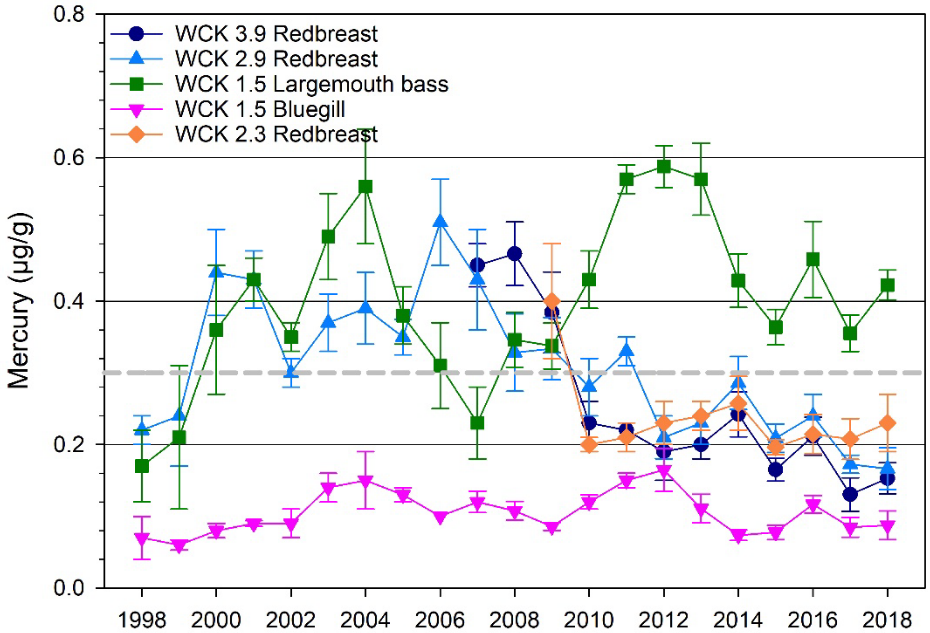
5.5.6.1 Bioaccumulation Studies

The bioaccumulation task for BMAP addresses two NPDES permit requirements at ORNL: (1) evaluate whether mercury at the site is contributing to a stream at a level that will adversely affect fish and other aquatic life or that will violate the recreational criteria and (2) monitor the status of PCB contamination in fish tissue in the WOC watershed. Concentrations of mercury in fish in the WOC watershed are monitored annually and are evaluated relative to the EPA AWQC of 0.3 µg/g in fish fillets, a concentration considered to be protective of human health and the environment. Concentrations of PCBs in fish fillets are also monitored annually and are evaluated relative to the TDEC fish advisory limit of 1 µg/g.

Bioaccumulation in Fish

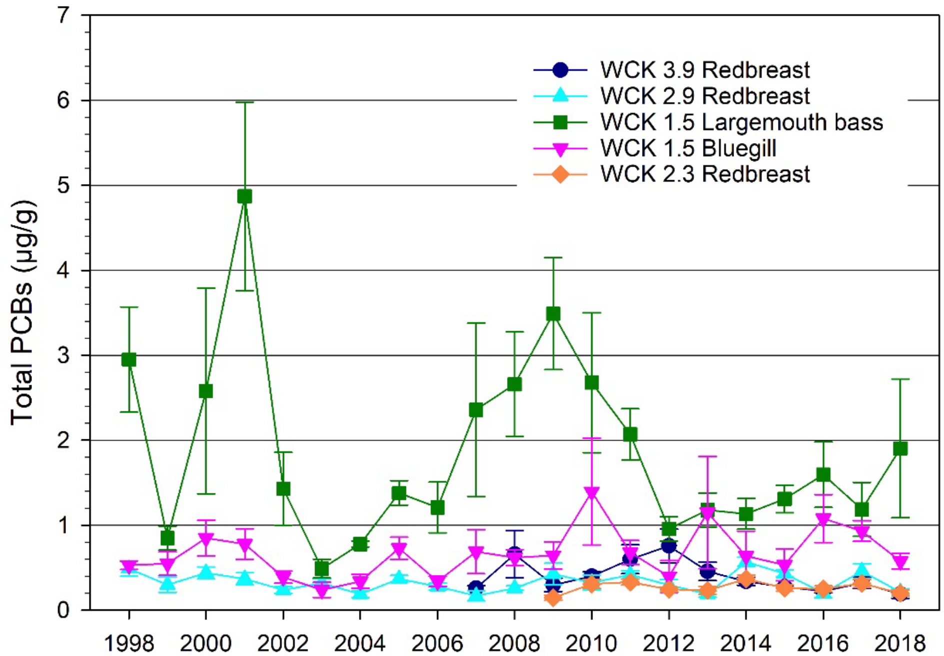
In WOC, mercury and PCB concentrations in fish have been at or near human health risk thresholds (e.g., EPA recommended fish-based AWQC [0.3 µg/g for mercury], TDEC fish advisory limits for PCBs). Actions taken in 2007 to treat a mercury-contaminated sump resulted in significant decreases in mercury concentrations in fish throughout WOC. The decreases were most apparent at upstream locations closest to the sump water reroute (Figure 5.30). While the overall trends in the uppermost locations sampled in the creek suggest that fish tissue concentrations are decreasing overall, there is some interannual variability. Fillet concentrations increased slightly at most stream sites in 2018 but remained below the AWQC for mercury in fish. Mean fillet concentrations increased from 0.13 µg/g in 2017 to 0.15 µg/g in 2018 at WCK 3.9, increased from 0.21 µg/g in 2017 to 0.23 µg/g in 2018 at WCK 2.3, and remained 0.17 µg/g in 2018 at WCK 2.9 (Figure 5.30). Mercury concentrations in largemouth bass collected from WCK 1.5 (White Oak Lake) have been fluctuating in recent years and increased from 0.36 µg/g in 2017 to 0.42 µg/g in 2018, remaining above the guideline. Mercury concentrations in bluegill collected from WCK 1.5 increased very slightly from 0.085 µg/g in 2017 to 0.088 µg/g in 2018 but remained below the recommended guideline.

PCB concentrations (defined as the sum of Aroclors 1248, 1254, and 1260) in redbreast sunfish from the WOC watershed decreased in 2018 and remained within historical ranges, with mean concentrations of 0.19 ± 0.05 µg/g at WCK 3.9, 0.21 ± 0.03 µg/g at WCK 2.9, and 0.20 ± 0.03 µg/g at WCK 2.3 (compared to 0.32 µg/g at WCK 3.9, 0.46 µg/g at WCK 2.9, and 0.31 µg/g at WCK 2.3, respectively in 2017; Figure 5.30). PCB concentrations in bluegill collected from WCK 1.5 also decreased from 0.93 µg/g in 2017 to 0.58 µg/g in 2018 while concentrations in largemouth bass collected from WCK 1.5 increased in 2018 from 1.19 to1.90 µg/g (Figure 5.31).



Dashed grey line indicates the US Environmental Protection Agency ambient water quality criterion for mercury (0.3 µg/g in fish tissue).

Figure 5.30. Mean concentrations of mercury (± standard error, N = 6) in muscle tissue of sunfish and bass from White Oak Creek kilometers (WCKs) 3.9, 2.9, and 2.3 and White Oak Lake (WCK 1.5), 1998–2018



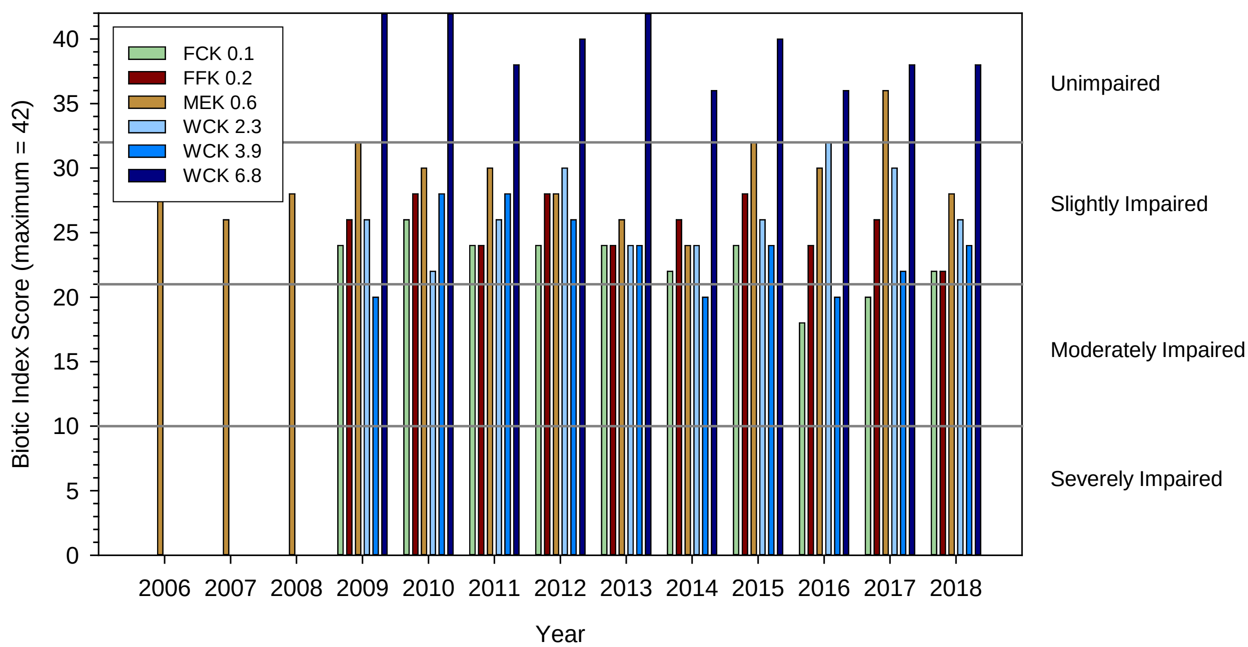
WCK = White Oak Creek kilometer

Figure 5.31. Mean total polychlorinated biphenyl (PCB) concentrations (± standard error, N = 6) in fish fillets collected from the White Oak Creek watershed (WCK 3.9, 2.9, 2.3, and 1.5), 1998–2018

5.5.6.2 Benthic Macroinvertebrate Communities

Monitoring of benthic macroinvertebrate communities in WOC, First Creek, and Fifth Creek continued in 2018. Additionally, monitoring of the macroinvertebrate community in lower Melton Branch (Melton Branch kilometer [MEK] 0.6) continued under the OREM Water Resources Restoration Program (WRRP). Benthic macroinvertebrate samples are collected annually following TDEC protocols and protocols developed by ORNL staff and used since 1986. The protocols developed by ORNL staff provide a continuous long-term record (32 years) of spatial and temporal trends in the invertebrate community from which the effectiveness of pollution abatement and remedial actions taken at ORNL can be evaluated and verified. The ORNL protocols also provide quantitative results that can be used to statistically evaluate changes in trends relative to historical conditions. The TDEC protocols provide a qualitative estimate of the condition of a macroinvertebrate community relative to a state-defined reference condition. During most years, sample results for benthic macroinvertebrate communities in WOC and its tributaries are not available for the same year in which the report is published. For instance, the 2017 annual site environmental report included samples from 2016 but not 2017. However, ORNL has worked diligently to reduce delays in sampling processing. This report includes results for both 2017 and 2018.

In 2017, results of TDEC protocols indicate that sites in White Oak Creek immediately downstream of effluent discharges (WCK 3.9) improved from moderately impaired to slightly impaired. In 2018, TDEC protocols suggested that conditions in First Creek improved as well from moderately to slightly impaired (Figure 5.32). In 2018, the only site rated as unimpaired was upper White Oak Creek (WCK 6.8). Melton Branch Creek has shifted in and out of unimpaired status from 2014 to 2018. The most downstream White Oak Creek site (WCK2.3) was rated as unimpaired in 2016 but has since remained in slightly impaired status in 2017 and 2018.



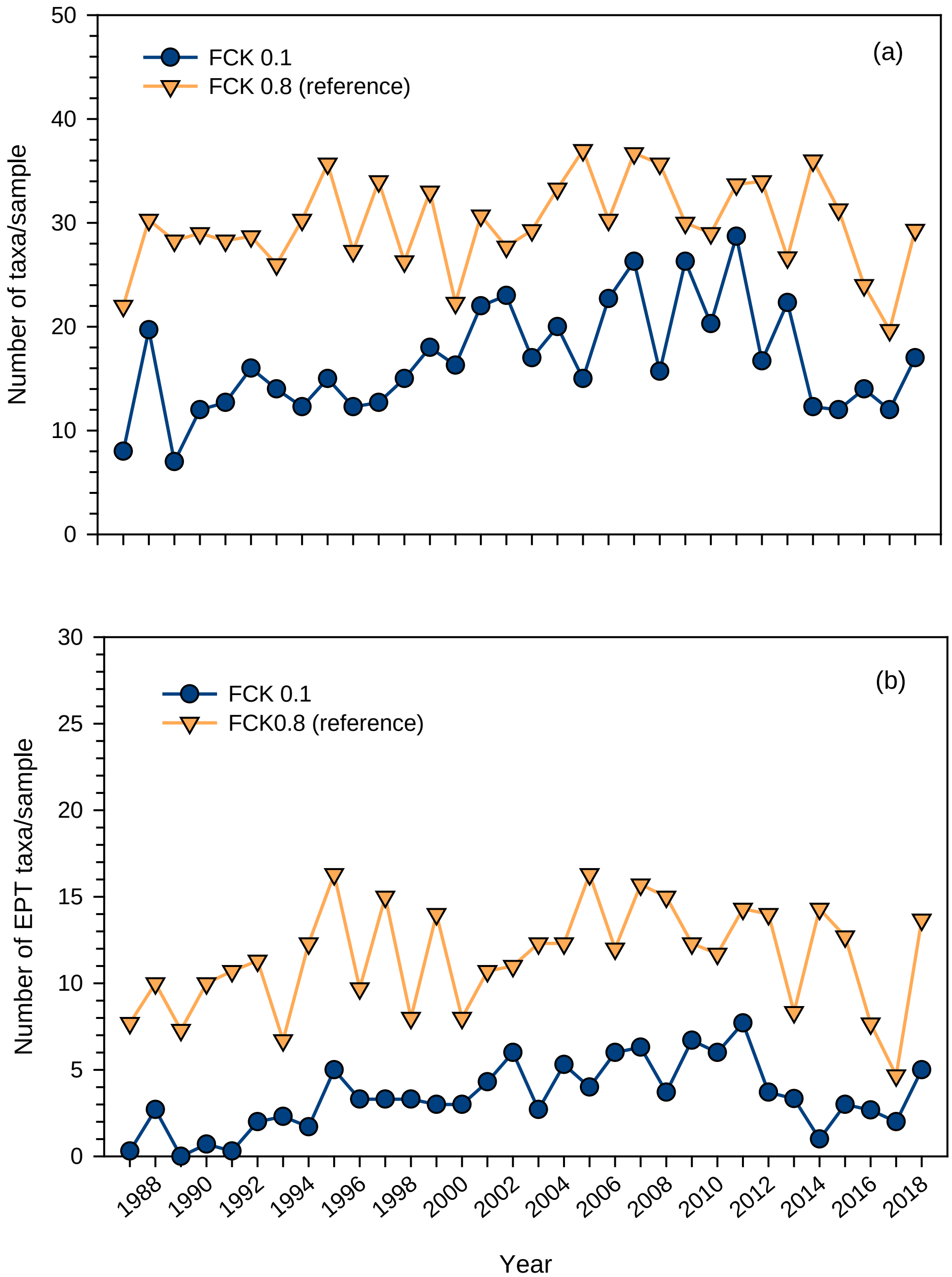
Horizontal lines show the lower thresholds for biotic condition ratings for index scores; respective narrative ratings for each threshold are shown at right of graph.

Acronyms: FCK = First Creek kilometer, FFK = Fifth Creek kilometer, MEK = Melton Branch kilometer, and WCK = White Oak Creek kilometer

Figure 5.32. Temporal trends in Tennessee Department of Environment and Conservation Biotic Index Scores for White Oak Creek watershed (FCK 0.1; FFK 0.2; MEK 0.6; and WCK 6.8, 3.9, and 2.3), August 2006–August 2018

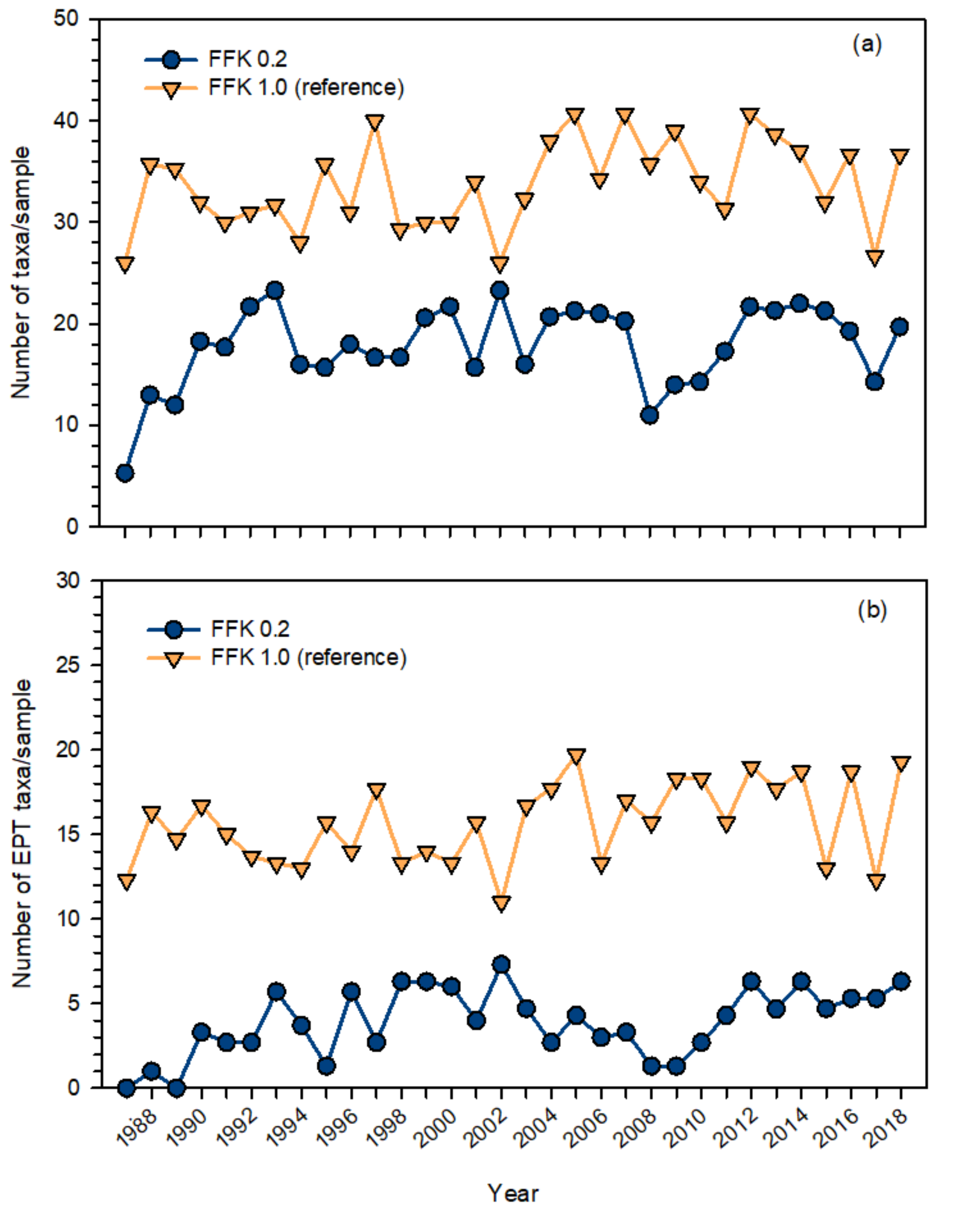
General trends in the results of ORNL protocols indicated significant recovery in these communities since 1987, but community characteristics indicated that ecological impairment remains (Figures 5.33–5.35). Relative to respective upstream reference sites, total taxonomic richness (i.e., the mean number of different species per sample) and richness of the pollution-intolerant taxa (i.e., the mean number of different mayfly, stonefly, and caddisfly species per sample or Ephemeroptera, Plecoptera, and Trichoptera [EPT] taxa richness) continued to be lower at these downstream sites. After modest increases in the mid-1990s, total taxa richness appeared to have generally decreased at FCK 0.1, and in 2014 the total number of taxa was the lowest it had been since 1989. Similarly, the number of pollution-intolerant EPT taxa decreased in 2012 and in 2014, EPT taxa richness was the lowest it had been since the early 1990s. After 6 consecutive years of low EPT taxa richness, values increased in 2018 to levels previously recorded in the late 2000s. Additionally upper First Creek (FCK 0.8), which serves as a reference for FCK 0.1, displayed three years of consecutive declines in total taxa richness and EPT taxa richness from 2014 to 2017, but in 2018 levels returned to values in previous years. The six year period of extremely low values in FCK 0.1 did not mirror those in FCK 0.8. This suggests that climate or hydrological change may have influenced conditions within the entire stream (both FCK 0.1 and FCK 0.8), but a more localized change may have occurred in conditions in lower First Creek. If a change has occurred, it is not known whether it is related to a change in chemical conditions (e.g., change in water quality or the possible presence of a toxicant), physical conditions (e.g., unstable substrate, increased frequency of high discharge events), or natural variation. Additionally, it is unclear at this time whether conditions have improved temporarily or for the long-term. Trends in metrics at Fifth Creek kilometer (FFK) 0.2 since the mid-1990s suggest that a change in conditions at that site occurred between 2007 and 2008. More recent results, however, suggest that improvements have occurred, and the condition of the invertebrate community is now comparable to what it was from the late 1990s through the early 2000s. Metric values for WCK 2.3 and WCK 3.9 continued to remain within the ranges of values found since the early 2000s, although they also continued to be notably lower than those for the reference sites, suggesting that no additional major changes had occurred at those sites for roughly 13 years. Since 2001, Walker Branch has served as an additional reference site for WOC mainstem sites downstream of Bethel Valley Road (Figure 5.35). Comparisons of WCK6.8 to WBK1.0 show that communities in WCK 6.8 represent ideal reference conditions. Additionally, the comparison of Walker Branch to downstream sites in WOC show that these communities remain impaired. Interestingly, a pattern similar to FCK 0.8 occurred in both WCK 6.8 and WBK 1.0, where consecutive declines in taxa richness and EPT richness have been observed in the past few years, followed by a return to previous levels in 2018. This suggests similar changes or pressures from climatological changes across the entire watershed, if not the entire ORR.

Macroinvertebrate community metrics for lower Melton Branch (MEK 0.6, Figure 5.36) suggested that in 2018 taxa richness metrics continued to be similar to reference conditions. However, like the results from the TDEC protocols, other invertebrate community metrics potentially sensitive to more specific types of pollutants, such as the percent density of pollution-intolerant and pollution-tolerant species (not shown), continued to fluctuate annually between comparable values and values below those of the reference sites. Thus, while the condition of the invertebrate community at MEK 0.6 was generally at or near reference conditions, annual changes in some characteristics of the community suggested that annual fluctuations in environmental conditions at the site appear to have some minor negative influence on the condition of the community.



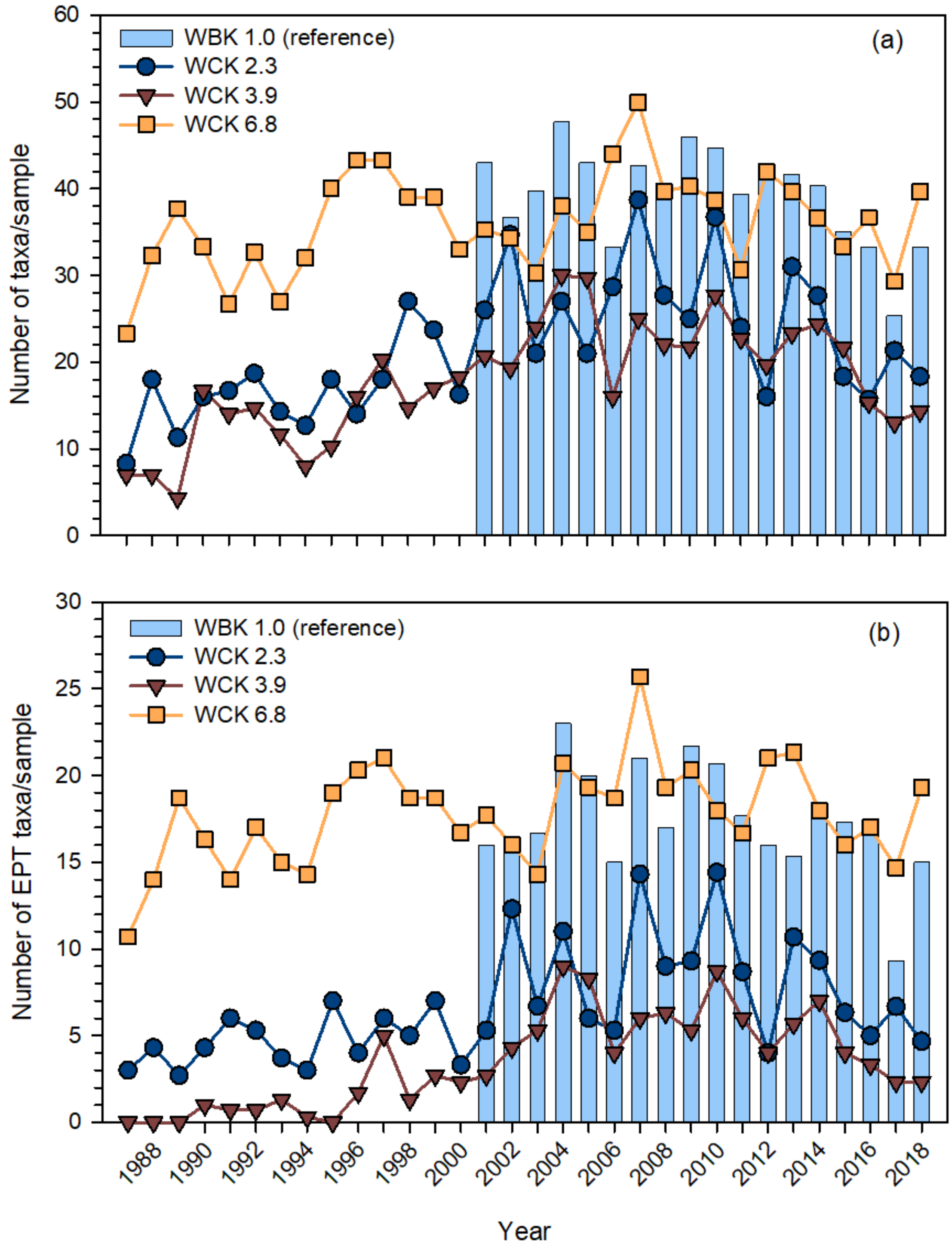
FCK = Fifth Creek kilometer; FCK 0.8 = reference site

Figure 5.33. Benthic macroinvertebrate communities in First Creek (FCK 0.1 and 0.8): total taxonomic richness (mean number of all taxa/sample) and taxonomic richness of the pollution-intolerant taxa, Ephemeroptera, Plecoptera, and Trichoptera (EPT); mean number of EPT taxa/sample, April sampling periods, 1987−2018



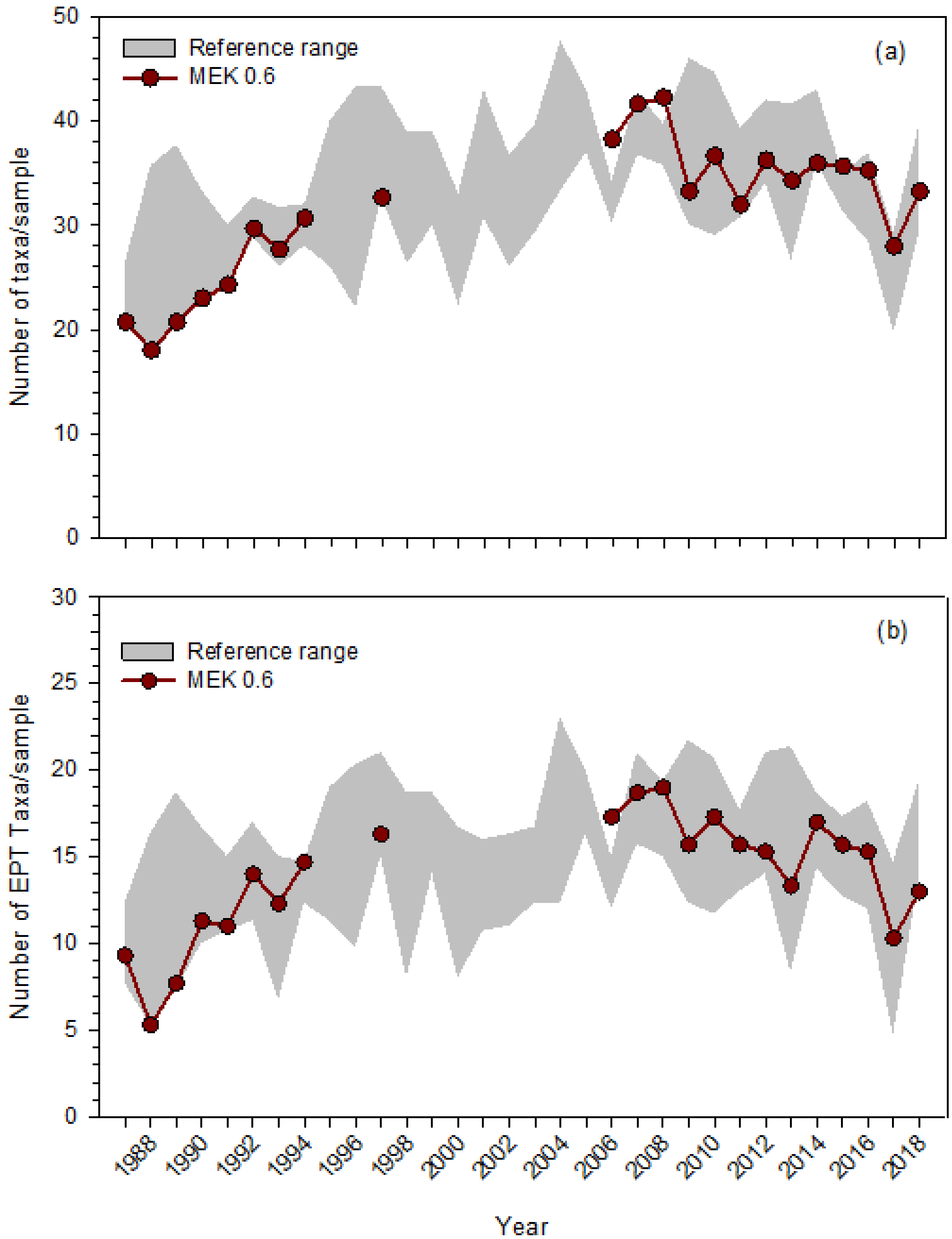
FFK = Fifth Creek kilometer; FFK 1.0 = reference site

Figure 5.34. Benthic macroinvertebrate communities in Fifth Creek (FFK 0.2 and 1.0): total taxonomic richness (mean number of all taxa/sample) and taxonomic richness of the pollution-intolerant taxa, Ephemeroptera, Plecoptera, and Trichoptera (EPT); mean number of EPT taxa/sample), April sampling periods, 1987−2018



WCK = White Oak Creek kilometer and WBK = Walker Branch kilometer; WBK 1.0 = reference site

Figure 5.35. Benthic macroinvertebrate communities in Walker Branch (WBK 1.0) and White Oak Creek (WCK 6.8, 3.9, and 2.3): (a) total taxonomic richness (mean number of all taxa/ sample) and (b) taxonomic richness of the pollution-intolerant taxa, Ephemeroptera, Plecoptera, and Trichoptera (EPT); mean number of EPT taxa/sample), April sampling periods, 1987−2018



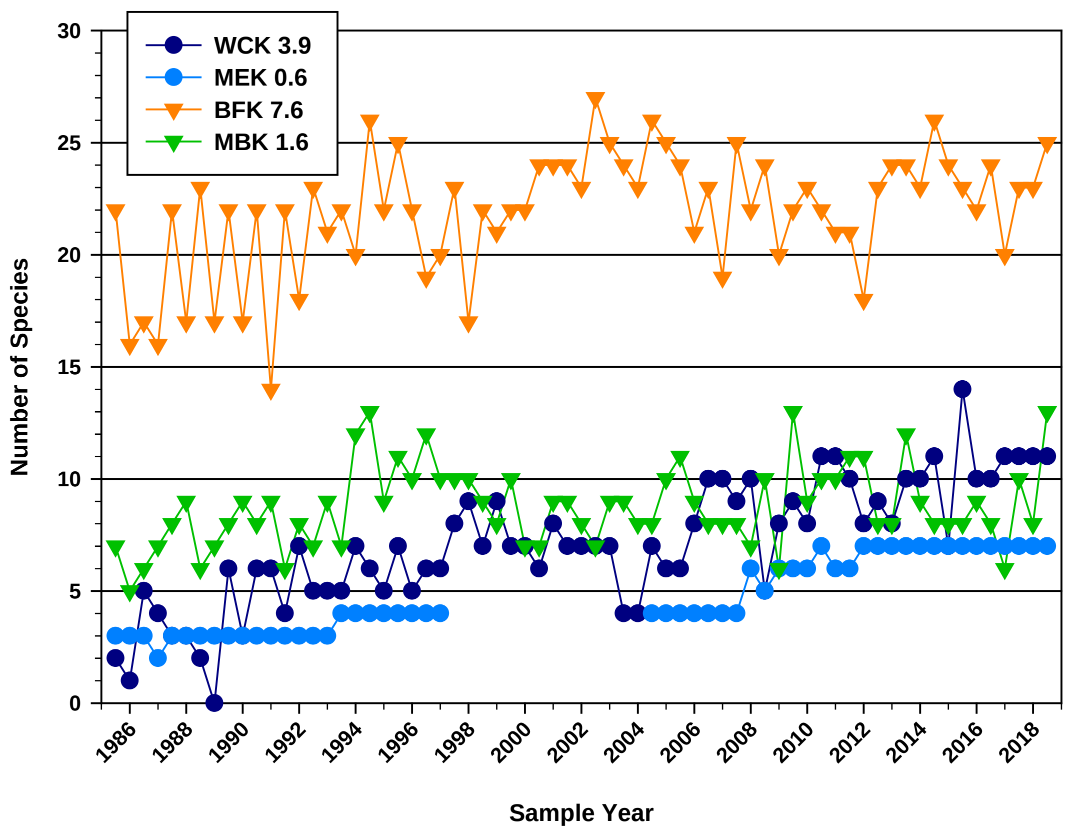
Maximum values for Oak Ridge National Laboratory Biological Monitoring and Abatement Program reference sites on First Creek and Fifth Creek (1987–2018), Walker Branch (2001–2018), and White Oak Creek (1987–2000, 2007–2018).

Figure 5.36. Benthic macroinvertebrate communities in lower Melton Branch (MEK 0.6): (a) total taxonomic richness (mean number of all taxa/sample) and (b) taxonomic richness of the pollution-intolerant taxa, Ephemeroptera, Plecoptera, and Trichoptera (EPT); mean number of EPT taxa/sample, April sampling periods, 1987−2018

5.5.6.3 Fish Communities

Monitoring of the fish communities in WOC and its major tributaries continued in 2018. Fish community surveys were conducted at 11 sites in the WOC watershed, including 5 sites in the main channel, 2 sites in First Creek, 2 sites in Fifth Creek, and 2 sites in Melton Branch. Streams located near or within the city of Oak Ridge (Mill Branch and Brushy Fork) were also sampled as reference sites for comparison.

In the WOC watershed, the fish community continued to be slightly degraded in 2018 compared with communities in reference streams. Sites closest to outfalls within the ORNL campus had lower species richness (number of species) (Figure 5.37), and fewer pollution-sensitive species. These sites also had more pollution-tolerant species, and elevated densities (number of fish per square meter) of pollution-tolerant species compared with similar-sized reference streams. Seasonal fluctuations in diversity and density are expected and may explain some of the variability seen at these sites. However, the combination of these factors indicates degraded water quality and/or habitat conditions. Overall, the fish communities in tributary sites adjacent to and downstream of ORNL outfalls also remained negatively affected by ORNL effluent in 2018 relative to reference streams and upstream sites.



BFK = Brushy Fork kilometer; MBK = Mill Branch kilometer; MEK = Melton Branch kilometer; and WCK = White Oak Creek kilometer

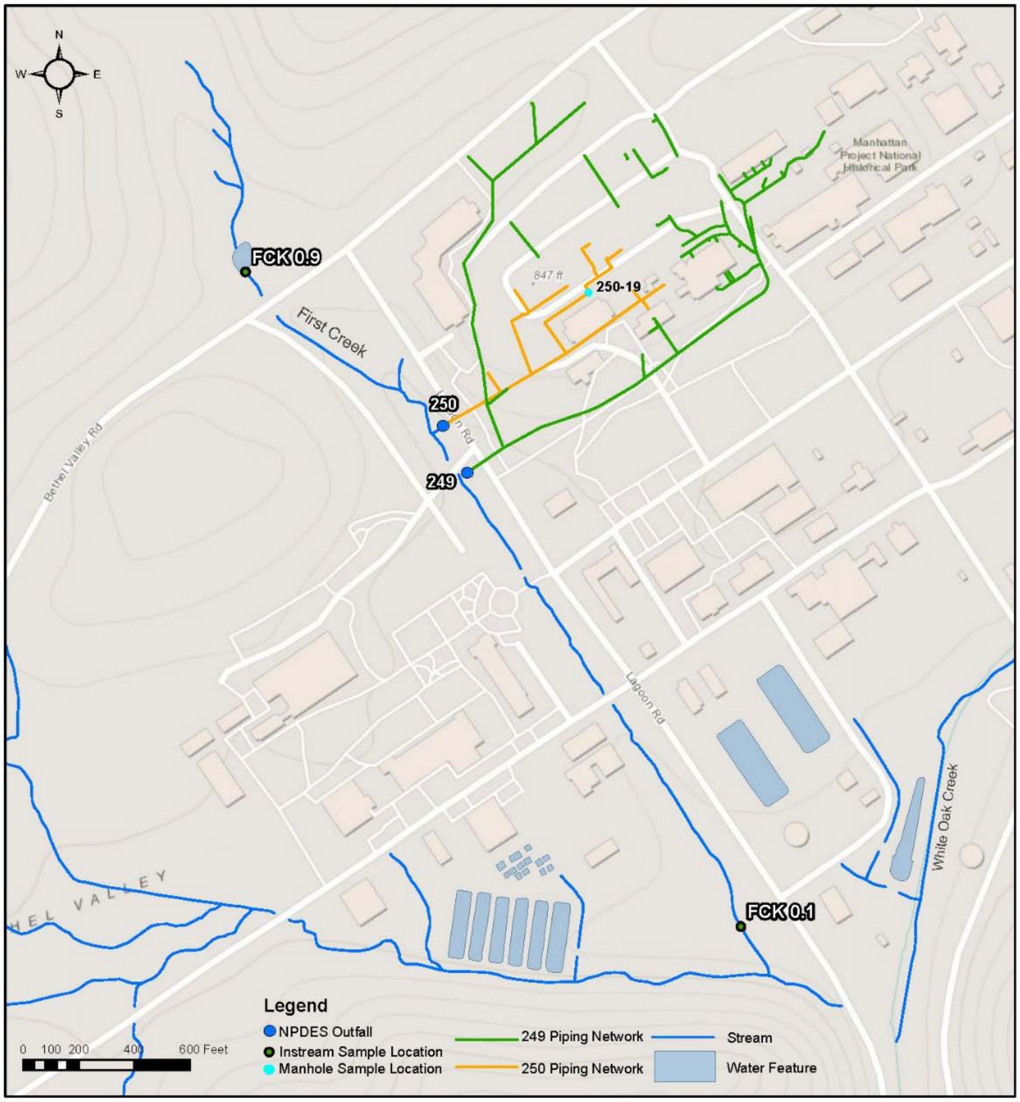
Figure 5.37. Fish species richness (number of species) in upper White Oak Creek (WCK 3.9) and lower Melton Branch (MEK 0.6) compared with two reference streams, Brushy Fork (BFK 7.6) and Mill Branch (MBK 1.6), 1985–2018

A project to introduce fish species that were not found in the WOC watershed but that exist in similar systems on ORR and that may have historically existed in WOC was initiated in 2008 with the stocking of six such native species. Reproduction has been noted for five of the species, and several species have expanded their ranges downstream and upstream from initial introduction sites to establish new reproducing populations. In general, introduced species have had more difficulty establishing populations at upstream sites in both WOC and Melton Branch, and as a result, introductions to supplement the small populations of these fish species have continued at sites within the watershed. One exception to this is the striped shiner (*Luxilus chrysocephalus*), which has expanded into upper Melton Branch, upper WOC, and lower First Creek. The introductions have enhanced species richness at almost all sample locations within the watershed and illustrate the capacity of this watershed to support increased fish diversity, which seems to be limited by impassible barriers such as dams, weirs, and culverts, and by limited access to source populations downstream.

5.5.7 Polychlorinated Biphenyls in the White Oak Creek Watershed

The initial objective of the source identification task in the WOC watershed was to identify the stream reaches, outfalls, or sediment areas that are contributing to elevated PCB levels in the watershed. Sample results for largemouth bass collected from White Oak Lake showed tissue PCB concentrations higher than those recommended by TDEC and EPA for frequent consumption (Figure 5.31), but the mobility of the fish precluded the possibility of source identification. PCBs are hydrophobic and tend not to be dissolved in water, resulting in undetected PCB concentrations in water samples, using conventional analytical methods, even if collected from a contaminated site. Therefore, semipermeable membrane devices (SPMDs) are used to assess the chronic low-level sources of PCBs at critical sites on the reservation. SPMDs are thin plastic sleeves filled with oil in which PCBs are soluble. Because SPMDs are deployed at a given site for 4 weeks and have a high affinity for PCBs, they allow for a time-integrated semiquantitative index of the relative PCB concentrations in the water column rather than a “snapshot” value that would be obtained from a grab sample.

In 2018, ORNL’s PCB monitoring efforts continued focusing on the First Creek watershed, which has been identified as a source of PCBs. SPMDs were also deployed on First Creek at Outfall 250, and the piping network of Outfall 250, which contributes to First Creek (Figure 5.38). The results for the SPMDs are summarized in Table 5.12.



FCK = First Creek kilometer

Figure 5.38. Locations of monitoring points for First Creek source investigation, 2018

Table 5.12. First Creek and WOC PCB source assessment, September 2018, total PCBs

Sample location	Location Type	SPMD (ppb)
OF 250	Outfall	523
250-19	Inlet/Outlet	3,696
Downstream OF 249	Instream	1,905
FCK 0.1	Instream	794
FCK 0.9	Instream	106

Acronyms
FCK = First Creek kilometer
OF = outfall
PCB = polychlorinated biphenyl
SPMD = semipermeable membrane device
WOC = White Oak Creek

Results from the 2018 assessment confirm that upper parts of outfalls 249 and 250 pipe networks continue to be of primary interest for investigation of legacy PCB sources in the First Creek watershed. The results from sample location 250-19 (Table 5.12) indicate that PCBs remain available in that area despite recent actions to remove PCB-contaminated building materials from the upper part of the outfall 250 watershed (Table 5.12). Therefore, First Creek remains the greatest area of concern for sources of PCBs and future remediation efforts. Results were lower in 2018 than in 2017 but this is likely due to differences in the flow regimes between the two years rather than a decrease in PCB inputs at these sites.

5.5.8 Oil Pollution Prevention

CWA Section 311 regulates the discharge of oils or petroleum products to waters of the United States and requires the development and implementation of spill prevention, control, and countermeasures (SPCC) plans to minimize the potential for oil discharges. These requirements are provided in 40 CFR 112, *Oil Pollution Prevention*. Each ORR facility implements a site-specific SPCC plan. NTRC, which is located off ORR, also has an SPCC plan covering the oil inventory at its location. CFTF is also located off ORR; however, that facility was evaluated, and a determination was made that it did not require a SPCC plan. The ORNL and NTRC SPCC plans were not changed in 2018. There were no regulatory actions related to oil pollution prevention at ORNL or NTRC in 2018. An oil-handler training program exists to comply with training requirements in 40 CFR 112.

5.5.9 Surface Water Surveillance Monitoring

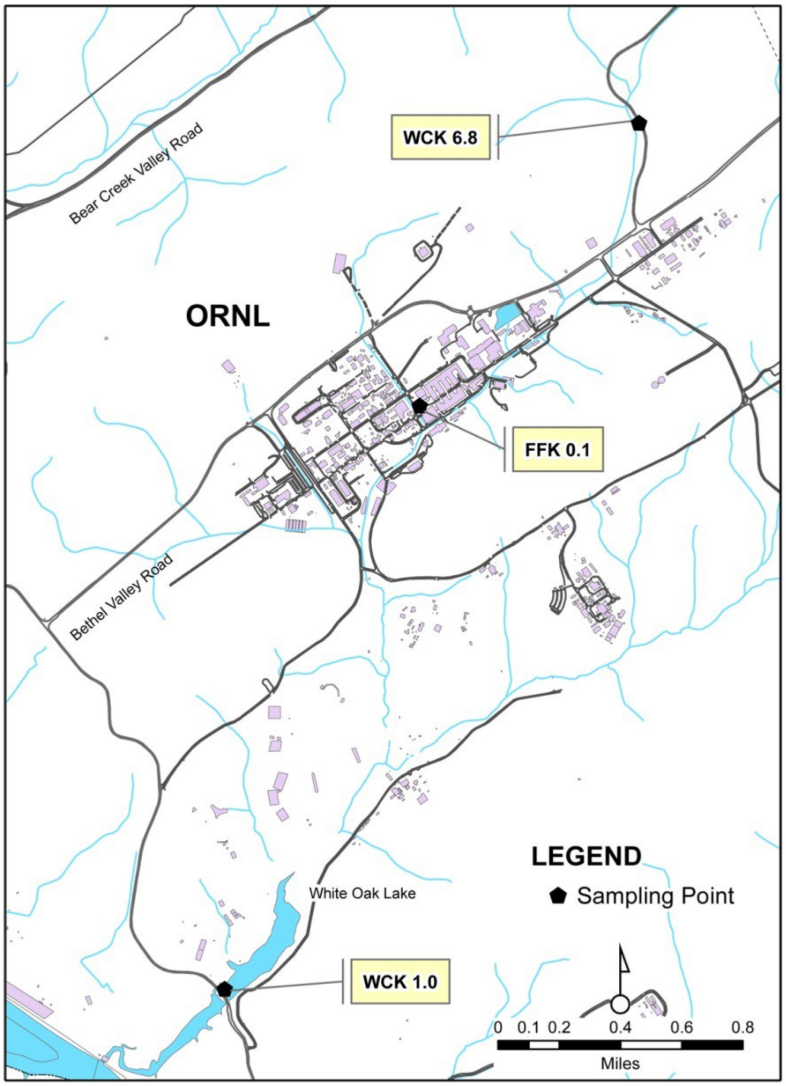
The ORNL surface water monitoring program is conducted in conjunction with the ORR surface water monitoring activities discussed in Section 6.4 to enable assessing the impacts of ongoing DOE operations on the quality of local surface water. The sampling locations (Figure 5.39) are used to monitor conditions upstream of ORNL main plant waste sources (WCK 6.8), within the ORNL campus (FFK 0.1), and downstream of ORNL discharge points (WCK 1.0).

Sampling frequencies and parameters vary by site and are shown in Table 5.13. Radiological monitoring at the discharge point downstream of ORNL (White Oak Lake at WOD) is conducted monthly under the ORNL WQPP (Section 5.5.3) and, therefore, is not duplicated by this program. Radiological monitoring at a point upstream of ORNL is conducted monthly under the ORNL WQPP (Section 5.5.3) and therefore is not duplicated by the surface water monitoring program. Total radioactive strontium is monitored quarterly by this surveillance program.

Samples are collected and analyzed for general water quality parameters and are screened for radioactivity at all locations (either under this program or under WQPP). Samples are further analyzed for specific radionuclides when general screening levels are exceeded. Samples from White Oak Lake at WOD are also checked for volatile organic compounds (VOCs), PCBs, and mercury. WCK 6.8 is also checked for PCBs. WCK 6.8 and WCK 1.0 are classified by the State of Tennessee for freshwater fish and aquatic life. Tennessee Water Quality Criteria (WQCs) associated with these classifications are used as references where applicable (TDEC 2015). The Tennessee WQCs do not include criteria for radionuclides. Four percent of the DOE DCS (DOE 2011a) is used for radionuclide comparison.

There were no radionuclides reported above 4 percent of DCS at the Fifth Creek location (FFK 0.1) in 2018. The beta activity and $^{89/90}$Sr concentrations were detected in samples from both sampling events at the Fifth Creek location and are related to known sources in the middle of the ORNL main campus. No $^{89/90}$Sr results above 4 percent of DCS were reported for samples collected at the upstream White Oak Creek sampling location (WCK 6.8). The other radionuclide results from WCK 6.8 and the radionuclide results from samples collected at WOD (before WOC empties into the Clinch River) are discussed in Section 5.5.3.

PCB-1254 and -1260 were not detected in 2018 as they had been one time in 2017 at low, estimated concentrations from WOC at WOD. PCBs had not been detected at WOC at WOD since 2012 until this one-time occurrence in 2017. Three VOC compounds were detected in samples from WOC at WOD during 2018: acetone was detected in the February sample, methylene chloride was detected at a low, estimated value in the September sample, and toluene was detected at a low, estimated value in the December sample. Each of these VOC compounds has been detected in surface water samples from WOC at WOD before and occasionally has been detected in at least one onsite groundwater well in past monitoring, including wells located in nearby Solid Waste Storage Area (SWSA) 6. Mercury was detected in the September 2018 sample from WOC at WOD.



FFK = Fifth Creek kilometer; WCK = White Oak Creek kilometer

Figure 5.39. Oak Ridge National Laboratory surface water sampling locations, 2018

Table 5.13. Oak Ridge National Laboratory surface water sampling locations, frequencies, and parameters, 2018

Location[a]	Description	Frequency and type	Parameters
WCK 1.0[b]	White Oak Lake at WOD	Quarterly, grab	Volatiles, mercury, PCBs, field measurements[c]
WCK 6.8[d]	WOC upstream from ORNL	Quarterly, grab	PCBs, Total radioactive strontium, field measurements[c]
FFK 0.1	Fifth Creek just upstream of WOC (ORNL)	Semiannually, grab	Gross alpha, gross beta, total radioactive strontium, gamma scan, tritium, field measurements[c]

[a] Locations identify bodies of water and locations on them (e.g., WCK 1.0 is 1 km upstream from the confluence of White Oak Creek and the Clinch River).
[b] For this location, radiological parameters are monitored under another program (the WQPP) and therefore are not included in this plan.
[c] Field measurements consist of dissolved oxygen, pH, and temperature.
[d] For this location, gross alpha, gross beta, gamma scan, and tritium are monitored under another program (the WQPP) so those radiological parameters are not included in this plan.

Acronyms
FFK = Fifth Creek kilometer
ORNL = Oak Ridge National Laboratory
PCB = polychlorinated biphenyl
WCK = WOC kilometer
WOC = White Oak Creek
WOD = White Oak Dam

5.5.10 Carbon Fiber Technology Facility Waste Water Monitoring

Facility and process wastewater from activities at CFTF are discharged to the City of Oak Ridge sanitary sewer system under conditions established in City of Oak Ridge Industrial Waste Water Discharge Permit 1-12. Permit limits, parameters, and 2018 compliance status for this permit are summarized in Table 5.14.

Table 5.14. Industrial and commercial user wastewater discharge permit compliance at the Oak Ridge National Laboratory Carbon Fiber Technology Facility, 2018

Effluent parameters	Permit limits		Permit compliance		
	Daily max. (mg/L)	Daily min. (mg/L)	Number of noncompliances	Number of samples	Percentage of compliance[a]
			Outfall 01 (Underground Quench Water Tank)		
Cyanide	3.9		0	0	100
pH (standard units)	9.0	6.0	0	0	100
			Outfall 02 (Electrolytic Bath Tank)		
pH (standard units)	9.0	6.0	0	2	100
			Outfall 03 (Sizing Bath Tank)		
Copper	0.87		0	0	100
Zinc	1.24		0	0	100
Total phenol	4.20		0	0	100
pH (standard units)	9.0	6.0	0	0	100

[a] Percentage compliance = 100 – [(number of noncompliances/number of samples) × 100]

5.6 Groundwater Monitoring Program

Groundwater monitoring at ORNL was conducted under two sampling programs in 2018: DOE OREM monitoring and DOE Office of Science (SC) surveillance monitoring. The DOE OREM groundwater monitoring program was conducted by UCOR in 2018. The SC groundwater monitoring surveillance program was conducted by UT-Battelle.

5.6.1 DOE Office of Environmental Management Groundwater Monitoring

Monitoring was performed as part of an ongoing comprehensive CERCLA cleanup effort in Bethel and Melton Valleys, the two administrative watersheds at the ORNL site. Groundwater monitoring for baseline and trend evaluation in addition to measuring effectiveness of completed CERCLA remedial actions (RAs) is conducted as part of the WRRP. The WRRP is managed by UCOR for the DOE OREM program. The results of CERCLA monitoring for ORR for FY 2018, including monitoring at ORNL, are evaluated and reported in the 2019 remediation effectiveness report (DOE 2019) as required by the ORR FFA. The monitoring results and remedial effectiveness evaluations for Bethel and Melton Valley are reported in Sections 2 and 3, respectively, in that report.

Groundwater monitoring conducted as part of the OREM program at ORNL includes routine sampling and analysis of groundwater in Bethel Valley to measure performance of several RAs and to continue contaminant and groundwater quality trend monitoring. In Melton Valley, where CERCLA RAs were completed in 2006 for the extensive waste management areas, the groundwater monitoring program includes monitoring groundwater levels to evaluate the effectiveness of hydrologic isolation of buried waste units. Additionally, groundwater is sampled and analyzed for a wide range of general chemical and contaminant parameters in 46 wells within the interior portion of the closed waste management area.

In FY 2010 DOE initiated activities on a groundwater treatability study at the Bethel Valley 7000 Services Area VOC plume. This plume contains trichloroethylene (TCE) and its transformation products cis-1,2-dichloroethene and vinyl chloride, all at concentrations greater than EPA primary drinking water standards. The treatability study is a laboratory and field demonstration to determine whether microbes inherent to the existing subsurface microbial population can fully degrade the VOCs to nontoxic end products.

During FY 2018 postremediation monitoring continued at SWSA 3 following completion of hydrologic isolation of the area by construction of a multilayer cap and upgradient stormflow/shallow groundwater diversion drain. RAs and monitoring were specified in a CERCLA RA work plan that was developed by DOE and approved by EPA and TDEC before the project was started.

5.6.1.1 Summary of DOE Office of Environmental Management Groundwater Monitoring

Bethel Valley

During FY 2011 construction was completed for RAs at SWSA 1 and SWSA 3, two former waste storage sites that were used for disposal of radioactively contaminated solid wastes between 1944 and 1950. Wastes disposed of at SWSA 1 originated from the earliest operations of ORNL; those at SWSA 3 originated from ORNL, Y-12, the K-25 Site (ETTP), and off-site sources. Although most of the wastes disposed of at SWSA 3 were solids, some were containerized liquid wastes. Some wastes were encapsulated in concrete after placement in burial trenches, but most of the waste was covered with soil. The Bethel Valley Record of Decision (ROD) (DOE 2002) selected hydrologic isolation using multilayer caps and groundwater diversion trenches as the RA for the waste burial grounds and construction of soil covers over the former contractor’s landfill and contaminated soil areas near SWSA 3. The baseline monitoring conducted during FY 2010 included measurement of groundwater levels to obtain baseline data to allow evaluation of postremediation groundwater-level suppression. Sampling and analysis of groundwater quality and contaminants were also conducted. Postremediation monitoring was specified for SWSA 3 in the *Phased Construction Completion Report for the Bethel Valley Burial Grounds at the Oak Ridge National Laboratory, Oak Ridge, Tennessee* (DOE 2012). Required monitoring includes quarterly groundwater-level monitoring in 42 wells with continuous water-level monitoring in 8 wells to confirm cap performance. Groundwater samples are collected semiannually at 13 wells for laboratory analyses to evaluate groundwater contaminant concentration trends.

FY 2018 monitoring results showed that the cap was effective, although target groundwater elevations have not yet been attained at three of eight wells. Drinking water standards are used as screening water quality concentrations to evaluate the site response to remediation. Strontium-90, a signature contaminant at SWSA 3, shows decreasing annual maximum concentrations with 5 of 10 monitored wells exhibiting ^{90}Sr concentrations less than the 8 pCi/L MCL derived concentration. Benzene, potentially from natural sources, shows decreasing annual maximum concentrations with FY 2018 maxima of 0.008 mg/L which is less than twice the 0.005 mg/L MCL. During FY 2018, as part of the DOE OREM program, three groundwater monitoring wells in Bethel Valley to the west of Tennessee Highway 95 were monitored to detect and track contamination from the SWSA 3 area. Data from those three wells supplement data being collected from a multiport well (4579) near SWSA 3 (included in the preceding paragraph discussion) for exit pathway groundwater monitoring in western Bethel Valley. Groundwater monitoring near SWSA 3, along with the exit pathway, and groundwater and surface water monitoring at the northwest tributary of WOC and in the headwaters of Raccoon Creek allow integration of data concerning SWSA 3 contaminant releases. The data are presented in the 2018 remediation effectiveness report (DOE 2019).

Groundwater monitoring continued at the ORNL 7000 Area during FY 2018 to evaluate treatability of the VOC plume at that site. Site characterization testing of the endemic microbial community showed that microbes were present that are capable of fully degrading TCE and its degradation products if sufficient electron donor compounds are present in the subsurface environment. During FY 2011 a mixture of emulsified vegetable oil and a hydrogen-releasing compound was injected into four existing monitoring wells in the 7000 area. Ongoing monitoring of VOC concentrations show that the effects of the biostimulation test continue to be apparent, although at decreasing levels.

The other principal element of the Bethel Valley ROD (DOE 2002) remedy that requires groundwater monitoring is the containment pumping to control and treat discharges from the ORNL Central Campus core hole 8 plume. The original action for the plume was a CERCLA removal action that was implemented in 1995. The remedy had performed well until the latter portion of FY 2008 when conditions changed and ^{90}Sr and $^{233/234}$U concentrations in monitoring wells and the groundwater collection system began increasing. During FY 2009 the remedy did not meet its performance goal, which is a reduction of ^{90}Sr in WOC. In March 2012 DOE completed refurbishment and enhancement of the groundwater collection system to increase the effectiveness of the plume containment.

Between FY 2012 and FY 2015 the Bethel Valley ROD goal for ^{90}Sr concentrations at the 7500 Bridge Weir monitoring location was met. During FY 2016 and FY 2017 that goal was exceeded because of contaminant releases from a deteriorated radiological wastewater drain that caused ^{90}Sr discharges from storm drain Outfall 304 into WOC. During FY 2018 the Bethel Valley ROD goal for ^{90}Sr at the 7500 Bridge Weir site was met. Continuing ^{90}Sr influxes to White Oak Creek from groundwater and storm drain discharges fed by releases from deteriorated infrastructure comprise the majority of ^{90}Sr measured at the 7500 Bridge Weir site.

Melton Valley

The Melton Valley ROD (DOE 2000) established goals for a reduction of contaminant levels in surface water, groundwater-level fluctuation reduction goals within hydrologically isolated areas, and minimization of the spread of groundwater contamination. Groundwater monitoring to determine the effectiveness of the remedy in Melton Valley includes groundwater-level monitoring in wells within and adjacent to hydrologically isolated shallow waste burial areas and groundwater quality monitoring in selected wells adjacent to buried waste areas.

Groundwater-level monitoring shows that the hydrologic isolation component of the Melton Valley remedy is effectively minimizing the amount of percolation water contacting buried waste and is reducing contaminated leachate formation. The total amount of rainfall during FY 2017 was about 4 in. greater than the long-term annual average for ORR. In a few areas groundwater levels within capped areas continue to respond to groundwater fluctuations imposed from areas outside the caps but contact of groundwater with buried waste is minimal. Overall the hydrologic isolation systems are performing as designed.

Groundwater quality monitoring in the interior of Melton Valley shows that in general groundwater contaminant concentrations are declining or are stable following RAs. Groundwater quality monitoring substantively equivalent to the former RCRA monitoring continues at SWSA 6. Several VOC substances continue to be detected in wells along the eastern edge of the site.

During the past 10 years of groundwater monitoring in the Melton Valley exit pathway, several site-related contaminants have been detected in groundwater near the Clinch River. Low concentrations of Sr, tritium, uranium, and VOCs have been detected intermittently in a number of the multizone sampling locations. Groundwater in the exit pathway wells has high alkalinity and sodium and exhibits elevated pH. During FY 2018 an off-site groundwater monitoring well array west of the Clinch River and adjacent to Melton Valley was monitored as part of the OREM program. Monitoring included groundwater-level monitoring to evaluate potential flowpaths near the river and sampling and analysis for a wide array of metals, anions, radionuclides, and VOCs. Groundwater-level monitoring showed that natural head gradient conditions cause groundwater seepage to converge toward the Clinch River from both the DOE (eastern) and off-site (western) sides of the river. Monitoring results are summarized in the 2018 remediation effectiveness report (DOE 2019).

5.6.2 DOE Office of Science Groundwater Monitoring

DOE O 458.1 (DOE 2011c) is the primary requirement for a site-wide groundwater protection program at ORNL. As part of the groundwater protection program, and to be consistent with UT-Battelle management objectives, groundwater surveillance monitoring was performed to monitor ORNL groundwater exit pathways and UT-Battelle facilities (“active sites”) potentially posing a risk to groundwater resources at ORNL. Results of the DOE SC groundwater surveillance monitoring program are reported in the following sections.

Exit pathway and active-sites groundwater surveillance monitoring points sampled during 2018 included seep/spring and surface-water monitoring locations in addition to groundwater surveillance monitoring wells. Seep/spring and surface-water monitoring points located in appropriate groundwater discharge areas were used in the absence of monitoring wells.

Groundwater pollutants monitored under the exit pathway groundwater surveillance and active-sites monitoring programs are not regulated by federal or state rules. Consequently, no permit-required or other applicable standards exist for evaluating results. To assess groundwater quality at these monitoring locations, and to facilitate comparison of results between locations, results were compared to selected federal and state standards even though those standards are not directly applicable. For radionuclide parameters for which alternative standards were not identified, results were compared to 4 percent of the DCSs (DOE 2011a). Regardless of the standards selected for comparison, it is important to note that no members of the public consume groundwater from ORNL wells, nor do any groundwater wells furnish drinking water to personnel at ORNL.

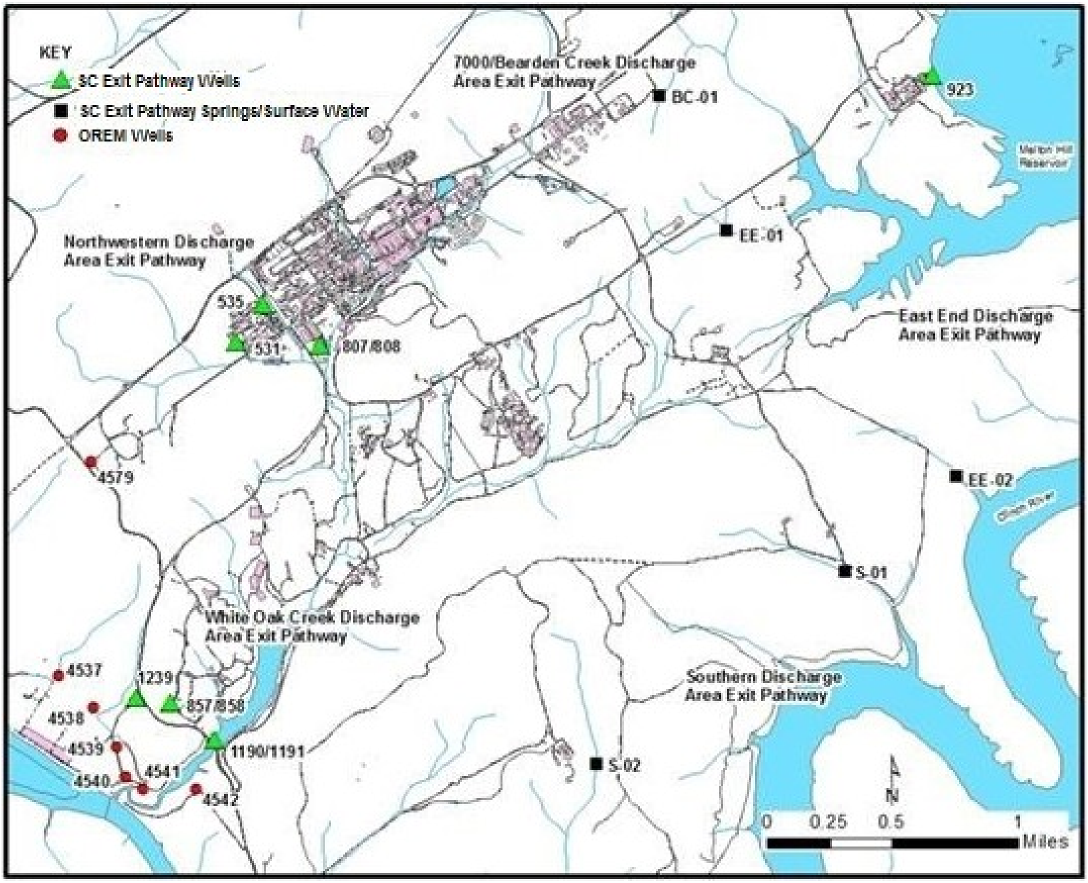
5.6.2.1 Exit Pathway Monitoring

During 2018, exit pathway groundwater surveillance monitoring was performed in accordance with the exit pathway sampling and analysis plan (Bonine 2012). Groundwater exit pathways at ORNL include areas from watersheds or sub-watersheds where groundwater discharges to the Clinch River–Melton Hill Reservoir to the west, south, and east of the ORNL main campus. The exit pathway monitoring points were chosen based on hydrologic features, screened interval depths (for wells), and locations relative to discharge areas proximate to DOE facilities operated by, or under the control of, UT-Battelle. The groundwater exit pathways at ORNL include four discharge zones identified by a data quality objectives process. One of the original exit pathway zones was split into two zones for geographic expediency. The Southern Discharge Area Exit Pathway was carved from the East End Discharge Area Exit Pathway.

The five zones are as follows:

- the WOC Discharge Area Exit Pathway,
- the 7000–Bearden Creek Discharge Area Exit Pathway,
- the East End Discharge Area Exit Pathway,
- the Northwestern Discharge Area Exit Pathway, and
- the Southern Discharge Area Exit Pathway.

Figure 5.40 shows the locations of the exit pathway monitoring points sampled in 2018.



OREM = DOE Office of Environmental Management; SC = DOE Office of Science

Figure 5.40. UT-Battelle exit pathway groundwater monitoring locations at Oak Ridge National Laboratory, 2018

The efficacy of the exit pathway monitoring program was reviewed in late 2011. As a result, the groundwater monitoring program was modified through an optimization approach that included frequency analysis of parameters and their concentrations based on an exhaustive review of historical groundwater sampling data. The modification resulted in a 10 year staggered groundwater monitoring schedule and analytical suite selection. This approach was initiated in 2012. The groundwater monitoring program implemented in 2018 is outlined in Table 5.15.

Unfiltered samples were collected from the exit pathway groundwater surveillance monitoring points in 2018. The organic suite was composed of VOCs and semivolatile organic compounds (SVOCs); the metallic suite included heavy and non-heavy metals; and the radionuclide suite was composed of gross alpha/gross beta activity, gamma emitters, $^{89/90}$Sr, and tritium. Under the monitoring strategy outlined in the exit pathway sampling and analysis plan (Bonine 2012), samples were collected semiannually during the wet (March/April) and dry (August) seasons.

Table 5.15. 2018 exit pathway groundwater monitoring schedule

Monitoring point	Season	
	Wet	Dry
	7000 Bearden Creek Discharge Area	
BC-01	Radiological, organics, and metals	Radiological
	East End Discharge Area	
923	Radiological	Radiological
EE-01	Radiological	Radiological
EE-02	Radiological	Radiological
	Northwestern Discharge Area	
531	Radiological	Radiological
535	Radiological	Radiological
807	Radiological	Radiological, organic, and metals
808	Radiological	Radiological
	Southern Discharge Area	
S-01	Radiological[a]	Radiological, organic, and metals[a]
S-02	Radiological	Radiological
	White Oak Creek Discharge Area	
857	Radiological	Radiological
858	Radiological	Radiological, organic, and metals
1190	Radiological, organic, and metals	Radiological, organic, and metals
1191	Radiological, organic, and metals	Radiological, organic, and metals
1239	Radiological	Radiological

[a] Location S01(a stream location) was not sampled in 2018 due to lack of water flow at that location.

Exit Pathway Monitoring Results

Table 5.16 provides a summary of radiological parameters detected in samples collected from exit pathway monitoring points during 2018. Metals are ubiquitous in groundwater exit pathways and so are not summarized in the table.

Table 5.16. Radiological concentrations detected in 2018 exit pathway groundwater monitoring

Parameter	Concentration[a] (pCi/L)		
	Season		Reference value[b]
	Wet	Dry	
	Spring BC-01—7000 Area/Bearden Creek Watershed		
Alpha activity	3.1	U0.34	15
Beta activity	4.3	3.1	50
^{214}Bi	37	ND	10,400
^{214}Pb	32	5.6	8,000
Tritium	U99	210	20,000
	Well 923—East End Discharge Point		
Beta activity	2.7	2.8	50
^{214}Bi	11	ND	10,400
^{214}Pb	14	ND	8,000

Table 5.16. Radiological concentrations detected in 2018 exit pathway groundwater monitoring (continued)

Parameter	Concentration[a] (pCi/L) Season Wet	Dry	Reference value[b]
Spring/Surface Water Monitoring Point EE-01—East End Discharge Area Exit Pathway			
Beta activity	2.4	U0.85	50
^{214}Bi	23	15	10,400
^{214}Pb	24	10	8,000
Spring/Surface Water Monitoring Point EE-02—East End Discharge Area Exit Pathway			
^{214}Bi	150	19	10,400
^{214}Pb	170	25	8,000
Well 531—Northwestern Discharge Area Exit Pathway			
Beta activity	U1.1	1.9	50
Tritium	U44	180	20,000
Well 535—Northwestern Discharge Area Exit Pathway			
^{214}Bi	16	6.8	10,400
^{214}Pb	17	ND	8,000
Well 807—Northwestern Discharge Area Exit Pathway			
Beta activity	6.8	4.7	50
^{214}Bi	43	9.4	10,400
^{214}Pb	51	7.0	8,000
^{40}K	U12	26	192
$^{89/90}Sr$	U1.2	1.4	44
^{208}Tl	2.5	ND	n/a
Tritium	240	360	20,000
Well 808—Northwestern Discharge Area Exit Pathway			
Beta activity	5.0	5.6	50
Spring/Surface Water Monitoring Point S-02—Southern Discharge Area Exit Pathway			
Alpha activity	U0.076	4.2	15
Beta activity	U1.2	3.1	50
^{214}Bi	18	8.3	10,400
^{214}Pb	13	6.1	8,000
Well 857—WOC Discharge Area Exit Pathway			
Beta activity	U0.33	3.2	50
^{214}Bi	110	190	10,400
^{214}Pb	ND	220	8,000
Tritium	300	310	20,000
Well 858—WOC Discharge Area Exit Pathway			
^{214}Bi	7.1	16	10,400
^{214}Pb	7.1	15	8,000
Tritium	U110	250	20,000
Well 1190—WOC Discharge Area Exit Pathway			
Alpha activity	5.0	4.7	15
Beta activity	2.4	3.8	50
^{214}Bi	220	13	10,400
^{212}Pb	10	ND	152
^{214}Pb	220	20	8,000
Tritium	16,000	20,000	20,000
Well 1191—WOC Discharge Area Exit Pathway			
Alpha activity	U2.7	U2.6	15

Table 5.16. Radiological concentrations detected in 2018 exit pathway groundwater monitoring (continued)

Parameter	Concentration[a] (pCi/L)		
	Season		Reference value[b]
	Wet	Dry	
Beta activity	240	220	50
^{214}Bi	110	ND	10,400
^{214}Pb	110	ND	8,000
$^{89/90}$Sr	110	110	44
Tritium	24,000	14,000	20,000
Well 1239—WOC Discharge Area Exit Pathway			
Alpha activity	U0.4	3.0	15
Beta activity	U1.9	2.5	50

[a] ND: not detected. "U" means that the analyte was analyzed for but not detected above the PQL/CRDL.

[b] Current federal and state standards were used as reference values. If no federal or state standard exists for a particular radionuclide, 4 percent of the DCS for a radionuclide is used.

Summary

The following bullets summarize the exit pathway groundwater surveillance program monitoring efforts for 2018 at ORNL:

- Nine radiological contaminants were detected in exit pathway groundwater samples collected in 2018. Tritium, $^{89/90}$Sr, and gross beta activity were the only radiological contaminants exceeding reference values at any of the discharge areas, and, as in past years, those three contaminants were observed at the WOC discharge area in 2018. No other radiological contaminants exceed reference values at other discharge areas.
- Twenty-seven metallic contaminants were detected in exit pathway groundwater samples collected in 2018; however, only three metals (iron, manganese, and aluminum) were detected at concentrations exceeding reference values. These metals are commonly found in groundwater at ORNL
- The semivolatile organic compound bis(2-ethylhexyl)phthalate was the only organic compound detected in exit pathway groundwater monitoring in 2018. It was detected in samples collected during the dry-season at wells 858, 1190 and 1191. This compound has been intermittently detected in previous years' monitoring events at these and other wells. Bis(2-ethylhexyl)phthalate is widely used in plastics such as polyvinyl chloride (PVC) and is prevalent in the environment; it is also a potential sampling or analytical artifact, especially when it is the only organic contaminant detected (Wisconsin DNR 2002).

Radiological and metal contaminant concentrations observed in groundwater exit pathway discharge areas were generally consistent with observations reported in past annual site environmental reports for ORR. Based on the results of the 2018 monitoring effort, there is no indication that current SC operations are significantly introducing contaminants to the groundwater at ORNL.

5.6.2.2 Active Sites Monitoring—High Flux Isotope Reactor

Two storm water outfall collection systems (Outfalls 281 and 383) intercept groundwater in the HFIR area and are routinely monitored under a monitoring plan associated with the ORNL NPDES permit. (See Section 5.5 for a discussion of results.)

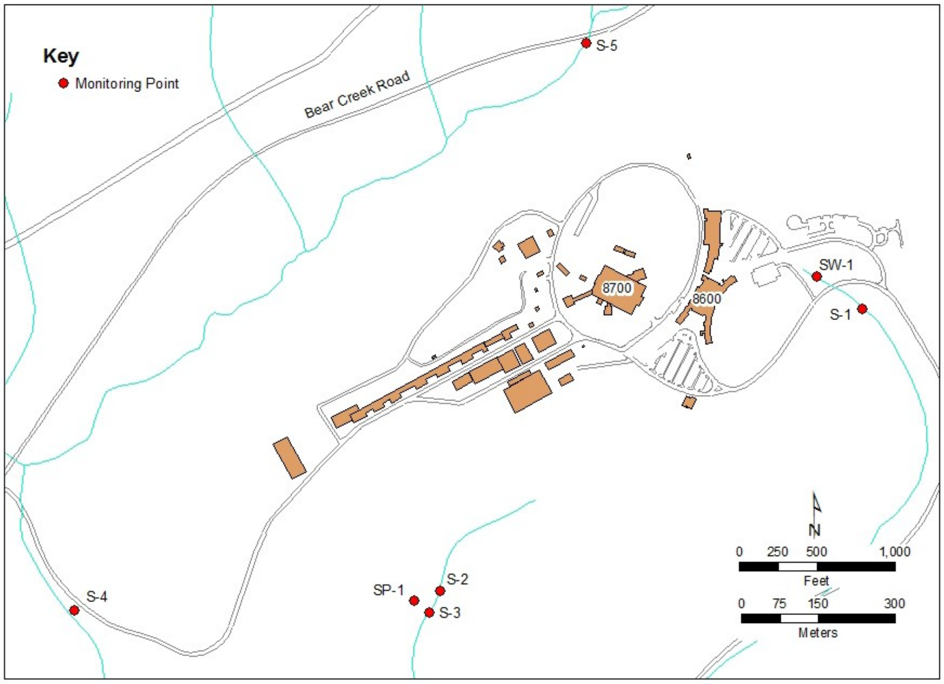
5.6.2.3 Active Sites Monitoring—Spallation Neutron Source

Active sites groundwater surveillance monitoring was performed in 2018 at the SNS site under the SNS operational monitoring plan (OMP) (Bonine, Ketelle, and Trotter 2007) due to the potential for adverse impact on groundwater resources at ORNL should a release occur. Operational monitoring was initiated following a 2 year (2004–2006) baseline monitoring program and will continue throughout the duration of SNS operations.

The SNS site is located atop Chestnut Ridge, northeast of the main ORNL facilities. The site slopes to the north and south, and small stream valleys, populated by springs and seeps, lie on the ridge flanks. Surface water drainage from the site flows into Bear Creek to the north and WOC to the south.

The SNS site is a hydrologic recharge area underlain by geologic formations that form karst geologic features. Groundwater flow directions at the site are based on the generally observed tendency for groundwater to flow parallel to geologic strike (parallel to the orientation of the rock beds) and via karst conduits that break out at the surface in springs and seeps located downgradient of the SNS site. A sizable fraction of infiltrating precipitation (groundwater recharge) flows to springs and seeps via the karst conduits. SNS operations have the potential for introducing radioactivity (via neutron activation) in the shielding berm surrounding the SNS linac, accumulator ring, and/or beam transport lines. A principal concern is the potential for water infiltrating the berm soils to transport radionuclide contamination generated by neutron activation to saturated groundwater zones. The ability to accurately model the fate and transport of neutron activation products generated by beam interactions with the engineered soil berm is complicated by multiple uncertainties resulting from a variety of factors, including hydraulic conductivity differences in earth materials found at depth, the distribution of water-bearing zones, the fate and transport characteristics of neutron activation products produced, diffusion and advection, and the presence of karst geomorphic features found on the SNS site. These uncertainties led to the initiation of the groundwater surveillance monitoring program at the SNS site. Objectives of the groundwater monitoring program outlined in the OMP include the following: (1) maintain compliance with applicable DOE contract requirements and environmental quality standards and (2) provide uninterrupted monitoring of the SNS site.

A total of seven springs, seeps, and surface water sampling points were routinely monitored as analogues to, and in lieu of, groundwater monitoring wells. Locations were chosen based on hydrogeological factors and proximity to the beam line. Figure 5.41 shows the locations of the specific monitoring points sampled during 2018.



S = springs, SP = seeps, SW = surface water sampling areas

Figure 5.41. Groundwater monitoring locations at the Spallation Neutron Source, 2018

In November 2011 the SNS historical tritium data were evaluated to determine whether sampling could be optimized. The influence of flow condition on the proportion of tritium detects and nondetects in water samples collected at SNS from April 2004 through September 2011 was examined. In addition, the effect of seasonality on the proportion of detects and nondetects was examined for the same data set. The results of the analysis indicated that the proportion of detects to nondetects is not related to flow conditions or seasonality. This implies that samples could be collected during any flow condition and season with the expectation that there would be no statistical difference in the proportion of tritium detects to nondetects.

The results of this statistical analysis of the April 2004–September 2011 data set were the basis for the modified OMP monitoring scheme implemented in 2012.

Quarterly sampling at each monitoring point continued in 2018, allowing the opportunity for monitoring in wet and dry seasons. All sampling performed in 2018 was performed in conjunction with rainfall events, with samples being collected during rising or falling (recession) limb flow conditions (see Figure 5.42). In Figure 5.42, the curves represent spring or seep flow (base flow, through flow, overland flow, peak flow); the bars represent rainfall amounts. Table 5.17 shows the sampling and parameter analysis schedule followed in 2018.

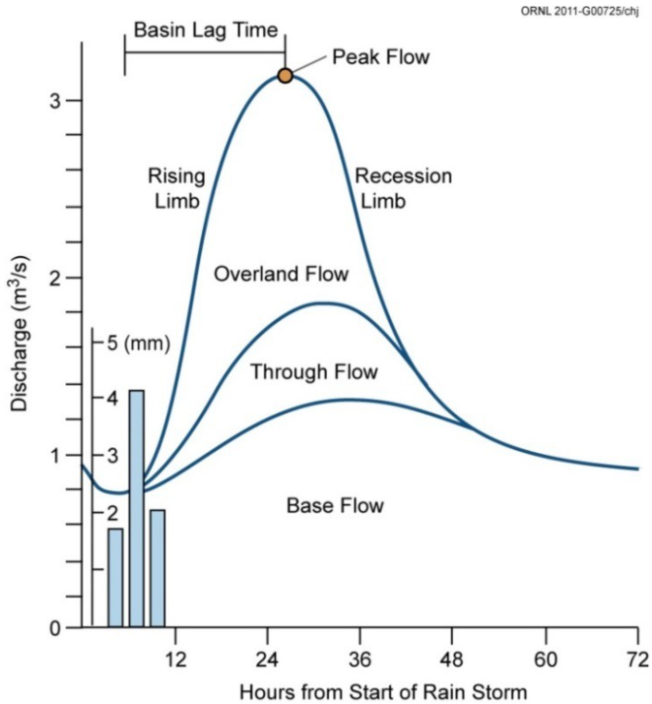


Figure 5.42. Simple hydrograph of spring discharge vs. time after initiation of rainfall

Table 5.17. 2018 Spallation Neutron Source monitoring program schedule

Monitoring location	Quarter 1 January–March	Quarter 2 April–June	Quarter 3 July–September	Quarter 4 October–December
SW-1	Tritium and expanded suite[a]	Tritium	Tritium	Tritium
S-1	Tritium and expanded suite	Tritium	Tritium	Tritium
S-2	Tritium	Tritium and expanded suite	Tritium	Tritium
S-3	Tritium	Tritium and expanded suite	Tritium	Tritium
S-4	Tritium	Tritium	Tritium and expanded suite	Tritium
S-5	Tritium	Tritium	Tritium and expanded suite	Tritium and expanded suite
SP-1	Tritium	Tritium	Tritium	Tritium

[a] The expanded suite includes gross alpha and gross beta activity, ^{14}C, and gamma emitters.

Spallation Neutron Source Site Results. In 2018 sampling at the SNS site occurred during each quarter. Low concentrations of several radionuclides were detected numerous times during 2018. Table 5.18 provides a summary of the locations for radionuclide detections observed during 2018.

Table 5.18. Radiological concentrations detected in samples collected at the Spallation Neutron Source during 2018

Parameter	Concentrations[a] (pCi/L)				Reference Value[b]
	February	May	September	November	
SW-1					
				nd[c]	
Beta				3.67	50
^{214}Bi				20.6	10,400
^{214}Pb				18.4	8,000
Tritium	2930	2490	364	1730	20,000
S-1					
				nd[d]	
Tritium	3090	1280	1480	643	20,000
S-2					
	nd[c]				
Beta	4.48				50
^{214}Bi	89.9				10,400
^{214}Pb	85.1				8,000
Tritium	943	752	1480	967	20,000
S-3					
	nd[c]				
Beta	3.89				50
^{214}Bi	116				10,400
^{214}Pb	113				8,000
Tritium	776	489	260	255	20,000
S-4					
		nd[d]			
Tritium	558	528	398	343	20,000
S-5					
		nd[c]			
Alpha		9.51			15
Beta		18.5			50
Tritium	445	242	1080	312	20,000
SP-1					
	nd[c]				
Alpha	2.16				15
Beta	2.21				50
Tritium	345	338	236	U173	20,000

[a] ND: not detected. "U" means that the analyte was analyzed for but not detected above the PQL/CRDL.

[b] Current federal and state standards were used as reference values. If no federal or state standard exists for a particular radionuclide, 4 percent of the DCS for a radionuclide is used.

[c] Only some of the parameters of the expanded suite (gross alpha and gross beta activity, ^{14}C, and gamma emitters) for this location/quarter were detected, and they are listed with their results.

[d] None of the parameters of the expanded suite (gross alpha and gross beta activity, ^{14}C, and gamma emitters) for this location/quarter were detected.

Sampling results were compared against reference values. Reference values used for comparison are current federal or state standards or 4 percent of the DCS. None of the detected radionuclides exceeded its reference value at SNS monitoring locations in 2018.

5.7 Quality Assurance Program

The UT-Battelle Quality Management System (QMS) has been developed to implement the requirements defined in DOE O 414.1D (DOE 2011d). The methods used for successful implementation of the QMS rely on the integration and implementation of quality elements/criteria flowed-down through multiple management systems and daily operating processes. These management systems and processes are described in SBMS, where basic requirements are communicated to UT-Battelle staff. Additional or specific customer requirements are addressed at the project or work activity level. The QMS provides a graded approach to implementation based upon risk. The application of quality assurance (QA) and quality control (QC) programs specifically focused on environmental monitoring activities on ORR is essential for generating data of known and defensible quality. Each aspect of an environmental monitoring program from sample collection to data management and record keeping must address and meet applicable quality standards. The activities associated with administration, sampling, data management, and reporting for ORNL environmental programs are performed by the UT-Battelle Environmental Protection Services Division (EPSD).

UT-Battelle uses SBMS to provide a systematic approach for integrating QA, environmental, and safety considerations into every aspect of environmental monitoring at ORNL. SBMS is a web-based system that provides a single point of access to all the requirements for staff to safely and effectively perform work. SBMS translates laws, orders, directives, policies, and best-management practices into laboratory-wide subject areas and procedures.

5.7.1 Work/Project Planning and Control

UT-Battelle’s work/project planning and control directives establish the processes and requirements for executing work activities at ORNL. All environmental sampling tasks are performed following the four steps required in the work control subject areas:

- define scope of work;
- perform work planning—analyze hazards and define controls;
- execute work; and
- provide feedback.

In addition, EPSD has approved project-specific standard operating procedures for all activities controlled and maintained through the Integrated Document Management System (IDMS).

Environmental sampling standard operating procedures developed for UT-Battelle environmental sampling programs provide detailed instructions on maintaining chain of custody; sample identification; sample collection and handling; sample preservation; equipment decontamination; and collection of QC samples such as field and trip blanks, duplicates, and equipment rinses.

5.7.2 Personnel Training and Qualifications

The UT-Battelle Training and Qualification Management System provides employees and nonemployee staff of UT-Battelle with the knowledge and skills necessary to perform their jobs safely, effectively, and efficiently with minimal supervision. This capability is accomplished by establishing site-level procedures and guidance for training program implementation with an infrastructure of supporting systems, services, and processes.

Likewise, the NWSol Training and Qualification program provides employees with the knowledge and skills necessary to perform their jobs safely, effectively, and efficiently with minimal supervision. This capability is accomplished by establishing site-level procedures and guidance for training program implementation with an infrastructure of supporting systems, services, and processes.

5.7.3 Equipment and Instrumentation

5.7.3.1 Calibration

The UT-Battelle QMS includes subject area directives that require all UT-Battelle staff to use equipment of known accuracy based on appropriate calibration requirements that are traceable to an authority standard. The UT-Battelle Facilities and Operations Instrumentation and Control Services team tracks all equipment used in the environmental monitoring programs conducted by UT-Battelle for the ORNL site and ORR through a maintenance recall program to ensure that equipment is functioning properly and within defined tolerance ranges. The determination of calibration schedules and frequencies is based on a graded approach at the activity planning level. EPSD environmental monitoring programs follow rigorous calibration schedules to eliminate gross drift and the need for data adjustments. Instrument tolerances, functions, ranges, and calibration frequencies are established based on manufacturer specifications, program requirements, actual operating environment and conditions, and budget considerations.

In addition, a continuous monitor used for CAA compliance monitoring at ORNL boiler 6 is subject to rigorous QA protocols as specified by EPA methods. A relative accuracy test audit (RATA) is performed annually to certify the Predictive Emissions Monitoring System (PEMS) for nitrogen oxides and oxygen. The purpose of a RATA is to provide a rigorous QA assessment in accordance with EPA 40 CFR, Performance Specification 16 (PS-16). The accuracy of PEMS is also evaluated by performing relative accuracy audits in accordance with PS-16. The results of these QA tests are provided to TDEC quarterly, semiannually, or annually as applicable.

5.7.3.2 Standardization

The UT-Battelle IDMS provides the necessary functionality and controls to ensure that controlled documents are managed, distributed, revised, and maintained in accordance with ORNL document control requirements. EPSD sampling procedures are maintained in IDMS and include requirements and instructions for the proper standardization and use of monitoring equipment. Requirements include the use of traceable standards and measurements; performance of routine, before-use equipment standardizations; and actions to follow when standardization steps do not produce required values. Standard operating procedures for sampling also include instructions for designating nonconforming instruments as “out-of-service” and initiating requests for maintenance.

5.7.3.3 Visual Inspection, Housekeeping, and Grounds Maintenance

EPSD environmental sampling personnel conduct routine visual inspections of all sampling instrumentation and sampling locations. These inspections identify and address any safety, grounds keeping, general maintenance, and housekeeping issues or needs.

5.7.4 Assessment

Independent audits, surveillance, and internal management assessments are performed to verify that requirements have been accurately specified and that activities that have been performed conform to expectations and requirements. External assessments are scheduled based on requests from auditing agencies. Table 5.1 presents a list of environmental audits and assessments performed at ORNL in 2018 and information on the number of findings identified, if any. EPSD also conducts internal management assessments of UT-Battelle environmental monitoring procedural compliance, safety performance, and work planning and control. Surveillance results, recommendations, and completion of corrective actions, if required, are also documented and tracked in the UT-Battelle Assessment and Commitment Tracking System.

NWSol and Isotek perform independent audits, surveillances, and internal management assessments to verify that requirements have been accurately specified and that activities that have been performed conform to expectations and requirements. NWSol corrective actions, if required, are documented and tracked in an issues management database or a deficiency reporting database, and Isotek corrective actions are tracked in its Assessment and Commitment Tracking System.

5.7.5 Analytical Quality Assurance

The contract laboratories that perform analyses of environmental samples from the UT-Battelle environmental monitoring programs at ORNL and on ORR are required to have documented QA/QC programs, trained and qualified staff, appropriately maintained equipment and facilities, and applicable certifications. Several laboratories are contracted under basic ordering agreements to perform analytical work to characterize UT-Battelle environmental samples. As applicable, the laboratories participate in accreditation, certification, and performance evaluation programs, including the National Environmental Laboratory Accreditation Program, Mixed Analyte Performance Evaluation Program, Discharge Monitoring Report Quality Assurance Study, and DOE Environmental Management Consolidated Audit Program. Any issues of concern identified through accreditation/certification programs or performance evaluation testing are addressed with analytical laboratories and are considered when determinations are made on data integrity.

A statement of work for each project specifies any additional QA/QC requirements and includes detailed information on data deliverables, turnaround times, and required methods and detection limits. Blank and duplicate samples are routinely submitted along with ORR environmental samples to provide an additional check on analytical laboratory performance.

5.7.6 Data Management and Reporting

Management of data collected by UT-Battelle in conjunction with ORR and ORNL environmental surveillance programs and with CWA activities at ORNL is accomplished using the Environmental Surveillance System (ESS), a web interface data management tool. A software QA plan for ESS has been developed to document ESS user access rules; verification and validation methods; configuration and change management rules; release history; software registration information; and the employed methods, standards, practices, and tools.

Field measurements and sample information are entered into ESS, and an independent verification is performed on all records to ensure accurate data entry. Sample results and associated information are loaded into ESS from electronic files provided by analytical laboratories. An automated screening is performed to ensure that all required analyses were performed, appropriate analytical methods were used, holding times were met, and specified detection levels were achieved.

Following the screening, a series of checks is performed to determine whether results are consistent with expected outcomes and historical data. QC sample results (i.e., blanks and duplicates) are reviewed to check for potential sample contamination and to confirm repeatability of analytical methods within required limits. More in-depth investigations are conducted to explain results that are questionable or problematic.

ORNL radiological airborne effluent monitoring data are managed using the Rad-NESHAPs Inventory Web Application and the Rad NESHAPs Source Data Application. Field measurements, analytical data inputs, and emission calculations results are independently verified.

5.7.7 Records Management

The UT-Battelle Records Management System provides the requirements for managing all UT-Battelle records. Requirements include creating and identifying record material; scheduling, protecting, and storing records in office areas and in the UT-Battelle Inactive Records Center; and destroying records.

NWSol and Isotek maintain all records specific to their projects at ORNL, and associated records management programs include the requirements for creating and identifying record material, protecting and storing records in applicable areas, and destroying records.

5.8 Environmental Management and Waste Management Activities at Oak Ridge National Laboratory

The three campuses on ORR have a rich history of research, innovation, and scientific discovery that shaped the course of the world. Unfortunately, today, despite their vitally important missions, they are hindered by environmental legacies remaining from past operations. The contaminated portions of ORR are on the EPA NPL, which includes hazardous waste sites across the nation that are to be cleaned up under CERCLA. Areas that require cleanup or further action on ORR have been clearly defined, and OREM is working to clean those areas under the Federal Facility Agreement with the EPA and TDEC. The 2018 Cleanup Progress Annual Report to the Oak Ridge Regional Community (UCOR 2018) provides detailed information on DOE OREM's 2018 cleanup activities.

5.8.1 Oak Ridge National Laboratory Wastewater Treatment

At ORNL, DOE OREM operates PWTC and the Liquid Low-Level Waste Treatment Facility. In 2018 316 million L of wastewater was treated and released at PWTC. In addition, the liquid LLW system at ORNL received 201,457 L of waste. The waste treatment activities of these facilities support both DOE OREM and DOE SC mission activities, ensuring that wastewaters from activities associated with projects of both offices are managed in a safe and compliant manner.

5.8.2 Oak Ridge National Laboratory Newly Generated Waste Management

ORNL is the largest, most diverse DOE SC laboratory in the DOE complex. Although much effort is expended to prevent pollution and to eliminate waste generation, some waste streams are generated as a by-product of performing research and operational activities and must be managed to ensure that the environment is protected from associated hazards. UT-Battelle, as the prime contractor for the management of ORNL, is responsible for management of most of the wastes generated from R&D activities and wastes generated from operation of the R&D facilities. Waste streams that can be treated by on-site liquid and/or gaseous waste treatment facilities operated by OREM are treated via these systems. Other R&D waste streams are generally packaged by UT-Battelle in appropriate shipping containers for off-site transport to commercial waste-processing facilities. In 2018, ORNL performed 92 waste shipments to off-site hazardous/radiological/mixed waste treatment and/or disposal vendors with no shipment rejections or violations.

5.8.3 Transuranic Waste Processing Center

TRU waste-processing activities carried out for DOE in 2018 by NWSol addressed CH solids/debris and RH solids/debris, which involved processing, treating, and repackaging of waste. Off-site transportation and disposal of LLW/mixed LLW at the Nevada National Security Site or other approved off-site facilities was also performed in 2018. TRU waste disposal at the Waste Isolation Pilot Plant resumed in 2017. TWPC made 47 CH TRU waste shipments in calendar year 2018 for a total of 1,999 containers or 419.8 m^3.

During 2018, 28.89 m^3 of CH waste and 57.16 m^3 of RH waste were processed, and 74.55 m^3 of mixed LLW (TRU waste that was recharacterized as low-level waste) was shipped off the site.

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6. Oak Ridge Reservation Environmental Monitoring Program

Environmental monitoring is performed on the ORR to measure radiological and nonradiological parameters directly in environmental media adjacent to the facilities. Data from the environmental monitoring program are analyzed to assess the environmental impact of DOE operations on the entire reservation and the surrounding area. Dose assessment information based on data from this program is presented in Chapter 7.

Due to different permit reporting requirements and instrument capabilities, this report uses various units of measurement. The lists of units of measure and conversion factors on pages xxvii and xxviii are included to help readers convert numeric values presented herein as needed for specific calculations and comparisons.

6.1 Meteorological Monitoring

Ten meteorological towers provide data on meteorological conditions and on the transport and diffusion qualities of the atmosphere on ORR. Data collected at the towers are used in routine dispersion modeling to predict impacts from facility operations and as input to emergency response atmospheric models, which are used for simulated and actual accidental releases from a facility. Data from the towers are also used to support various research and engineering projects.

6.1.1 Description

The 10 meteorological towers on ORR are described in Table 6.1 and are depicted in Figure 6.1. In this document, the individual ORR-managed towers are designated by “MT” followed by a numeral. Other commonly used names for these sites are also provided in Table 6.1. Meteorological data are collected at different levels above the ground (2, 10, 15, 30, 33, 35, and 60 m) to assess the vertical structure of the atmosphere, particularly with respect to wind shear and stability. Stable boundary layers and significant wind shear zones (associated with the local ridge-and-valley terrain and the Great Valley of Eastern Tennessee; see Appendix B) can significantly affect the movement of a plume after a facility release (Bowen et al. 2000). Data are collected at the 10 or 15 m level at most towers, but the wind measurement height is 25 m for MT11 and 20 m for MT13. Data are collected at some towers at 30, 33, 35, and 60 m levels. Temperature, relative humidity, and precipitation are measured at some sites at 2 m, but wind speed and wind direction typically are not. Atmospheric stability (a measure of vertical mixing properties of the atmosphere) is measured at most towers; however, measurements involving vertical temperature profiles (i.e., measurements made by the solar radiation delta-T method) limit accurate determination of nighttime stability to the towers that are 60 m in height (when using the solar radiation delta-T method). Stability is also calculated for most sites using the sigma phi method which relies heavily on the measurement of standard deviation of vertical wind speed using three-dimensional sonic wind monitors. Barometric pressure is measured at one or more of the towers at each ORR plant (MT2, MT4, MT6, MT7, MT9, MT12, and MT13). Precipitation is measured at MT6 and MT9 at the Y-12 National Security Complex (the Y-12 Complex); at MT7 and MT13 at the East Tennessee Technology Park (ETTP); and at MT2, MT3, MT4, and MT12 at Oak Ridge National Laboratory (ORNL). Solar radiation is measured at MT6 and MT9 at the Y-12 Complex, MT7 at ETTP, and at MT2 and MT12 at ORNL. Instrument calibrations are managed by UT-Battelle and are performed every 6 months by an independent auditor (Holian Environmental).

Table 6.1. Oak Ridge Reservation meteorological towers

Tower	Alternate tower names	Location (lat., long.)	Altitude (m above MSL)	Measurement heights (m)
		ETTP		
MT7	L, 1209	35.92522N, -84.39414W	233	2, 15, 30
MT13	J, YEOC	35.93043N, -84.39346W	237	20
		ORNL		
MT2	D,[a] 1047	35.92559N, -84.32379W	261	2, 15, 35, 60
MT3	B, 6555	35.93273N, -84.30254W	256	15, 30
MT4	A, 7571	35.92185N, -84.30470W	266	15, 30
MT10	M, 208A	35.90947N, -84.38796W	244	10
MT12	F	35.95285N, -84.30314W	354	10
		Y-12 Complex		
MT6	W, West	35.98058N, -84.27358W	326	2, 10, 30, 60
MT9	Y, PSS Tower	35.98745N, -84.25363W	290	2, 15, 33
MT11	S, South Tower	35.98190N, -84.25504W	352	25

[a] Tower "C" before May 2014.

Acronyms
ETTP = East Tennessee Technology Park
ORNL = Oak Ridge National Laboratory
Y-12 Complex = Y-12 National Security Complex
MSL = mean sea level
PSS = plant shift superintendent
YEOC = Y-12 Complex Emergency Operations Center

Sonic detection and ranging (SODAR) devices have been installed at the east end of the Y-12 Complex and adjacent to Tower MT2 at ORNL. The SODAR devices use acoustic waves to estimate wind direction, wind speed, and turbulence at altitudes higher than the reach of meteorological towers (40 m up to 900 m above ground level). Although SODAR measurements are somewhat less accurate than measurements made on the meteorological towers, the SODAR devices provide useful information regarding stability, upper air winds, and mixing depth. Mixing depth represents the thickness of the air layer adjacent to the ground over which an emitted or entrained inert nonbuoyant tracer could potentially be mixed by turbulence within 1 h or less.

Data are collected in real time for 1 min, 15 min, and hourly average intervals for emergency response purposes and for dispersion modeling at the ORNL and Y-12 Complex Emergency Operations Centers.

Annual dose estimates are calculated from the archived hourly data. Data quality is checked continuously against predetermined data constraints, and out-of-range parameters are marked as invalid and are excluded from compliance modeling. Appropriate substitution data are identified when possible. Quality assurance records of missing and erroneous data are routinely kept for the 10 ORR towers.

ORNL 2018-G00374/mhr

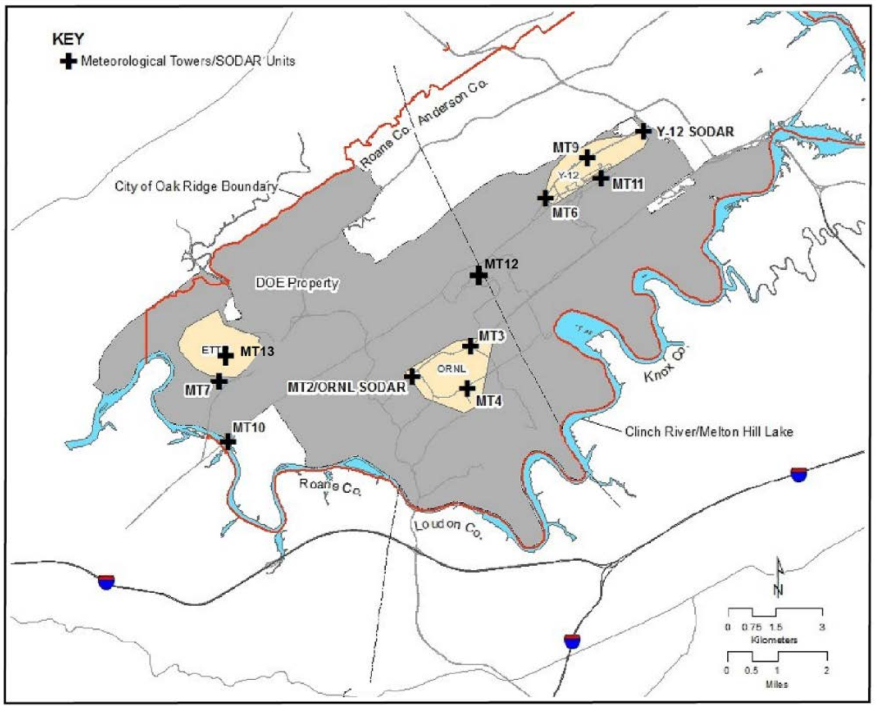

Figure 6.1. The Oak Ridge Reservation meteorological monitoring network, including sonic detection and ranging (SODAR) devices

6.1.2 Results

Prevailing winds are generally up-valley from the southwest and west-southwest or down-valley from the northeast and east-northeast, a pattern that typically results from channeling effects produced by the parallel ridges flanking ORR sites. Winds in the valleys tend to follow the ridge axes, limiting cross-ridge flow within local valley bottoms. These conditions dominate over most of ORR, but flow variation is greater at ETTP, which is located within a less-constrained open valley bottom.

On ORR, low wind speeds dominate near the valley surfaces, largely because of the decelerating influence of nearby ridges and mountains. Wind acceleration sometimes is observed at ridge-top level, particularly when flow is not parallel to the ridges (see Appendix B).

The atmosphere over ORR is often dominated by stable conditions at night and for a few hours after sunrise. These conditions, when coupled with low wind speeds and channeling effects in the valleys, result in poor dilution of emissions emitted from the facilities. However, high roughness values (caused by terrain and obstructions such as trees and buildings) may significantly mitigate these factors through an increase in turbulence (atmospheric mixing). These features are captured in dispersion model data input and are reflected in modeling studies conducted for each facility.

Precipitation data from tower MT2 are used in stream-flow modeling and in certain research efforts. The data indicate the variability of regional precipitation: the high winter rainfall resulting from frontal systems and the uneven, but occasionally intense, summer rainfall associated with frequent air mass thunderstorms. The total precipitation at ORNL during 2018 (1,597 mm or 62.87 in.) was about 20 percent above the long-term average of 1,337.5 mm (52.64 in.). The average annual wind data recovery rates (a measure of acceptable data) across locations used for modeling during 2018 were greater than 97.7 percent for wind sensors at the ORNL sites MT2, MT3, MT4, MT10, and MT12. Site MT12, located at the Spallation Neutron Source facility, successfully completed its first full calendar year of operation in 2018. Annual wind data recovery from Y-12 meteorological towers during 2018 exceeded 98 percent (towers MT6, MT9, and MT11). At ETTP, problems with the 15 m Tower MT1 wind sensor limited its recovery to 88.8 percent, but the upper 30 m sensor data recovery was nearly 99 percent. The Y-12–operated site at ETTP experienced data recovery of better than 97 percent.

6.2 External Gamma Radiation Monitoring

6.2.1 Data Collection and Analysis

External gamma exposure rates are continuously recorded by dual-range Geiger-Müller tube detectors colocated with ORR ambient air stations. Figure 6.2 shows locations that were monitored during 2018, and Table 6.2 summarizes the data for each station.

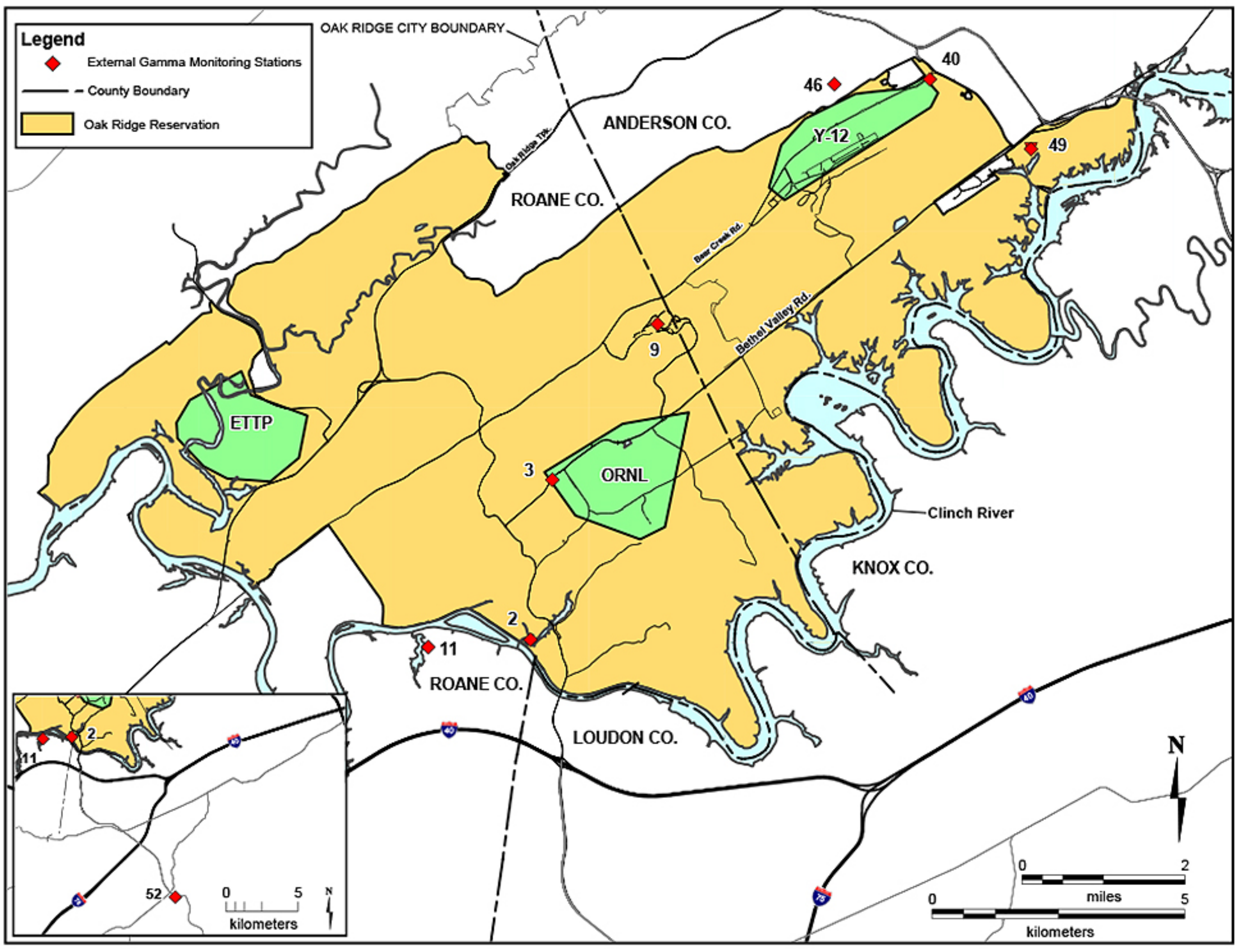

Figure 6.2. External gamma radiation monitoring locations on the Oak Ridge Reservation

6.2.2 Results

The mean exposure rate for the reservation network in 2018 was 9.9 μR/h, and the mean rate at the reference location was 9.1 μR/h. Background direct radiation exposure rates have been collected at an off-site location for many years. From 2008 through 2017 (the preceding 10 years), the exposure rates at the background off-site location ranged from 4.2 to 11.4 µR/h. The average exposure rate for those years was 7.7 µR/h (rounded to 8 µR/h).

Table 6.2. External gamma (exposure rate) averages for the Oak Ridge Reservation, 2018

Monitoring location	Number of data points (daily)	Measurement (µR/h)[a]		
		Min	Max	Mean
02	349	8.6	10.3	9.1
03	360	8.9	10.6	9.3
09	355	8.9	12.6	9.6
11	360	10.1	12.3	10.8
40	359	9.3	11.1	10
46	352	10	11.8	10.5
49	360	9.1	11	9.7
52	358	8.6	10.6	9.1

[a] To convert microroentgens per hour (µR/h) to milliroentgens per year, multiply by 8.760.

6.3 Ambient Air Monitoring

In addition to exhaust stack monitoring conducted at ORR installations (see chapters 3, 4, and 5), ambient air monitoring is performed to measure radiological parameters directly in the ambient air adjacent to the facilities (Figure 6.3). Ambient air monitoring provides a means to verify that contributions of fugitive and diffuse sources are insignificant, serves as a check on dose-modeling calculations, and would allow determination of contaminant levels at monitoring locations in the event of an emergency.

Figure 6.3. Oak Ridge Reservation ambient air station

Ambient air monitoring conducted by individual site programs is discussed in chapters 3, 4, and 5. The ORR ambient air monitoring program complements the individual site programs and permits the impacts of ORR operations to be assessed on an integrated basis. This program is discussed in detail in the following sections.

The objectives of the ORR ambient air monitoring program are to perform surveillance of airborne radionuclides at the reservation perimeter and to collect reference data from a location not affected by activities on ORR. The perimeter air monitoring network was established in the early 1990s. Since then there have been significant operational changes on ORR (e.g., addition of Spallation Neutron Source and Transuranic Waste Processing Center operations and shutdown of the Toxic Substances Control Act Incinerator), and significant cleanup and remediation projects have been completed. The network was modified in 2016 to better reflect current DOE activities and operations. The stations monitored in 2018 are shown in Figure 6.4. Reference samples are collected from Station 52 (Fort Loudoun Dam). Sampling was conducted at each ORR station during 2018 to quantify levels of alpha-, beta-, and gamma-emitting radionuclides.

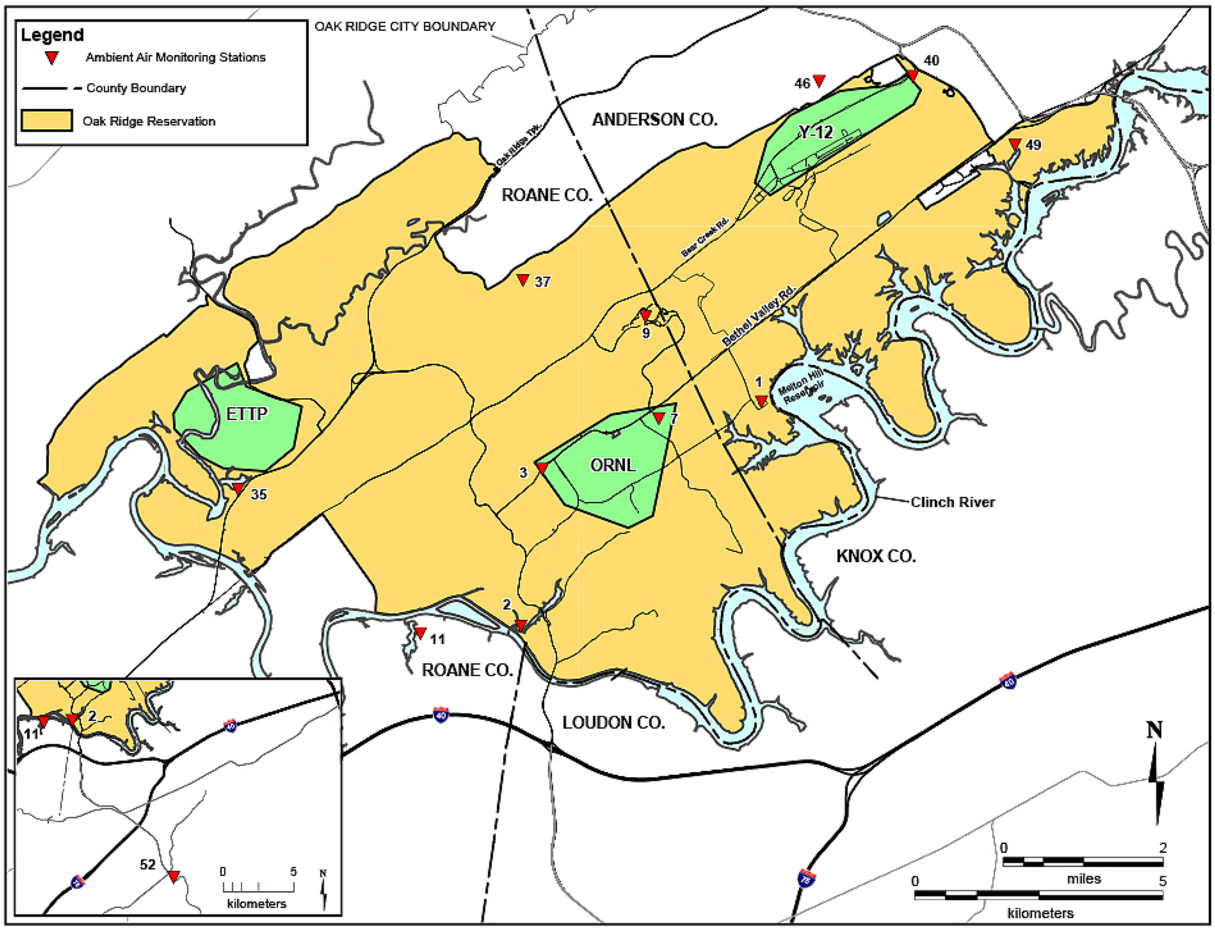

Figure 6.4. Locations of Oak Ridge Reservation perimeter air monitoring stations

Atmospheric dispersion modeling was used to select appropriate sampling locations. The locations selected are those likely to be affected most by releases from the Oak Ridge facilities. Therefore, in the event of a release, no residence or business near ORR should receive a radiation dose greater than doses calculated at the sampled locations.

The sampling system consists of two separate instruments. Particulates are captured by high-volume air samplers equipped with glass-fiber filters. The filters are collected weekly, composited quarterly, and then submitted to an analytical laboratory to quantify gross alpha and beta activity and to determine the concentrations of specific isotopes of interest on ORR. The second system is designed to collect tritiated water vapor. The sampler consists of a prefilter followed by an adsorbent trap that contains indicating silica gel. The samples are collected weekly or biweekly, composited quarterly, and then submitted to an analytical laboratory for tritium analysis.

6.3.1 Results

Data from the ORR ambient air network are analyzed to assess the impact of DOE operations on the local air quality. Each measured radionuclide concentration (Table 6.3) is compared with derived concentration standards (DCSs) for air established by DOE as guidelines for controlling exposure to members of the public (DOE 2011). All radionuclide concentrations measured at the ORR ambient air stations during 2018 were less than 1 percent of applicable DCSs, indicating that activities on the reservation are not adversely affecting local air quality.

Table 6.3. Radionuclide concentrations at Oak Ridge Reservation perimeter air monitoring stations, 2018

Parameter	N detected/N total	Concentration (pCi/mL)[a]		
		Average	Minimum	Maximum
		Station 1		
^{7}Be	4/4	4.02E-08	2.42E-08	4.69E-08
^{40}K	0/4	-7.97E-11[b]	-5.30E-10[b]	3.49E-10
Tritium	0/4	1.73E-06	6.38E-07	2.96E-06
^{234}U	4/4	2.18E -12	1.84E-12	2.46E-12
^{235}U	0/4	1.91E-13	-2.59E-14[b]	3.91E-13
^{238}U	4/4	1.85E-12	1.34E-12	2.06E-12
		Station 2		
^{7}Be	4/4	3.91E-08	1.90E-08	5.23E-08
^{40}K	0/4	1.05E-10	-7.28E-11[b]	4.52E-10
Tritium	0/4	1.97E-06	6.62E-07	3.48E-06
^{234}U	4/4	2.31E-12	1.91E-12	3.46E-12
^{235}U	0/4	3.18E-14	-3.44E-14[b]	1.45E-13
^{238}U	4/4	1.30E-12	9.83E-13	1.53E-12
		Station 3		
^{7}Be	4/4	3.97E-08	1.38E-08	5.51E-08
^{40}K	0/4	6.20E-11	-1.97E-10[b]	2.29E-10
Tritium	0/4	9.94E-07	3.64E-07	1.37E-06
^{234}U	4/4	2.07E-12	1.29E-12	2.71E-12
^{235}U	2/4	2.04E-13	1.51E-14	3.78E-13
^{238}U	4/4	1.39E-12	1.05E-12	1.84E-12
		Station 9		
^{7}Be	4/4	3.56E-08	1.70E-08	4.87E-08
^{40}K	0/4	-1.47E-11[b]	-1.25E-10[b]	1.13E-10
Tritium	3/4	7.94E-06	1.89E-06	1.38E-05
^{234}U	4/4	3.22E-12	2.28E-12	4.48E-12
^{235}U	1/4	3.13E-13	2.27E-13	3.95E-13
^{238}U	4/4	1.91E-12	1.01E-12	2.36E-12

Table 6.3 Radionuclide concentrations at Oak Ridge Reservation perimeter air monitoring stations, 2018 (continued)

Parameter	N detected/N total	Concentration (pCi/mL)[a]		
		Average	Minimum	Maximum
		Station 11		
^{7}Be	4/4	3.50E-08	1.27E-08	5.42E-08
^{40}K	0/4	-2.77E-11[b]	-2.38E-10[b]	1.80E-10
Tritium	0/4	1.18E-06	7.70E-07	1.73E-06
^{234}U	4/4	2.17E-12	1.24E-12	4.49E-12
^{235}U	0/4	1.23E-13	-1.87E-14[b]	2.69E-13
^{238}U	4/4	1.25E-12	9.76E-13	1.49E-12
		Station 35		
^{7}Be	4/4	3.67E-08	1.46E-08	5.95E-08
^{40}K	0/4	-7.23E-11[b]	-2.62E-10[b]	1.34E-10
^{99}Tc	1/4	2.17E-10	-3.11E-10[b]	1.14E-09
Tritium	1/4	1.90E-06	3.56E-07	4.68E-06
^{234}U	4/4	5.25E-11	9.20E-13	2.05E-10
^{235}U	3/4	4.00E-12	2.95E-13	1.46E-11
^{238}U	4/4	2.08E-11	8.77E-13	7.43E-11
		Station 37		
^{7}Be	4/4	4.14E-08	1.97E-08	5.64E-08
^{40}K	0/4	-1.07E-10[b]	-2.54E-10[b]	8.89E-11
Tritium	0/4	6.51E-07	3.23E-07	1.14E-06
^{234}U	4/4	2.58E-12	1.85E-12	3.61E-12
^{235}U	0/4	3.24E-13	2.26E-13	4.17E-13
^{238}U	4/4	1.77E-12	7.45E-13	3.67E-12
		Station 40		
^{7}Be	4/4	3.83E-08	1.93E-08	5.53E-08
^{40}K	0/4	-1.11E-10[b]	-7.91E-10[b]	2.13E-10
Tritium	0/4	1.01E-06	6.30E-08	3.13E-06
^{234}U	4/4	6.73E-12	4.36E-12	8.52E-12
^{235}U	3/4	6.72E-13	2.15E-13	1.52E-12
^{238}U	4/4	2.30E-12	1.70E-12	2.68E-12
		Station 46		
^{7}Be	4/4	4.12E-08	1.26E-08	5.36E-08
^{40}K	0/4	2.22E-11	-3.72E-10[b]	2.78E-10
Tritium	0/4	9.28E-07	-4.03E-07[b]	2.09E-06
^{234}U	4/4	4.05E-12	2.87E-12	5.77E-12
^{235}U	3/4	3.55E-13	1.71E-13	6.14E-13
^{238}U	4/4	1.77E-12	9.39E-13	2.39E-12
		Station 49		
^{7}Be	4/4	3.78E-08	1.53E-08	5.10E-08
^{40}K	0/4	-2.53E-10[b]	-3.89E-10[b]	-1.67E-10[b]
Tritium	0/4	2.09E-06	1.49E-07	5.01E-06

Table 6.3 Radionuclide concentrations at Oak Ridge Reservation perimeter air monitoring stations, 2018 (continued)

Parameter	N detected/N total	Concentration (pCi/mL)[a]		
		Average	Minimum	Maximum
^{234}U	4/4	2.75E-12	1.57E-12	4.50E-12
^{235}U	1/4	1.76E-13	0	3.70E-13
^{238}U	4/4	1.49E-12	7.92E-13	2.14E-12
Station 52[c]				
^{7}Be	4/4	3.68E-08	1.92E-08	4.62E-08
^{214}Bi	0/4	4.94E-11	0	1.98E-10
^{40}K	0/4	-1.69E-10[b]	-3.67E-10[b]	1.07E-10
^{99}Tc	2/4	3.85E-10	-3.59E-10[b]	1.76E-09
Tritium	0/4	-4.61E-07[b]	-1.09E-06[b]	1.49E-07
^{234}U	4/4	1.77E-12	1.10E-12	2.29E-12
^{235}U	0/4	1.01E-13	-6.79E-14[b]	3.11E-13
^{238}U	4/4	1.39E-12	8.13E-13	1.80E-12

[a] 1 pCi = 3.7×10^{-2} Bq.
[b] At very low sample activity levels, close to the instrument background, it is possible to obtain a sample result that is less than the background. When the background activity is subtracted from the sample activity to obtain a net value, a negative value results.
[c] Station 52 is the reference location.

6.4 Surface Water Monitoring

6.4.1 Oak Ridge Reservation Surface Water Monitoring

The ORR surface water monitoring program consists of sample collection and analysis from four locations on the Clinch River, including public water intakes (Figure 6.5). The program is conducted in conjunction with site-specific surface water monitoring activities to enable an assessment of the impacts of past and current DOE operations on the quality of local surface water.

Grab samples are collected quarterly at all four locations and are analyzed for general water quality parameters, screened for radioactivity, and analyzed for mercury and specific radionuclides when appropriate. Table 6.4 lists the specific locations and associated sampling frequencies and parameters.

At the sampling locations, the Clinch River is classified by the State of Tennessee for multiple uses, including recreation and domestic supply. These two designated uses have numeric Tennessee Water Quality Criteria (WQCs) related to protection of human health. These WQCs are used as references where applicable (TDEC 2014). The Tennessee WQCs do not include criteria for radionuclides. Four percent of the DOE DCS is used for radionuclide comparison.

6.4.2 Results

A comparison of radionuclide concentrations from 2018 sampling results for surface water collected upstream of DOE inputs with concentrations in surface water collected downstream of DOE inputs shows no statistically significant differences. No radionuclides were detected above 4 percent of the respective DCSs.

Mercury was detected above its MCL in the third-quarter 2018 samples from each of the three sampling locations where mercury samples are collected, Clinch River kilometer (CRK) 66, CRK 32, and CRK 16.

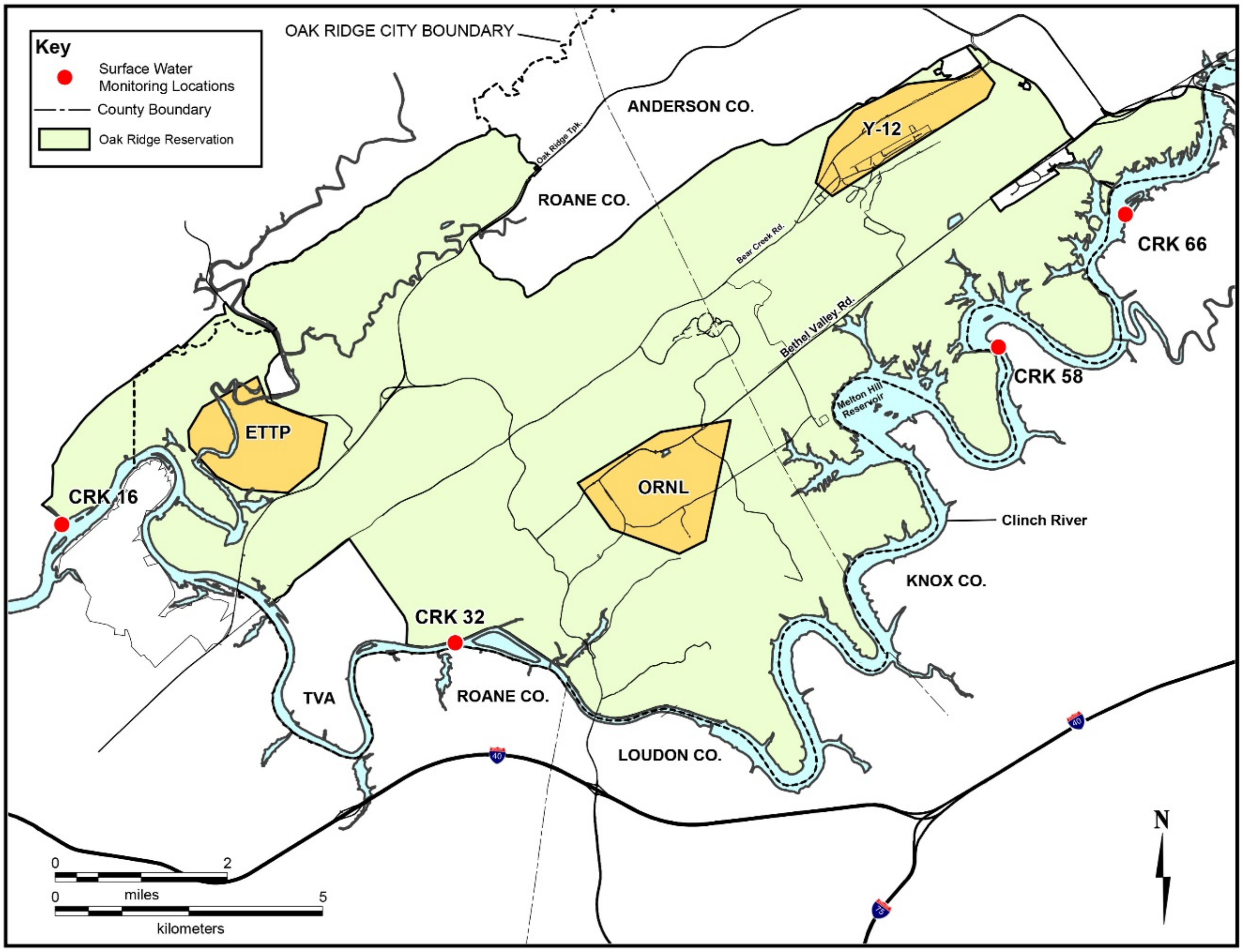

Figure 6.5. Oak Ridge Reservation surface water surveillance sampling locations

Table 6.4. Oak Ridge Reservation surface water sampling locations, frequencies, and parameters, 2018

Location[a]	Description	Frequency	Parameters
CRK 16	Clinch River downstream from all DOE ORR inputs	Quarterly	Mercury, gross alpha, gross beta, gamma scan, ^{3}H, field measurements[b]
CRK 32	Clinch River downstream from ORNL	Quarterly	Mercury, gross alpha, gross beta, gamma scan, total radioactive strontium, ^{3}H, field measurements[b]
CRK 58	Water supply intake for Knox County	Quarterly	Gross alpha, gross beta, gamma scan, ^{3}H, field measurements[b]
CRK 66	Melton Hill Reservoir above City of Oak Ridge water intake	Quarterly	Mercury, gross alpha, gross beta, gamma scan, total radioactive strontium, ^{3}H, field measurements[b]

[a] Locations indicate the water body and distances upstream of the confluence of the Clinch and Tennessee Rivers (e.g., CRK 16 is 16 km upstream from the confluence of the Clinch River with the Tennessee River, Watts Bar Reservoir).

[b] Field measurements consist of dissolved oxygen, pH, and temperature.

Acronyms

CRK = Clinch River kilometer

DOE = US Department of Energy

ORNL = Oak Ridge National Laboratory

ORR = Oak Ridge Reservation

6.5 Groundwater Monitoring

Work continued in 2018 to implement key recommendations from the *Groundwater Strategy for the U.S. Department of Energy Oak Ridge Reservation* (DOE 2013), which was agreed to in 2014 by DOE, EPA, and the Tennessee Department of Environment and Conservation (TDEC). During 2018 ORR Groundwater Program transitioned from previous tasks, including off-site groundwater quality assessment and regional-scale groundwater flow model development, to planning continued off-site monitoring and development of site-scale groundwater flow models for the ORNL site.

6.5.1 Off-site Groundwater Assessment

During FY 2018 OREM (the Oak Ridge Office of Environmental Management) continued to collect and analyze samples from the off-site groundwater monitoring well array west of the Clinch River adjacent to Melton Valley. In addition, exit pathway groundwater monitoring in Melton Valley is conducted as part of the OREM program, including sampling at six multiport monitoring wells in western Melton Valley (wells 4537, 4538, 4539, 4540, 4541, and 4542). Results of this monitoring are summarized in the 2019 remediation effectiveness report (DOE 2019).

DOE completed an off-site groundwater assessment project and issued a final report on the off-site groundwater study in October 2017 (DOE 2017). The project was a cooperative effort among the parties to the ORR Federal Facility Agreement to investigate off-site groundwater quality and potential movement. As follow-on work from the off-site groundwater assessment, DOE plans to conduct annual sampling and analysis of groundwater from several off-site residential wells and springs.

6.5.2 Regional and Site-Scale Flow Model

During FY 2017 DOE completed a project to construct and calibrate a regional-scale groundwater flow model that encompasses ORR and adjacent areas. The regional model provides an underlying framework to support creation of smaller, site-scale groundwater flow models for use in planning and monitoring effectiveness of future cleanup decisions and actions. During FY 2018 DOE developed more refined groundwater flow models for the ORNL site. The new models can be used for evaluating groundwater contaminant migration in the vicinity of Bethel and Melton Valleys.

6.6 Food

Food sources are analyzed to evaluate potential radiation doses to consumers of local food crops, fish, and harvested game and to monitor trends in environmental contamination and possible long-term accumulation of radionuclides. Samples of hay, vegetables, milk, fish, deer, Canada geese, and turkeys are usually collected every year from areas that could be affected by activities on the reservation and from off-site reference locations. Milk was not collected in 2018 because the dairy that had supplied milk samples went out of business in 2016. The areas identified as potential areas of impact from DOE activities will be checked during 2019 for dairy operations.

The wildlife administrative release limits associated with deer, turkey, and geese harvested on ORR are conservative and were established based on the "as low as reasonably achievable (ALARA)" principle to ensure that doses to consumers are managed at levels well below regulatory dose thresholds. The ALARA concept is not a dose limit but rather a philosophy that has the objective of maintaining exposures to workers, members of the public, and the environment below regulatory limits and as low as can be reasonably achieved. An administrative release limit of 5 pCi/g ^{137}Cs is based on the assumption that one person consumes all of the meat from a maximum-weight deer, goose, or turkey. This limit ensures that members of the public who harvest wildlife on the reservation will not receive significant radionuclide doses from that consumption pathway. In addition, a conservative administrative limit of 1.5 times background for gross beta activity has been established, a threshold that is near the detection limit for field measurements of $^{89/90}$Sr in deer leg bone.

6.6.1 Hay

Hay is collected and analyzed from one location on ORR. Eating beef and drinking milk obtained from hypothetical cattle that eat hay is an environmental pathway to potential radiation doses to consumers. Hay samples collected on ORR during June 2018 were analyzed for gross alpha, gross beta, gamma emitters, and uranium isotopes. Radionuclides detected in hay are shown in Table 6.5. Statistically significant concentrations of gross beta activity, ^{7}Be, ^{40}K, ^{234}U, and ^{238}U were detected at that sampling location.

Table 6.5. Concentrations of radionuclides detected in hay, 2018 (pCi/kg)[a]

Gross alpha	Gross beta	^{7}Be	^{40}K	^{234}U	^{235}U	^{238}U
b	2,060	10,800	4,230	3.92	*b*	4.58

[a] Detected radionuclides are those at or above minimum detectable activity. 1 pCi = 3.7×10^{-2} Bq.
[b] Value was less than or equal to minimum detectable activity.

6.6.2 Vegetables

Turnip greens and turnips were purchased in 2018 from farms near ORR and from reference locations outside the potential DOE impact area. The locations were chosen based on availability and on the likelihood of effects from routine releases from the Oak Ridge facilities.

6.6.2.1 Results

Samples were analyzed for gross alpha, gross beta, gamma emitters, and uranium isotopes. No gamma-emitting radionuclides were detected above the minimum detectable activity (MDA), except for the naturally occurring radionuclides ^{7}Be and ^{40}K (Table 6.6).

Table 6.6. Concentrations of radionuclides detected in vegetables, 2018 (pCi/kg)[a]

Location	Gross alpha	Gross beta	^{7}Be	^{40}K	^{234}U	^{235}U	^{238}U
			Turnips				
East of Y-12, Claxton vicinity	*b*	1,300	*b*	4,110	*b*	*b*	*b*
South of ORNL	*b*	1,110	*b*	2,740	*b*	*b*	*b*
East of ORNL	*b*	2,040	*b*	3,000	*b*	*b*	*b*
Reference location	42.5	1,550	*b*	2,200	3.46	*b*	*b*
			Turnip Greens				
East of Y-12, Claxton vicinity	*b*	4,440	*b*	3,970	*b*	*b*	*b*
South of ORNL	*b*	4,240	*b*	4,660	3.59	*b*	*b*
East of ORNL	78.5	5,040	1,740[c]	3,820	*b*	1.37	*b*
Reference location	*b*	3,770	*b*	2,320	2.65	*b*	*b*

[a] Detected radionuclides are those at or above minimum detectable activity. 1 pCi = 3.7×10^{-2} Bq.
[b] Value was less than or equal to minimum detectable activity.
[c] There was no peak for the analyte. There were random counts in the region of interest above the background, and the software net-quantifies a result; flagged to indicate that the activity is not from the analyte. The absence of a peak indicates that the analyte is not present.

Acronyms

ORNL = Oak Ridge National Laboratory
Y-12 = Y-12 National Security Complex

6.6.3 Milk

Milk is a potentially significant exposure pathway to humans for some radionuclides deposited from airborne emissions because of the relatively large surface area on which a cow can graze daily, the rapid transfer of milk from producer to consumer, and the importance of milk in the diet.

The one dairy that had been supplying milk samples to ORNL went out of business in 2016. During the 2 years since, surveys to locate dairies in areas that could receive deposition from ORR activities were conducted; however, no dairies were identified to replace the one that closed. When a dairy or dairies are located, ORNL will resume milk-sampling and analyses.

6.6.4 Fish

Members of the public could be exposed to contaminants originating from DOE ORR activities through consumption of fish caught in area waters. This potential exposure pathway is monitored annually by collecting fish from three locations on the Clinch River and by analyzing edible flesh for specific contaminants. The locations are as follows (Figure 6.6):

- Clinch River upstream from all DOE ORR inputs (CRK) 70,

- Clinch River downstream from ORNL (CRK 32), and
- Clinch River downstream from all DOE ORR inputs (CRK 16).

Sunfish (*Lepomis macrochirus*, *L. auritus*, and *Ambloplites rupestris*) and catfish (*Ictalurus punctatus*) are collected from each of the three locations to represent both top-feeding and bottom-feeding-predator species. In 2018, a composite sample of each of those species at each location was analyzed for selected metals, polychlorinated biphenyls (PCBs), tritium, gross alpha, gross beta, gamma-emitting radionuclides, and total radioactive strontium. To accurately estimate exposure levels to consumers, only edible portions of the fish were submitted for analysis.

TDEC issues advisories on consumption of certain fish species caught in specified Tennessee waters. These advisories apply to fish that could contain potentially hazardous contaminants. TDEC has issued a "do not consume" advisory for catfish in the Melton Hill Reservoir in its entirety, not just in areas that could be affected by ORR activities, because of PCB contamination. Similarly, a precautionary advisory for catfish in the Clinch River arm of Watts Bar Reservoir has been issued because of PCB contamination (TDEC 2019). TDEC also issues advisories for consumption of fish when mercury levels are over 0.3 ppm; the three locations on the Clinch River where ORR fish are collected do not have mercury "do not consume" advisories. See additional information **here**.

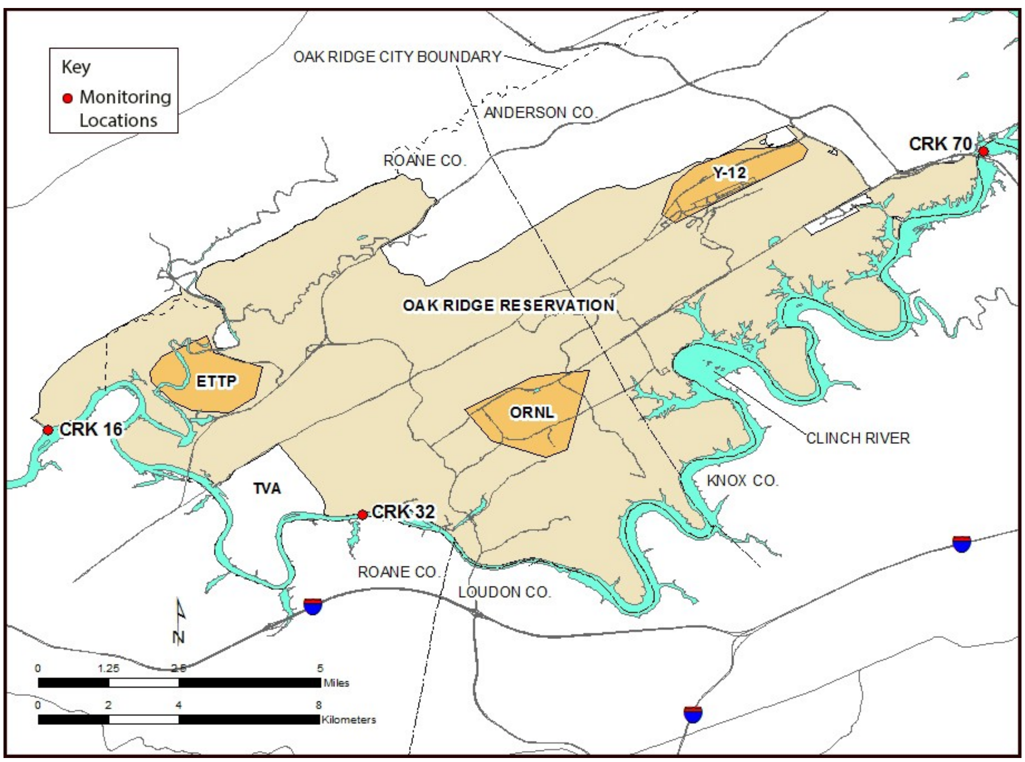

Figure 6.6. Fish-sampling locations for the Oak Ridge Reservation Surveillance Program

6.6.4.1 Results

PCBs, specifically Aroclor-1260, and mercury were detected in both sunfish and catfish at all three locations in 2018. These results are consistent with the TDEC advisories. Detected PCBs, mercury, and radionuclide concentrations are shown in Table 6.7.

Table 6.7. Tissue concentrations in catfish and sunfish for detected mercury, PCBs, and radionuclides, 2018[a]

Parameter	Catfish	Sunfish
Clinch River downstream from all DOE ORR inputs (CRK 16)		
Metals (mg/kg)		
Hg	0.045	0.08
Pesticides and PCBs (µg/kg)		
PCB-1260	41	J12[b]
Radionuclides (pCi/g)[c]		
Alpha activity	0.13	0.14
Beta activity	1.5	1.3
^{40}K	2.3	3.6
Clinch River downstream from ORNL (CRK 32)		
Metals (mg/kg)		
Hg	0.059	0.028
Pesticides and PCBs (µg/kg)		
PCB-1260	34	J6.6[b]
Radionuclides (pCi/g)[c]		
Alpha activity	0.096	0. 22
Beta activity	0.76	1.3
^{40}K	1.3	2.8
Clinch River (Solway Bridge) upstream from all DOE ORR inputs (CRK 70)		
Metals (mg/kg)		
Hg	0.035	J0.014[b]
Pesticides and PCBs (µg/kg)		
PCB-1260	50	J9.2[b]
Radionuclides (pCi/g)[c]		
Beta activity	0.97	1.0
^{40}K	1.8	3.0

[a] Only parameters that were detected for at least one species are listed in the table.
[b] "J" indicates that the result is an estimated value.
[c] Radionuclide concentrations were significantly greater than zero. Detected radionuclides are at or above the minimum detectable activity.

Acronyms

CRK = Clinch River kilometer
ORNL = Oak Ridge National Laboratory
PCB = polychlorinated biphenyl
DOE = US Department of Energy
ORR = Oak Ridge Reservation

6.6.5 White-Tailed Deer

Three weekend quota deer hunts were held on ORR during the final quarter of 2018. The hunts took place November 3 and 4, November 10 and 11, and December 8 and 9. Each hunt was limited to 450 shotgun/muzzleloader permittees and 600 archery permittees. UT-Battelle staff; Tennessee Wildlife Resources Agency (TWRA) personnel; and student members of the Wildlife Society, University of Tennessee (UT) chapter, performed most of the necessary operations at the checking station.

Approximately 25,053 acres were available to deer hunters on the Oak Ridge Wildlife Management Area (ORWMA) in 2018 (15,227 acres for gun hunting and 9,826 acres for archery hunting). The ORWMA includes some properties not owned by DOE, including Haw Ridge Park (city of Oak Ridge), the Clinch River Small Modular Reactor Site (the Tennessee Valley Authority), and the UT Arboretum. The total harvest in 2018 was 194 deer, of which 116 (~59.8 percent) were bucks and 78 (~40.2 percent) were does. The heaviest buck weighed 175 lb, was 3.5 years old, and had 12 antler points, which was the greatest number of antler points on any buck harvested. The heaviest doe weighed 126 lb and was also 3.5 years old. The harvest was higher than it was in 2017 but still somewhat lower than it had been in previous years. This is most likely due to the inclement weather during the last weekend hunt, which resulted in a lower hunter turnout than in years past. The outbreak of epizootic hemorrhagic disease (EHD) in the Tennessee deer herds during the summer of 2017 impacted deer populations on the ORWMA, as evidenced by the number of 2017's dead deer reports and low harvest numbers.

Since 1985, 13,173 deer have been harvested from the ORWMA, of which 218 (~1.7 percent) have been retained because of potential radiological contamination. The heaviest buck ever harvested weighed 218 lb (1998), and the heaviest doe ever harvested weighed 139 lb (1985). The average weight of all harvested deer is ~86 lb. The oldest deer harvested was a doe estimated to be 12 years old (1989); the average age of all harvested deer is ~2 years. See ORR hunt information website **here** for more information.

6.6.5.1 Results

None of the 194 deer harvested on ORR during the 2018 hunts were retained for exceeding the administrative release limit of 1.5 times background for beta activity in bone (~20 pCi/g $^{89/90}$Sr), nor for exceeding 5 pCi/g ^{137}Cs in edible tissue.

6.6.6 Canada Geese

On the Three Bends Area of ORR (excluding the shoreline of Gallaher Bend), Canada goose hunting was allowed during the statewide season, one half-hour before sunrise until noon on 5 days during September and 4 days during October. The consumption of Canada geese is a potential pathway for exposing members of the public to radionuclides released from ORR operations. To determine concentrations of gamma-emitting radionuclides accumulated by waterfowl that feed and live on ORR, Canada geese are rounded up each summer for noninvasive gross radiological surveys.

6.6.6.1 Results

Nineteen geese (17 adults, 2 goslings) were captured during the June 21, 2018, roundup at the Solway Boat Ramp, Anderson County. All 19 geese were subjected to live whole-body gamma scans. Gamma scan results for the 17 adult geese and 2 goslings showed that all were well below the administrative release limit of 5 pCi/g ^{137}Cs.

6.6.7 Turkey Monitoring

Two wild turkey hunts, managed by DOE and TWRA, were held on the reservation in 2018 (April 14 and 15 and April 28 and 29). Each hunt was limited to 225 hunters, preselected in a quota drawing. Approximately 21,879 acres were available to turkey hunters in 2018 because the 255 acres that were designated as archery-only in 2017 were eliminated and were converted to safety zones in 2018. Twenty-three male turkeys were harvested on the two hunts, of which 3 (~ 15 percent) were juveniles and 20 (~ 85 percent) were adults. The average weight of all turkeys harvested during spring 2018 hunts was ~19.2 lb, and the largest turkey weighed 22.2 lb. The average beard length was ~9.1 in., and the longest beard was 11.2 in. The average spur length was ~ 1.3 in., and the longest spur was 1.75 in. The largest turkey harvested to date on ORR weighed 25.7 lb (harvested in 2009).

6.6.7.1 Results

None of the 23 turkeys harvested in 2018 exceeded the administrative release limits established for radiological contamination. Since 1997, 892 turkeys have been harvested on spring turkey hunts. Ten additional turkeys have been harvested (since 2012) by archery hunters during fall deer hunts. Of all turkeys harvested, only three (< 0.4 percent) have been retained because of potential radiological contamination; one in 1997, one in 2001, and one in 2005. Additional information is available **here**.

6.7 Quality Assurance

The activities associated with administration, sampling, data management, and reporting for ORR environmental surveillance programs are performed by UT-Battelle. Project scope is established by a task team whose members represent DOE; UT-Battelle; Consolidated Nuclear Security, LLC; and URS | CH2M Oak Ridge LLC. UT-Battelle integrates quality assurance, environmental, and safety considerations into every aspect of ORR environmental monitoring. (See Chapter 5, Section. 5.7, for a detailed discussion of UT-Battelle quality assurance program elements for environmental monitoring and surveillance activities.)

6.8 References

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7. Dose

Activities on the ORR have the potential to release small quantities of radionuclides and hazardous chemicals to the environment. These releases could expose members of the public to low concentrations of radionuclides or chemicals. Monitoring of materials released from the reservation and environmental monitoring and surveillance on and around the reservation provide data used to show that doses from released radionuclides and chemicals are in compliance with the law.

In 2018, a hypothetical maximally exposed individual (MEI) could have received an effective dose (ED) of about 0.2 mrem from radionuclides emitted to the atmosphere from all ORR sources; this is well below the National Emission Standards for Hazardous Air Pollutants for Radionuclides standard of 10 mrem/year for protection of the public.

A worst-case analysis of exposures to waterborne radionuclides for all pathways combined gives a maximum possible individual ED of about 0.2 mrem. This dose is based on a person eating 27 kg/year (60 lb/year) of fish, drinking 730 L/year (193 gal/year) of drinking water, and using the shoreline for 60 h/year as well as swimming, boating, and irrigation.

In addition, if a hypothetical person consumed one deer, one turkey, and two geese (containing the maximum ^{137}Cs concentration and maximum weights), that person could have received an ED of about 2 mrem. This calculation is conducted to provide an estimated upper-bound ED from consuming wildlife harvested from ORR.

Therefore, the annual dose to an MEI from all these potential exposure pathways combined was estimated to be about 3 mrem. There are no known significant doses from discharges of radioactive constituents from ORR other than those reported. DOE Order 458.1, *Radiation Protection of the Public and the Environment* (DOE 2011), limits the ED that an individual may receive from all exposure pathways from all radionuclides released from ORR during 1 year to no more than 100 mrem. The 2018 maximum ED was about 3 percent of the limit given in DOE Order 458.1.

The potential doses to aquatic and terrestrial biota from contaminated soil and water were evaluated using a graded approach. Results of the screening calculations indicate that contaminants released from ORR site activities do not have an adverse impact on aquatic and terrestrial biota.

Due to different permit reporting requirements and instrument capabilities, this report uses various units of measurement. The lists of units of measure and conversion factors on pages xxvii and xxviii are included to help readers convert numeric values presented herein as needed for specific calculations and comparisons.

7.1 Radiation Dose

Small quantities of radionuclides were released to the environment from operations at ORR facilities during 2018. Those releases were described, characterized, and quantified in previous chapters of this report. This chapter presents estimates of potential radiation doses to the public from the releases. The dose estimates were obtained using monitored and estimated release data, environmental monitoring and surveillance data, estimated exposure conditions that tend to maximize calculated doses, and environmental transport and dosimetry codes that may also tend to overestimate the calculated doses. Therefore, the presented doses are likely overestimates of the doses received by actual people in the ORR vicinity.

7.1.1 Terminology

Exposures to radiation from nuclides located outside the body are called “external exposures”; exposures to radiation from nuclides deposited inside the body are called “internal exposures.” This distinction is important because external exposures occur only when a person is near or in a radionuclide-containing medium, whereas internal exposures continue while the radionuclides remain inside a person. Also, external exposures may result in uniform irradiation of the entire body, including all organs, while internal exposures usually result in nonuniform irradiation of the body and organs. When taken into the body, most radionuclides deposit preferentially in specific organs or tissues and typically do not irradiate the body uniformly.

Several specialized terms and units used to characterize exposures to ionizing radiation are defined in Appendix E. “Effective dose” (ED) is a risk-based equivalent dose that is used to estimate health effects or risks to exposed persons. It is a weighted sum of dose equivalents to specified organs and is expressed in rem or sieverts (1 rem = 0.01 Sv). One rem of ED, regardless of radiation type or method of delivery, has the same total radiological (in this case, also biological) risk effect. Because the doses discussed here are very small, EDs are expressed in millirem (mrem), which is one one-thousandth of a rem. (See Appendix E for a comparison and description of various dose levels.)

7.1.2 Methods of Evaluation

7.1.2.1 Airborne Radionuclides

The radiological consequences of radionuclides released to the atmosphere from ORR operations during 2018 were characterized by calculating EDs to maximally exposed on- and off-site members of the public and to the entire population residing within 80 km (50 miles) of ORR center. The calculations were performed for each major facility and for the entire ORR. The dose calculations were made using the Clean Air Act Assessment Package—1988 (CAP-88 PC) Version 4 (EPA 2015), a software program developed under sponsorship of the EPA to demonstrate compliance with 40 CFR 61, Subpart H, which governs the emissions of radionuclides other than radon from DOE facilities. CAP-88 PC implements a steady-state Gaussian plume atmospheric dispersion model to calculate concentrations of radionuclides in the air and on the ground and uses food-chain models to calculate radionuclide concentrations in foodstuffs (vegetables, meat, and milk) and subsequent intakes by humans.

In this assessment, adult dose coefficients were used to estimate doses. These coefficients are weighted sums of equivalent doses to 12 specified tissues or organs plus a remainder term that accounts for the rest of the tissues and organs in the body.

A total of 24 emission points on ORR were modeled during 2018. The total includes 3 (two combined) points at Y-12, 19 points at ORNL, and 2 points at the ETTP. Table 7.1 lists the emission-point parameter values and receptor locations used in the dose calculations.

Table 7.1. Emission point parameters and receptor location used in the dose calculations, 2018

Source	Stack height (m)	Stack diameter (m)	Effective exit gas velocity (m/s)[a]	Distance (m) and direction to the maximally exposed individual			
				From each site		From ORR	
Oak Ridge National Laboratory							
X-Laboratory Hoods							
X-1000 Lab Hoods	15	0.5	0	4,270	SW	11,260	NE
X-2000 Lab Hoods	15	0.5	0	4,630	SW	10,910	NE
X-3000 Lab Hoods	15	0.5	0	5,030	SW	10,510	NE
X-4000 Lab Hoods	15	0.5	0	5,200	SW	10,360	NE
X-6000 Lab Hoods	15	0.5	0	5,780	SW	9,800	NE
X-7000 Lab Hoods	15	0.5	0	5,210	WSW	10,750	NNE
X-2026	22.9	1.05	7.59	4,750	SW	10,790	NE
X-2099	3.66	0.18	16.88	4,740	SW	10,800	NE
X-3018	61	1.75	0.95	4,960	SW	10,570	NE
X-3020	61	1.22	14.62	4,900	SW	10,640	NE
X-3039	76.2	2.44	6.57	4,970	SW	10,570	NE
X-3544	9.53	0.28	24.75	4,740	SW	10,820	NE
X-3608 Filter Press	8.99	0.36	9.27	4,860	SW	10,720	NE
X-4501	19.81	0.66	9.63	5,150	SW	10,400	NE
X-7503	30.5	0.91	13.59	5,230	SW	10,580	NNE
X-7830 Group	4.6	0.25	6.71	3,840	WSW	12,130	NNE
X-7856-CIP	18.29	0.48	9.33	3,840	WSW	12,190	NNE
X-7877	13.9	0.41	13.56	3,810	WSW	12,180	NNE
X-7880	27.7	1.52	13.79	3,770	WSW	12,200	NNE
X-7911	76.2	1.52	14.8	5,160	WSW	10,810	NNE
X-7935							
X-7935 Building Stack	15.24	0.51	26.85	5,170	SW	10,740	NNE
X-7935 Glove Box	9.14	0.25	0	5,170	SW	10,740	NNE
X-7966	6.10	0.29	6.33	5,240	SW	10,660	NNE
X-8915	104.0	1.22	7.04	8,000	SSW	7,580	NE
X-Decom Areas	15	0.5	0	5,240	SW	10,310	NE
East Tennessee Technology Park							
K-1407-AL CWTS	2.74	0.15	0	400	WSW	14,770	ENE
K-2500-H-C	8.23	0.61	12.9	620	SE	15,400	ENE
Y-12 National Security Complex							
Y-Monitored	20	0.5	0	2,270	NE	2,270	NE
Y-Unmonitored Processes	20	0.5	0	2,270	NE	2,270	NE
Y-Unmonitored Lab Hoods	20	0.5	0	2,270	NE	2,270	NE

[a] Exit gas temperatures are "ambient air" unless noted otherwise.

Acronyms
CIP = Capacity Increase Project
CWTS = Chromium Water Treatment System
Decom= Decommissioned
ORR = Oak Ridge Reservation

Meteorological data used in the calculations for 2018 were in the form of joint frequency distributions of wind direction, wind speed class, and atmospheric stability category. (See Table 7.2 for a summary of tower locations used to model the various sources.) During 2018, rainfall, as averaged over the six rain gauges located on ORR, was about 162 cm (64 in.). The average air temperature was 14.9°C (58.7°F) at the 10 to 15 m levels, and the average mixing-layer height for ETTP and ORNL was 881.2 m (2,891ft) and for Y-12 was 812.8 m (2,666 ft). The mixing height is the depth of the atmosphere adjacent to the surface within which air is mixed.

For occupants of residences, the dose calculations assume that the occupant remained at home during the entire year and obtained food according to the rural pattern. This pattern specifies that 70 percent of the vegetables and produce, 44 percent of the meat, and 40 percent of the milk consumed are produced in the local area (e.g., a home garden). The remaining portion of each food category is assumed to be produced within 80 km (50 miles) of ORR. The same assumptions are used for occupants of businesses, but the resulting doses are divided by 2 to compensate for the fact that businesses are occupied for less than half a year and less than half of a worker's food intake occurs at work. For collective ED estimates, production of beef, milk, and crops within 80 km (50 miles) of ORR was calculated using the production rates provided with CAP-88 PC Version 4.

Table 7.2. Meteorological towers and heights used to model atmospheric dispersion from source emissions, 2018

Tower	Height (m)	Source
		Y-12 National Security Complex
MT6 (West Y-12)	30	All Y-12 sources
		East Tennessee Technology Park
MT7 (K1209)	10	K-1407-AL CWTS, K-2500-H-C
		Oak Ridge National Laboratory
MT4 (Tow A)	15	X-7830, X-7877, X-7935 Glove Box, X-7935 Building, X 7966, and X-7000 Lab Hoods
	30	X-7503, X-7856-CIP, X-7880, and X-7911
MT3 (Tow B)	15	X-6000 Lab Hoods
MT2 (Tow D)	15	X-2099, X-3544, X-3608 FP, X-Decom Hoods, X-1000, X-2000, X-3000, and X-4000 Lab Hoods
	35	X-2026, X-4501
	60	X-3018, X-3020, and X-3039
MT12 (Tow F)	10	X-8515 (SNS)

Acronyms
CWTS = Chromium Water Treatment System
Decom= Decommissioned
FP = Filter Press
ORNL = Oak Ridge National Laboratory

Results

Calculated EDs from radionuclides emitted to the atmosphere from ORR are listed in Table 7.3 (maximum individual) and Table 7.4 (collective). The hypothetical maximally exposed individual (MEI) for ORR was located about 2,270 m northeast of the main Y-12 release point, about 10,810 m north-northeast of the 7911 stack at ORNL, and about 14,770 m east-northeast of the K-1407-AL Chromium Water Treatment System (CWTS) at ETTP (see Figure 7.1). This individual could have received an ED of about 0.2 mrem, which is well below the National Emission Standards for Hazardous Air Pollutants for Radionuclides standard of 10 mrem and is about 0.07 percent of the roughly 300 mrem that the average individual receives from natural sources of radiation (40 CFR 61 Subpart H).

ORNL 2012-G00588/mhr

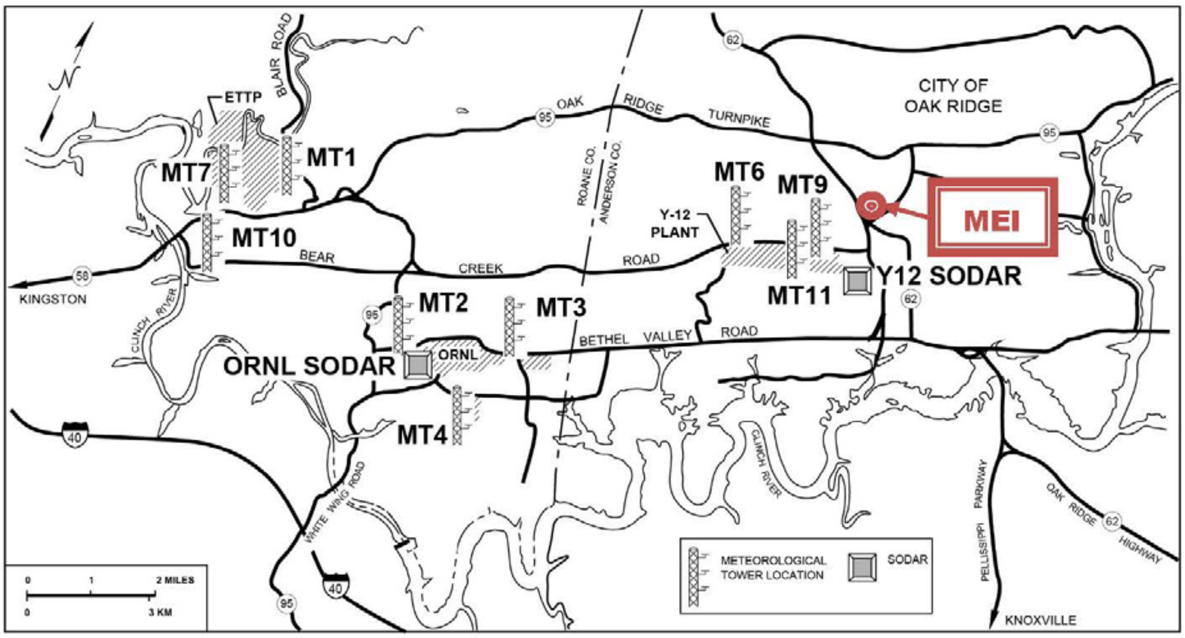

Figure 7.1. Location of the maximally exposed individual (MEI) for ORR

Based on the 2010 population census data, the calculated collective ED to the entire population within 80 km (50 miles) of ORR (about 1,172,530 persons) was about 6.8 person-rem, which is about 0.002 percent of the 351,759 person-rem that this population received from natural sources of radiation (based on an individual dose of about 300 mrem/year). CAP-88 PC Version 4 was used in 2018 to calculate both individual and collective doses.

Table 7.3. Calculated radiation doses to maximally exposed off-site individuals from airborne releases from ORR, 2018

Plant	Maximum effective dose, mrem (mSv)			
	From each site		From ORR	
	mrem	mSv	mrem	mSv
Oak Ridge National Laboratory	0.1[a]	0.001	0.04	0.0004
East Tennessee Technology Park	0.0006[b]	6×10^{-6}	8×10^{-6}	8×10^{-8}
Y-12 National Security Complex	0.2[c]	0.002	0.2	0.002
Entire Oak Ridge Reservation	*d*		0.2[e]	0.002

[a] The MEI was located 4,970 m SW of X-3039 and 5,160 m WSW of X-7911.
[b] The MEI was located 400 m WSW of K-1407-AL Chromium Water Treatment System.
[c] The MEI was located 2,270 m NE of Y-12 National Security Complex release point.
[d] Not applicable.
[e] The MEI for the entire Oak Ridge Reservation is also the Y-12 MEI.

Acronyms
MEI = maximally exposed individual
ORR = Oak Ridge Reservation

Table 7.4. Calculated collective effective doses from airborne releases, 2018

Plant	Collective effective dose[a]	
	Person-rem	Person-Sv
Oak Ridge National Laboratory	5.0	0.05
East Tennessee Technology Park	0.0003	3×10^{-6}
Y-12 National Security Complex	1.8	0.018
Entire Oak Ridge Reservation	6.8	0.068

[a] Collective effective dose to the 1,172,530 persons residing within 80 km (50 miles) of the Oak Ridge Reservation (based on 2010 census data).

The MEI for Y-12 was located at a residence about 2,270 m (1.4 miles) northeast of the main Y-12 release point. This individual could have received an ED of about 0.2 mrem from Y-12 airborne emissions. Inhalation and ingestion of uranium radioisotopes (i.e., ^{233}U, ^{234}U, ^{235}U, ^{236}U, and ^{238}U) accounted for about 99 percent, and ^{99}Tc accounted for about 0.5 percent of the dose (Figure 7.2). The contribution of Y-12 emissions to the 50-year committed collective ED to the population residing within 80 km (50 miles) of ORR was calculated to be about 1.8 person-rem, which is about 27 percent of the collective ED for ORR.

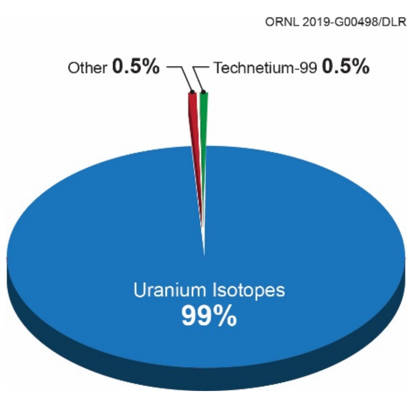

Figure 7.2. Nuclides contributing to the effective dose at Y-12 National Security Complex, 2018

The MEI for ORNL was located at a residence about 4,970 m (3.1 miles) southwest of the 3039 stack and 5,160 m (3.2 miles) west-southwest of the 7911 stack. This individual could have received an ED of about 0.1 mrem from ORNL airborne emissions. Lead-212 contributed 54 percent, ^{138}Cs contributed 21 percent, and ^{41}Ar contributed 14 percent of the ORNL dose (Figure 7.3). The total contribution from uranium radioisotopes (i.e., ^{230}U, ^{232}U, ^{233}U, ^{234}U, ^{235}U, ^{236}U, ^{238}U, ^{239}U, and ^{240}U) accounted for about 0.04 percent of the dose, and ^{238}U contributed about 0.02 percent of the dose. The contribution of ORNL emissions to the collective ED to the population residing within 80 km (50 miles) of ORR was calculated to be about 5.0 person-rem or about 73 percent of the collective ED for ORR.

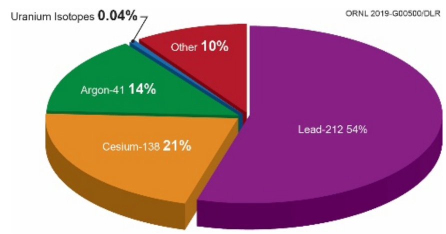

Figure 7.3. Nuclides contributing to effective dose at Oak Ridge National Laboratory, 2018

The MEI for ETTP was located at a business about 400 m (0.3 miles) west-southwest of the K-1407-AL CWTS. The ED received by this individual from airborne emissions was calculated to be about 0.0006 mrem. About 88 percent of the dose is from uranium radioisotopes (^{234}U, ^{235}U, ^{236}U, and ^{238}U), and 9 percent of the dose is from ^{99}Tc (Figure 7.4). The contribution of ETTP emissions to the collective ED to the population residing within 80 km (50 miles) of ORR was calculated to be about 0.0003 person-rem, or about 0.005 percent of the collective ED for the reservation.

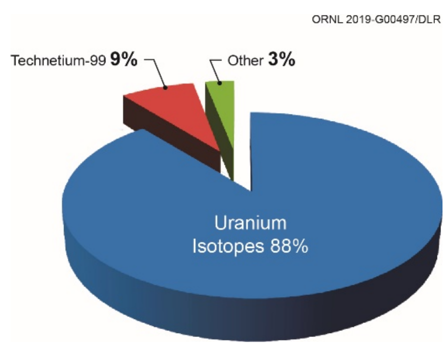

Figure 7.4. Nuclides contributing to effective dose at East Tennessee Technology Park, 2018

To evaluate the validity of the estimated doses calculated using CAP-88 PC Version 4 and emissions data (Table 7.5), the doses are compared to the EDs calculated using measured air concentrations of radionuclides (excluding naturally occurring ^{7}Be and ^{40}K) at ORR perimeter area monitoring (PAM) stations and at ORNL ambient air monitors 1, 2, 3, and 11 (AAM1, AAM2, AAM3, and AAM11). Based on measured air concentrations, hypothetical individuals assumed to reside at AAM1, AAM2, AAM3, AAM11, and PAM stations 35–49 could have received EDs between 0.0006 and 0.02 mrem/year. Based on emissions data using CAP-88 PC Version 4, the above individuals could have received EDs between 0.03 and 0.2 mrem/year. As shown in Table 7.5, EDs calculated using CAP-88 PC Version 4 and emissions data tend to be greater than or equivalent to EDs calculated using measured air concentrations.

Table 7.5. Hypothetical effective doses from living near ORR, ORNL, and ETTP ambient air monitoring stations, 2018

Station	Calculated effective doses			
	Using air monitor data		Using CAP-88[a] and emission data	
	mrem/year	mSv/year	mrem/year	mSv/year
		ORR and ORNL		
1	0.0007	7×10^{-6}	0.2	0.002
2	0.0006	6×10^{-6}	0.1	0.001
3	0.0006	6×10^{-6}	0.2	0.002
11	0.0006	6×10^{-6}	0.2	0.002
35[b]	0.02	0.0002	0.03	0.0003
37	0.0008	8×10^{-6}	0.08	0.0008
40	0.002	2×10^{-5}	0.2	0.002
46	0.001	1×10^{-5}	0.07	0.0007
49	0.0008	8×10^{-6}	0.09	0.0009
52[b,c]	0.01	0.0001	0.008	0.00008
		ETTP		
K2	0.0009	9×10^{-6}	0.02	0.0002
K11	0.003	3×10^{-5}	0.02	0.0002
K12	0.04	0.0004	0.02	0.0002

[a] CAP-88 PC Version 4 software, developed under US Environmental Protection Agency sponsorship to demonstrate compliance with 40 CFR 61, Subpart H.
[b] At Stations 35 and 52, ^{99}Tc was requested for analyses as well as other radionuclides.
[c] Background ambient air monitoring station.

Acronyms
ETTP = East Tennessee Technology Park
ORNL = Oak Ridge National Laboratory
ORR = Oak Ridge Reservation

Station 52, located remotely from ORR, gives an indication of potential EDs from background sources. As noted above, ^{99}Tc was analyzed at Station 35 and Station 52, and the ^{99}Tc air concentrations were similar at both locations. Based on measured air concentrations, the ED was estimated to be 0.01 mrem/year (the isotopes ^{7}Be and ^{40}K were not included in the background air monitoring station calculation); the estimated ED based on calculated air concentrations using CAP-88 PC Version 4 was also estimated to be 0.008 mrem/year. The measured air concentrations of ^{7}Be were similar at the PAM stations and at the background air monitoring station.

Of interest is a comparison of EDs calculated using measured air concentrations of radionuclides at PAM stations located near the MEIs for each plant and EDs calculated for those individuals using source emissions data. Station K11 is located near the on-site MEI for ETTP. The ED calculated with measured air concentrations was 0.003 mrem/year, which is lower than the ED of 0.02 mrem/year estimated using source emissions data. Ambient air station 11 is located near the off-site MEI for ORNL. The ED calculated with measured air concentrations was 0.0006 mrem/year, which is lower than the ED of 0.2 mrem/year estimated using source emissions data. PAM station 40 is located near the off-site MEI for Y-12 Complex and ORR and the ED calculated with measured air concentrations was 0.002 mrem/year, which is also less than the ED of 0.2 mrem/year estimated using source emissions data.

7.1.2.2 Waterborne Radionuclides

Radionuclides discharged to surface waters from ORR enter the Tennessee River system by way of the Clinch River. Discharges from Y-12 enter the Clinch River via Bear Creek and East Fork Poplar Creek (EFPC), each of which enters Poplar Creek before it enters the Clinch River, and discharges from Rogers Quarry enter into McCoy Branch and then into Melton Hill Lake. Discharges from ORNL enter the Clinch River via White Oak Creek (WOC) and enter Melton Hill Lake via some small drainage creeks. Discharges from ETTP enter the Clinch River either directly or via Poplar Creek. This section discusses the potential radiological impacts of these discharges to persons who drink water; eat fish; and swim, boat, and use the shoreline at various locations along the Clinch and Tennessee Rivers.

For assessment purposes, surface waters potentially affected by ORR are divided into seven segments:

- Melton Hill Lake above all possible ORR inputs
- Melton Hill Lake
- Upper Clinch River (from Melton Hill Dam to confluence with Poplar Creek)
- Lower Clinch River (from confluence with Poplar Creek to confluence with the Tennessee River)
- Upper Watts Bar Lake (from near the confluence of the Clinch and Tennessee Rivers to below Kingston)
- the lower system (the remainder of Watts Bar Lake and Chickamauga Lake to Chattanooga)
- Poplar Creek (including the confluence of EFPC)

Two methods are used to estimate potential radiation doses to the public. The first method uses radionuclide concentrations in the medium of interest (i.e., in water and fish) determined by laboratory analyses of water and fish samples (see Sections 6.4 and 6.6). The second method calculates possible radionuclide concentrations in water and fish from measured radionuclide discharges and known or estimated stream flows. In both methods, reported concentrations of radionuclides were used if the reported value was statistically significant and/or detected. The advantage of the first method is the use of radionuclide concentrations measured in water and fish; disadvantages are the inclusion of naturally occurring radionuclides (e.g., ^{40}K, uranium and its progeny, thorium and its progeny, and unidentified alpha and beta activities), the possible inclusion of radionuclides discharged from sources not part of ORR, and the possibility that some radionuclides of ORR origin might be present in quantities too low to be measured. The advantages of the second method are that most radionuclides discharged from ORR can be quantified and that naturally occurring radionuclides may not be considered or may be accounted for separately. The disadvantage is the use of models to estimate the concentrations of the radionuclides in water and fish. Both methods use the same models (Hamby 1991) to estimate radionuclide concentrations in media and at locations other than those that are sampled (e.g., downstream). However, utilizing the two methods to estimate potential doses takes into account both field measurements and discharge measurements.

Drinking Water Consumption

Surface Water

Water treatment plants that draw water from the Clinch and Tennessee River systems could be affected by discharges from ORR. No in-plant radionuclide concentration data are available for these plants; however, the dose estimates given in this section likely are high because they are based on radionuclide concentrations in water before it enters a processing plant. Based on a nationwide food consumption survey (EPA 2011) and weighted based on the combined population of Anderson, Knox, Loudon, and Roane counties, the drinking water consumption rate for the MEI is 730 L/year (193 gal/year), and the drinking water consumption rate for the average person is 330 L/year (87 gal/year). The average drinking water consumption rate is used to estimate the collective ED. At all locations in 2018, estimated maximum EDs to a person drinking water were calculated using both measured radionuclide concentrations in and measured radionuclide discharges to off-site surface water, excluding naturally occurring radionuclides such as ^{40}K and ^{7}Be.

- **Upper Melton Hill Lake above all possible ORR inputs.** Based on samples from Melton Hill Lake above possible ORR inputs (at Clinch River kilometer [CRK] 66 near the City of Oak Ridge Water Intake Plant), a MEI drinking water at this location could have received an ED of about 0.04 mrem. The collective ED to the 47,933 persons who drink water from the City of Oak Ridge water plant would be 0.9 person-rem.
- **Melton Hill Lake.** The only water treatment plant located on Melton Hill Lake that could be affected by discharges from ORR is a Knox County plant. This plant is located near surface water sampling location CRK 58. An MEI could have received an ED of about 0.04 mrem; the collective dose to the 63,779 persons who drink water from this plant could have been 1 person-rem.
- **Upper Clinch River.** ETTP (Gallaher) water plant, which drew water from the Clinch River near CRK 23, was deactivated in 2014; therefore, doses from drinking water are no longer calculated. ETTP and the Rarity Ridge community receive drinking water from the City of Oak Ridge water plant, which is located near CRK 66.
- **Lower Clinch River.** There are no known drinking water intakes in this river segment (from the confluence of Poplar Creek with the lower Clinch River to the confluence of the lower Clinch River with the Tennessee River).
- **Upper Watts Bar Lake.** The Kingston and Rockwood municipal water plants draw water from the Tennessee River not far from its confluence with the Clinch River. An MEI could have received an ED of about 0.03 mrem. The collective dose to the 30,955 persons who drink water from these plants could have been about 0.4 person-rem.
- **Lower system.** Several water treatment plants are located on tributaries of Watts Bar Lake and Chickamauga Lake. Persons drinking water from those plants could not have received EDs greater than the 0.02 mrem. The collective dose to the 301,858 persons who drink water within the lower system could have been about 2 person-rem.
- **Poplar Creek/Lower EFPC.** No drinking water intakes are located on Poplar Creek or on lower EFPC.

Groundwater

As mentioned in Section 6.5, during FY 2018 OREM (the Oak Ridge Office of Environmental Management) continued to collect and analyze samples from the off-site groundwater monitoring well array west of the Clinch River adjacent to Melton Valley. Currently, no water is consumed from these off-site groundwater wells.

Fish Consumption

Fishing is quite common on the Clinch and Tennessee River systems. Based on a nationwide food consumption survey (EPA 2011) and weighted based on the combined population of Anderson, Knox, Loudon, and Roane counties, it was assumed that avid fish consumers would have eaten 27 kg (60 lb) of fish during 2018. For the average person used for collective dose calculations, it was assumed that 11 kg (24 lb) of fish was consumed in 2018. The estimated maximum ED will be based on either the first method, measured radionuclide concentrations in fish, or by the second method, which calculates possible radionuclide concentrations in fish from measured radionuclide discharges and known or estimated stream flows. The number of individuals who could have eaten fish is based on lake creel surveys conducted annually by the Tennessee Wildlife Resources Agency (TWRA 2018a).

- **Upper Melton Hill Lake above All Possible ORR Inputs.** For reference purposes, a hypothetical avid fish consumer who ate fish caught at CRK 66, which is above all possible ORR inputs, could have received an ED of about 0.09 mrem. The collective ED to the nine persons who could have eaten such fish was about 0.0003 person-rem.
- **Melton Hill Lake.** An avid fish consumer who ate fish from Melton Hill Lake could have received an ED of about 0.09 mrem. The collective ED to the 79 persons who could have eaten such fish could be about 0.003 person-rem.
- **Upper Clinch River.** An avid fish consumer who ate fish from the upper Clinch River could have received an ED of about 0.09 mrem. The collective ED to the 100 persons who could have eaten such fish could have been about 0.004 person-rem.
- **Lower Clinch River.** An avid fish consumer who ate fish from the lower Clinch River (CRK 16) could have received an ED of about 0.09 mrem. The collective ED to the 233 persons who could have eaten such fish could have been about 0.008 person-rem.
- **Upper Watts Bar Lake.** An avid fish consumer who ate fish from upper Watts Bar Lake could have received an ED of about 0.02 mrem. The collective ED to the 666 persons who could have eaten such fish could be about 0.004 person-rem.
- **Lower System.** An avid fish consumer who ate fish from the lower system could have received an ED of about 0.01 mrem. The collective ED to the about 9,949 persons who could have eaten such fish could have been about 0.05 person-rem.
- **Poplar Creek/Lower East Fork Poplar Creek.** An avid fish consumer who ate fish from Poplar Creek could have received an ED of about 1.0 mrem; it is considered unlikely that a person would consume fish from these locations. Assuming 100 people could have eaten fish from lower EFPC and from Poplar Creek, the collective ED could have been about 0.05 person-rem.

Other Uses

Other uses of ORR area waterways include swimming or wading, boating, and use of the shoreline. A highly exposed “other user” was assumed to swim or wade for 30 h/year, boat for 63 h/year, and use the shoreline for 60 h/year. The average individual, who is used for collective dose estimates, was assumed to swim or wade for 10 h/year, boat for 21 h/year, and use the shoreline for 20 h/year. The potential EDs from these activities were estimated from measured and calculated concentrations of radionuclides in water; the equations that were used were derived from the LADTAP XL code (Hamby 1991) and were modified to account for radioactive data and shoreline use. The number of individuals who could have been other users are different for each section of water. Recreational activities for Melton Hill Reservoir are based on surveys conducted by the University of Tennessee (Stephens et al. 2006). A recent survey was conducted regarding visitor and property owner activities for Chickamauga and Watts Bar Reservoir (Poudyal et al. 2017). The survey data from these reports were used to identify the variety of recreational activities on these water bodies. It was found that respondents often participated in more than one recreational activity. This information has replaced earlier assumptions regarding number of people involved in water recreational activities.

- **Upper Melton Hill Lake above all possible ORR inputs**. A hypothetical maximally exposed other user of upper Melton Hill Lake above possible ORR inputs (CRK 66) could have received an ED of about 3×10^{-7} mrem. The collective ED to the 14,483 other users could have been 5×10^{-7} person- rem.
- **Melton Hill Lake.** An individual other user of Melton Hill Lake could have received an ED of about 0.0005 mrem. The collective ED to the 40,044 other users could have been about 0.003 person-rem.

- **Upper Clinch River.** An individual other user of the upper Clinch River could have received an ED of about 8×10^{-6} mrem. The collective ED to the 13,114 other users could have been about 7×10^{-6} person-rem.
- **Lower Clinch River.** An individual other user of the lower Clinch River could have received an ED of about 0.0002 mrem. The collective ED to the 30,599 other users could have been about 0.0006 person-rem.
- **Upper Watts Bar Lake.** An individual other user of upper Watts Bar Lake could have received an ED of about 2×10^{-6} mrem. The collective ED to the 87,424 other users could have been about 9×10^{-6} person-rem.
- **Lower system (Watt Bar and Chickamauga Lakes).** An individual other user of the lower system could have received an ED of about 1×10^{-6} mrem. The collective ED to the 3,173,432 other users could have been about 0.0002 person-rem.
- **Poplar Creek/Lower EFPC.** An individual other user of Lower EFPC, above its confluence with Poplar Creek, could have received an ED of about 0.001 mrem. The collective ED to the 200 other users of Poplar Creek and Lower EFPC could have been about 4×10^{-5} person-rem.

Irrigation

Although there are no known locations that use water from water bodies around ORR to irrigate food or feed crops, it was decided to determine whether irrigation could contribute to radiation doses to a member of the public. To make this determination, the method described by the Nuclear Regulatory Commission (NRC 1977) was used. Based on measured and calculated concentrations of radionuclides at CRK 16, which is a location on the lower Clinch River and downstream of ORR, the maximum potential dose (excluding the naturally occurring radionuclides ^{7}Be and ^{40}K) to an individual due to irrigation ranged from 0 to 0.08 mrem in 2018. The individual was assumed to consume 24 kg of leafy vegetables, 90 kg of produce, 321 L of milk and 63 kg of meat (beef) during the year.

Summary

Table 7.6 is a summary of potential EDs from identified waterborne radionuclides around ORR. Excluding Lower EFPC and Poplar Creek from the other water systems evaluated (Melton Hill, Clinch River, Watts Bar Lake, and Chickamauga Lake), the estimated maximum individual ED would be about 0.1 mrem to a person obtaining his or her drinking water, annual complement of fish from, and participating in other water uses throughout these water systems. The maximum collective ED to the 80 km (50 mile) population was estimated to be 5 person-rem. These are small percentages of individual and collective doses attributable to natural background radiation, about 0.03 percent of the average individual background dose of roughly 300 mrem/year and 0.001 percent of the 351,759 person-rem that this population received from natural sources of radiation.

Table 7.6. Summary of annual maximum individual (mrem) and collective (person-rem) effective doses from waterborne radionuclides, 2018[a,b]

Effective dose	Source			Total[c]
	Drinking water	Eating fish	Other uses	
Upstream of all Oak Ridge Reservation discharge locations (CRK 66, City of Oak Ridge Water Plant)				
Individual	0.04	0.09	3×10^{-7}	0.1
Collective	0.9	3×10^{-4}	5×10^{-7}	0.9
Melton Hill Lake (CRK 58, Knox County Water Plant)				
Individual	0.04	0.09	0.0005	0.1

Table 7.6. Summary of annual maximum individual (mrem) and collective (person-rem) effective doses from waterborne radionuclides, 2018 (continued)[a,b]

Effective dose	Source			Total[c]
	Drinking water	Eating fish	Other uses	
Collective	1.1	0.003	0.003	1.2
Upper Clinch River (CRK 23, 32)				
Individual	NA[d]	0.09	8×10^{-6}	0.09
Collective	NA[d]	0.004	7×10^{-6}	0.004
Lower Clinch River (CRK 16)				
Individual	NA[d]	0.09	0.0002	0.09
Collective	NA[d]	0.008	0.0006	0.009
Upper Watts Bar Lake, Kingston Municipal Water Plant				
Individual	0.03	0.02	2×10^{-6}	0.04
Collective	0.4	0.004	9×10^{-6}	0.4
Lower system (Lower Watts Bar Lake and Chickamauga Lake)				
Individual	0.02	0.01	1×10^{-6}	0.04
Collective	2.4	0.05	2×10^{-4}	2.4
Lower East Fork Poplar Creek and Poplar Creek				
Individual	NA[d]	1.0	0.001	1.0
Collective	NA[d]	0.06	4×10^{-5}	0.06

[a] 1 mrem = 0.01 mSv.
[b] Doses based on measured radionuclide concentrations in water or estimated from measured discharges and known or estimated stream flows.
[c] Total doses and apparent sums over individual pathway doses may differ because of rounding.
[d] Not at or near drinking water supply locations.

Acronyms
CRK = Clinch River kilometer.

7.1.2.3 Radionuclides in Other Environmental Media

The CAP-88 PC computer codes are used to calculate radiation doses from ingestion of meat, milk, and vegetables that contain radionuclides released to the atmosphere. These doses are included in the dose calculations for airborne radionuclides. Some environmental media, including milk and vegetables, have been sampled in previous years as part of ORR surveillance program. However, milk samples were not available to be collected in 2018.

7.1.2.4 Food

Milk

During 2018, no milk samples were collected from a nearby dairy (in Claxton, Tennessee) because the dairy farm went out of business. Milk samples had been collected from that dairy for several years. Surveys to locate other dairies in areas that could receive deposition from ORR activities are conducted annually; however, the survey did not identify any dairies to replace the one that went out of business in 2016. The milk-sampling program will resume when a replacement for that dairy is identified.

Vegetables

The food-crop sampling program is described in Chapter 6. Samples of leafy greens and root vegetables were obtained from four gardens, three local and one distant. In 2018, tomatoes samples were not available from these gardens. All radionuclides detected in the food crops can be found in the natural environment and all but ^{7}Be and ^{40}K also may also be emitted from ORR. Dose estimates are based on hypothetical consumption rates of vegetables that contain statistically significant amounts and/or detected radionuclides that could have come from ORR. Based on a nationwide food consumption survey (EPA 2011), a hypothetical home gardener (weighted based on the combined population of Anderson, Knox, Loudon, and Roane counties) was assumed to have eaten a maximum of about 24 kg (53 lb) of homegrown leafy greens and 90 kg (198 lb) of root vegetables. The hypothetical local gardener could have received an ED of between 0.01 and 0.05 mrem, depending on garden location. Of this total, between 0.0 and 0.02 mrem could have come from eating leafy greens and between 0.0 and 0.03 mrem from eating root vegetables. The highest dose to a local gardener could have been about 0.05 mrem from consuming both types of homegrown vegetables. A person eating vegetables from the distant (background) garden could have received a committed ED of 0.1 mrem from consuming both vegetables.

An example of a naturally occurring and fertilizer-introduced radionuclide is ^{40}K, which is specifically identified in the samples and accounts for most of the beta activity found in them. The presence of ^{40}K in the samples adds, on average, about 10 mrem to the hypothetical home gardener's ED. In 2018, the gardeners were asked about water sources and fertilizers used. It was reported that commercially available fertilizers were used at three garden locations. No water was added at two of three garden locations; whereas, city water was used for one garden. At the distant location, cow manure was used for fertilizer, but no water was added. It is believed ^{40}K and most of the excess unidentified alpha activities are due to naturally occurring radionuclides, not radionuclides discharged from ORR.

Hay

Another environmental pathway that was evaluated was eating beef and drinking milk obtained from hypothetical cattle that ate hay harvested from one location on ORR. Hay samples collected on ORR during July 2018 were analyzed for gross alpha, gross beta, gamma emitters, and uranium isotopes. Radionuclides detected in hay are shown in Chapter 6, Table 6.5. Statistically significant concentrations of ^{7}Be, ^{40}K, ^{234}U, ^{235}U, and ^{238}U were detected at that sampling location. Excluding the doses from ^{7}Be and ^{40}K (both naturally occurring), the average ED from drinking milk and eating beef was estimated to be 0.007 mrem.

White-Tailed Deer

The Tennessee Wildlife Resources Agency (TWRA) conducted three 2-day deer hunts during 2018 on the Oak Ridge Wildlife Management Area, which is part of ORR (see Chapter 6). During the hunts, 194 deer were harvested and were brought to the TWRA checking station. At the station, a bone sample and a muscle tissue sample were taken from each deer. The samples were field-counted for radioactivity to ensure that the deer met the wildlife release criteria of less than net counts not greater than 1½ times background (~20 pCi/g $^{89/90}$Sr) of beta activity in bone or the administrative limit of 5 pCi/g of ^{137}Cs in edible tissue (ORNL 2011). No deer exceeded the wildlife release criteria.

The average ^{137}Cs concentration in muscle tissue of the 194 released deer, as determined by field counting, was 0.5 pCi/g; the maximum ^{137}Cs concentration in released deer was 0.8 pCi/g. Most of the ^{137}Cs concentrations were less than minimum detectable levels. The average weight of released deer was approximately 42 kg (92 lb); the maximum weight was 79 kg (175 lb). The EDs attributed to field-measured ^{137}Cs concentrations and actual field weights of the released deer ranged from about 0.2 to 1.1 mrem, with an average of about 0.6 mrem.

Potential doses attributed to deer that might have moved off ORR and been harvested elsewhere were also evaluated. In this scenario, an individual who consumed one hypothetical average-weight deer (42 kg [92 lb], assuming that 55 percent of the field weight is edible meat) containing the 2018 average field-measured concentration of ^{137}Cs (0.5 pCi/g) could have received an ED of about 0.6 mrem. The maximum field-measured ^{137}Cs concentration was 0.8 pCi/g, and the maximum deer weight was 79 kg (175 lb). A hunter who consumed a hypothetical deer of maximum weight and ^{137}Cs content could have received an ED of about 2 mrem.

Muscle tissue samples collected in 2018 from five released deer were subjected to laboratory analyses. Requested radioisotopic analyses included ^{137}Cs, ^{90}Sr, and ^{40}K radionuclides. Comparison of the released-deer field results to analytical ^{137}Cs concentrations found that the field concentrations were greater than the analytical results and that all were less than the administrative limit of 5 pCi/g (ORNL 2011). Using analytically measured ^{137}Cs and ^{90}Sr (excluding ^{40}K, a naturally occurring radionuclide) and actual deer weights, the estimated doses for the five released deer ranged from 0 to 0.7 mrem.

The maximum ED to an individual consuming venison from two or three deer was also evaluated. Twenty-one hunters harvested either two or three deer from ORR. Based on ^{137}Cs concentrations determined by field counting and actual field weight, the ED range to a hunter who consumed two or more harvested deer was estimated to be between 0.6 and 2 mrem.

The collective ED from eating all the harvested venison from ORR with a 2018 average field-derived ^{137}Cs concentration of 0.5 pCi/g and an average weight of 42 kg (92 lb) is estimated to be about 0.1 person-rem. The collective dose is based on number of hunters that harvested deer. It is possible that additional individuals may also consume the harvested venison; however, the collective dose would remain the same.

Canada Geese

Nineteen geese were captured during the 2018 goose roundup and were subjected to live whole-body gamma scans. The geese were field-counted for radioactivity to ensure that they met wildlife release criteria (< 5 pCi/g of ^{137}Cs in tissue). The average ^{137}Cs concentration was 0.2 pCi/g, with a maximum ^{137}Cs concentration in the released geese of 0.5 pCi/g. All ^{137}Cs concentrations were below minimum detectable activity levels. The average weight of the geese screened during the roundup was about 4.1 kg (9 lb), and the maximum weight was about 5.7 kg (13 lb).

The EDs attributed to field-measured ^{137}Cs concentrations of the geese ranged from 0.018 to 0.022 mrem. However, for bounding purposes, if a person consumed a released goose with an average weight of 4.1 kg (9 lb) and an average ^{137}Cs concentration of 0.2 pCi/g, the estimated ED would be approximately 0.02 mrem. It is assumed that about half the weight of a Canada goose is edible. The estimated ED to an individual who consumed a hypothetical goose with the maximum ^{137}Cs concentration of 0.5 pCi/g and maximum weight of 5.7 kg (13 lb) is about 0.07 mrem.

It is possible that a person could eat more than one goose that spent time on ORR. The average seasonal goose bag per active hunter from Tennessee in the Mississippi Flyway has ranged from 1.9 to 3.0 geese per hunting season between 1999 and 2010 (TWRA 2010). Hypothetically, if one person consumed two geese of maximum weight with the highest measured concentration of ^{137}Cs, that person could have received an ED of about 0.1 mrem.

Between 2000 and 2009, 22 samples of goose tissue were analyzed. An evaluation of potential doses was made based on laboratory-determined concentrations of the following radionuclides: ^{40}K, ^{137}Cs, ^{90}Sr, thorium (^{228}Th, ^{230}Th, ^{232}Th), uranium ($^{233/234}U$, ^{235}U, ^{238}U), and transuranic elements (^{241}Am, $^{243/244}Cm$,

^{238}Pu, $^{239/240}$Pu). The total dose, less the contribution of ^{40}K, ranged from 0.01 to 0.5 mrem, with an average of 0.2 mrem (EP&WSD 2010).

Eastern Wild Turkey

Participating hunters are permitted to harvest one turkey from the reservation in a given season unless a harvested turkey is retained, in which case, the hunter is permitted to hunt for another turkey. Two wild turkey hunts took place on the reservation in 2018: April 14 and 15 and April 28 and 29. Twenty-three turkeys were harvested during that time frame, and no harvested turkeys were retained. The average weight of the released turkeys was about 8.6 kg (19 lb). The maximum turkey weight was about 10 kg (22 lb). However, in 2018, the summarized gamma analyses data were unrecoverable due to computer issues. For perspective, the EDs attributed to the field-measured ^{137}Cs concentrations of the released turkeys for the last 5 years ranged from about 0 to 0.05 mrem with average doses ranging from 0.02 to 0.03 mrem. Concentrations of ^{137}Cs were less than detection levels for four of the last five years.

No tissue samples were analyzed in 2018. Earlier evaluations of doses based on laboratory-determined concentrations of radionuclides included ^{40}K, ^{137}Cs, ^{90}Sr, ^{230}Th, ^{3}H, ^{234}U, ^{235}U, ^{238}U, and transuranic elements (^{241}Am, ^{244}Cm, ^{237}Np, ^{239}Pu). The total dose, less the contribution of ^{40}K, ranged from 0.06 to 0.2 mrem (EP&WSD 2010).

Direct Radiation

The principal sources of natural external exposure are the penetrating gamma radiations emitted by ^{40}K and the series originating from ^{238}U and ^{232}Th (NCRP 2009). Due to radiological activities on ORR, external radiation exposure rates are measured at perimeter ambient air monitoring stations. External gamma exposure rates were continuously recorded by dual-range Geiger-Müller tube detectors co-located with ORR ambient air stations. In 2018, exposure rates averaged about 10 µR/h and ranged from 8.6 to 12.3 µR/h. These exposure rates correspond to an annual average dose of about 61 mrem with a range of 53 to 76 mrem. At the remote ambient air station, the exposure rate averaged about 9.1 µR/h and ranged from 8.6 to 10.6 µR/h. The resulting average annual dose was about 56 mrem with a range of 53 to 65 mrem. The annual dose based on measured exposure rates at or near ORR boundaries were typically within the range of the doses measured at the remote location; slightly higher exposure rates were observed at ambient air station 11.

7.1.3 Current-Year Summary

A summary of the maximum EDs to individuals by pathway of exposure is given in Table 7.7. In the unlikely event that any person was exposed to all those sources and pathways for the duration of 2018, that person could have received a total ED of about 3 mrem. Of that total, 0.2 mrem would have come from airborne emissions, approximately 0.2 mrem from waterborne emissions (0.04 mrem from drinking water, 0.09 mrem from consuming fish, 0.0005 mrem from other water uses along the Clinch River, and 0.08 mrem from irrigation at CRK 16), and about 2 mrem from consumption of wildlife. Current direct radiation measurements at PAM stations are at or near background levels. There are no known significant doses from discharges of radioactive constituents from ORR other than those reported.

Table 7.7. Summary of maximum estimated effective doses from ORR activities to an adult by exposure pathway, 2018

Pathway	Dose to maximally exposed individual		Percentage of DOE mrem/year limit (%)	Estimated collective radiation dose[a]			
				Pathway		Background (person-rem)	Total Population
	mrem	mSv		person-rem	person-Sv		
Airborne effluents							
All pathways	0.2	0.002	0.2	6.8	0.068		1,172,530[b]
Liquid effluents							
Drinking water	0.04	0.0004	0.04	4.7	0.047		444,525[c]
Eating fish	0.09	0.0009	0.09	0.1	0.001		11,237[d]
Other activities	0.0005	5×10^{-6}	0.0005	0.004	0.00004		3,359,287[d]
Irrigation	0.08	0.0008	0.08				
Other pathways							
Eating deer	2[e]	0.02	2	0.1	0.001		194
Eating geese	0.1[f]	0.001	0.1	*g*	*g*		
Eating turkey	0.05[h]	0.0005	0.05	0.001	1×10^{-5}		23
Direct radiation	NA[i]	NA					
All pathways							
Total	**3**[j]	**0.03**	**3**	**11.7**	**0.117**	**363,484**	

[a] Estimated background collective dose is based on the roughly 300 mrem/year individual dose and the population within 80 km (50 miles) of the Oak Ridge Reservation.
[b] Population based on 2010 census data.
[c] Population estimates based on community and non-community drinking water supply data from TDEC Division of Water.
[d] Population estimates for fish based on creel data and fraction of fish harvested from Melton Hill, Watts Bar, and Chickamauga reservoirs. Melton Hill, Watts Bar and Chickamauga recreational use information was obtained from TVA (Stephens et al. 2006 and Poudyal et al. 2017). Other activities include swimming, boating, and shoreline use; the population estimates include individuals involved in more than one activity and also include visitors that may live outside the 80 km radius.
[e] Estimates for eating deer are based on consuming one hypothetical worst-case deer, a combination of the heaviest deer harvested and the highest measured concentrations of ^{137}Cs in released deer on the Oak Ridge Reservation; collective dose based on number of hunters that harvested deer.
[f] Estimates for eating geese are based on consuming two hypothetical worst-case geese, each a combination of the heaviest goose harvested and the highest measured concentrations of ^{137}Cs in released geese.
[g] Collective doses were not estimated for the consumption of geese because no geese were harvested for consumption during the goose roundup.
[h] Estimates for eating turkey are based on consuming one turkey based on the highest dose from field measurements in the past 5 years. The collective dose is based on the number of hunters who harvested turkey and the cited individual dose.
[i] Current exposure rate measurements at PAM stations are at or near background levels.
[j] Dose estimates have been rounded.

The dose of 3 mrem is about 1 percent of the annual dose (roughly 300 mrem) from background radiation. The ED of 3 mrem includes the person who received the highest EDs from eating wildlife harvested on ORR. If the MEI did not consume wildlife harvested from ORR, the estimated dose would be about 0.4 mrem. DOE O 458.1 limits the ED that an individual may receive from all exposure pathways from all radionuclides released from ORR during 1 year to no more than 100 mrem. The 2018 maximum ED should not have exceeded about 3 mrem, or about 3 percent of the limit given in DOE O 458.1.

The total collective ED to the population living within an 80 km (50 mile) radius of ORR was estimated to be about 11.7 person-rem. This dose is about 0.003 percent of the 363,484 person-rem that this population received from natural sources during 2018.

7.1.4 Five-Year Trends

EDs associated with selected exposure pathways for years 2014 to 2018 are given in Table 7.8. In 2018, the air pathway dose is within the range of air pathway doses that have been estimated over the last 5 years, although 2014 air pathway dose was somewhat higher than the other 4 years. Starting in 2016, dose estimates take into account terrain height for the Spallation Neutron Source because it is located on a ridge above most of ORR. The 2018 dose from fish consumption is somewhat elevated as compared to 2015 and 2017 doses due to ^{90}Sr being detected at CRK 66, which is above ORR discharge locations. In 2016, some issues associated with cross-contamination in analytical equipment used to quantify radionuclides in ORR-wide surface water samples from CRK 66, 58, 32, 23, and 16 led to biased results for several 2016 sampling events. The increase in the 2014 fish consumption was due to a composite fish sample collected at CRK 16, in which ^{90}Sr was a primary dose contributor. There was a decrease in drinking water dose in 2014, but the doses in 2018 are comparable to other earlier estimated doses. Recent direct radiation measurements indicate doses near background levels. Doses from consumption of wildlife have been similar for the last 5 years with a slight increase in dose due to consumption of geese in 2016.

Table 7.8. Trends in effective dose from ORR activities, 2014–2018 (mrem)[a]

Pathway	2014	2015	2016	2017	2018
All routes – Inhalation	0.6	0.4	0.2	0.3	0.2
Fish consumption (Clinch River)	1.2	0.03	1.3	0.05	0.09
Drinking water (Kingston)	0.003	0.02	0.03	0.01	0.03
Deer	2	1	1	2	2
Geese	0.1	0.08	0.2	0.08	0.1
Turkey	0.04	0.05	0.05	0.08	0.05

[a]1 mrem = 0.01 mSv

7.1.5 Doses to Aquatic and Terrestrial Biota

7.1.5.1 Aquatic Biota

DOE O 458.1 (DOE 2011) sets an absorbed dose rate limit of 1 rad/day to native aquatic organisms from exposure to radioactive material in liquid wastes discharged to natural waterways (see Appendix E for definitions of absorbed dose and rad). To demonstrate compliance with this limit, the aquatic organism assessment was conducted using the RESRAD-Biota code (1.8), a companion tool for implementing DOE technical standard *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE 2019a). The code serves as DOE's biota dose evaluation tool and uses the screening (i.e., biota concentration guides [BCGs]) and analysis methods in the technical standard. The BCG is the limiting concentration of a radionuclide in sediment or water that would not cause dose limits for protection of aquatic biota populations to be exceeded.

The intent of the graded approach is to protect populations of aquatic organisms from the effects of exposure to anthropogenic ionizing radiation. Certain organisms are more sensitive to ionizing radiation than others. Therefore, it is generally assumed that protecting the more-sensitive organisms will adequately protect other, less-sensitive organisms. Depending on the radionuclide, either aquatic organisms (e.g., crustaceans) or riparian organisms (e.g., raccoons) may be the more sensitive and are typically the limiting organisms for the general screening phase of the graded approach for aquatic organisms.

At ORNL, doses to aquatic organisms are based on surface water concentrations at the following instream sampling locations.

- Melton Branch (Melton Branch [X13])
- WOC headwaters (WOC 6.8), WOC (X14), and White Oak Dam (WOD) (X15)
- First Creek
- Fifth Creek
- Northwest Tributary
- Raccoon Creek
- Clinch River CRKs 16, 32, 58, and 66

All locations, except WOD (X15) passed the general screening phase (comparison of maximum radionuclide water concentrations to default BCGs). WOD (X15) passed when average water concentrations and adjusted bioaccumulation factors for ^{137}Cs were used to reflect site-specific bioaccumulation of these radionuclides in fish. Riparian organisms are the limiting receptor for ^{137}Cs in surface water; however, the best available bioaccumulation data for WOC are for fish. Because fish are consumed by riparian organisms (e.g., raccoons), adjustment of the fish bioaccumulation factor modified the bioaccumulation of ^{137}Cs in riparian organisms. This resulted in absorbed dose rates to aquatic organisms below DOE aquatic dose limit of 1 rad/day at the ORNL sampling locations.

At Y-12, doses to aquatic organisms were estimated from surface water concentrations and sediment concentrations (at Station 9422-1 and S24) at the following instream sampling locations.

- Surface Water Hydrological Information Support System Station 9422-1 (also known as station 17)
- Bear Creek at Bear Creek kilometer 9.2 (BCK 9.2)
- Discharge Point S24 (Bear Creek at BCK 9.4)
- Discharge Point S17 (unnamed tributary to the Clinch River)
- Discharge Point S19 (Rogers Quarry)

All locations passed the general screening phase (maximum water concentrations and default parameters for BCGs). This resulted in absorbed dose rates to aquatic organisms below DOE aquatic dose limit of 1 rad/day at the Y-12 locations.

At ETTP, doses to aquatic organisms were estimated from surface water concentrations at the following instream sampling locations.

- Mitchell Branch at K1700; Mitchell Branch kilometers 0.45, 0.59, 0.71, and 1.4 (upstream location)
- Poplar Creek at K-716 (downstream)
- K1007-B and K-1710 (upstream location)
- K-702A and K901-A (downstream of ETTP operations)
- Clinch River (CRK 16 and CRK 23)

All these locations passed the initial general screening (using maximum concentrations and default parameters for BCGs). This resulted in absorbed dose rates to aquatic organisms that were below DOE aquatic dose limit of 1 rad/day at the ETTP sampling locations.

7.1.5.2 Terrestrial Biota

A terrestrial organism assessment was conducted to evaluate impacts on biota in accordance with requirements in DOE O 458.1 (DOE 2011). An absorbed dose rate of 0.1 rad/day is recommended as the limit for terrestrial animal exposure to radioactive material in soils. As for aquatic and riparian biota, certain terrestrial organisms are more sensitive to ionizing radiation than others, and it is generally assumed that protecting the more-sensitive organisms will adequately protect other, less-sensitive organisms. Initial soil sampling for terrestrial dose assessment was initiated in 2007 and reassessed in 2014. This biota sampling strategy was developed by taking into account guidance provided in *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE 2019a) and existing radiological information on the concentrations and distribution of radiological contaminants on ORR. In 2014, as well as in 2007, the soil sampling focused on unremediated areas, such as floodplains and some upland areas. Floodplains are often downstream of contaminant source areas and are dynamic systems where soils are eroding in some places and being deposited in others. Soil sampling locations are identified as follows.

- WOC floodplain and upland location
- Bear Creek Valley floodplain
- Mitchell Branch floodplain
- Two background locations: Gum Hollow and near Bearden Creek

The soil samples collected in 2014 were in similar locations as in 2007; except one location where a soil sample was not collected due to site inaccessibility. Except for samples collected on the WOC floodplain (collected on the WOC floodplain upstream from WOD), samples collected at all other soil sampling locations passed either the initial-level screening (comparison of maximum radionuclide soil concentrations to default BCGs) or second-level screening, for which BCG default parameters and average soil concentrations were used. Cesium-137 is the primary dose contributor in the soil samples collected on the WOC floodplain.

Biota sampling in the WOC floodplain was conducted in 2009. White-footed mice (*Peromyscus leucopus*), deer mice (*Peromyscus maniculatus*), and hispid cotton rats (*Sigmodon hispidus)* were selected for sampling because they live and forage in these areas, are food for other mammals, and have relatively small home ranges. The biota sampling locations were at the confluence of Melton Branch and WOC and in the floodplain upstream of White Oak Lake. Based on the current measured concentrations in soil and tissue concentrations collected, the absorbed doses to the terrestrial organisms collected along the confluence of Melton Branch and WOC and in the floodplain upstream of White Oak Lake were less than 0.1 rad/day. The next evaluation of exposure to terrestrial organisms would be within the next 5 years or if an abnormal event occurs that could have adverse effects on terrestrial organisms.

7.2 Chemical Dose

7.2.1 Drinking Water Consumption

7.2.1.1 Surface Water

To evaluate the drinking water pathway, hazard quotients (HQs) were estimated downstream of ORNL and downstream of ORR discharge points (Table 7.9). The HQ is a ratio that compares the estimated exposure dose or intake to the reference dose. Based on a nationwide food consumption survey (EPA 2011) and weighted based on the combined population of Anderson, Knox, Loudon, and Roane counties, it was assumed that the drinking water consumption rate for the MEI is 730 L/year (2 L/day). This is the same drinking water consumption rate used in the estimation of the maximum exposed radiological dose from consumption of drinking water. Chemical analytes were measured in surface water samples collected at CRK 66, CRK 32, CRK 23 and CRK 16. The water intake for ETTP used to be located near CRK 23 but was deactivated in 2014. Mercury concentrations were measured in surface water samples collected at CRK 66 and CRK 32.

As shown in Table 7.9, at all locations, HQs were less than 1 for detected chemical analytes for which there are reference doses or a maximum contaminant level. CRK 16 is located downstream of all DOE discharge points. Although CRK 16 is not a source of drinking water, data from this location were used as an indicator of the potential effect of drinking water from the Clinch River.

Acceptable risk levels for carcinogens typically range in magnitude from 10^{-4} to 10^{-6}. A risk value of 5×10^{-6} and 6×10^{-6} calculated for the intake of arsenic in water collected at CRK 16 and CRK 23, respectively. Risk values of $4{\times}10^{-6}$ and $1{\times}10^{-5}$ were calculated for the intake of chromium (VI) in water collected at CRK 16 and CRK 23, respectively.

Table 7.9. Chemical hazard quotients and estimated risks for drinking water from the Clinch River at CRK 66, 32, 23, and 16, 2018[a]

Chemical	Hazard quotient			
		Metals		
	CRK 66[b]	**CRK 32[c]**	**CRK 23[d]**	**CRK 16[e]**
Antimony			0.005	0.004
Arsenic			0.03	0.03
Chromium (VI)			0.02	0.006
Copper			0.0002	0.0003
Lead			0.02	0.02
Mercury	0.006	0.006	5×10^{-5}	0.0005
Nickel			0.001	0.0006
Selenium			0.002	0.004
Silver				5×10^{-5}
Uranium			0.03	0.03
Zinc			0.0003	0.0004
		Risk for carcinogens		
Arsenic			6×10^{-6}	5×10^{-6}
Chromium			1×10^{-5}	4×10^{-6}
Lead			1×10^{-8}	1×10^{-8}

[a] CRK = Clinch River kilometer (CRK).
[b] Melton Hill Reservoir at CRK 66, above city of Oak Ridge water intake.
[c] CRK 32, downstream of Oak Ridge National Laboratory.
[d] CRK 23, is located across from ETTP, no longer a water intake location
[e] CRK 16, is downstream of all US Department of Energy inputs and not a water intake location.

7.2.1.2 Groundwater

As mentioned in Section 6.5, during FY 2018 OREM (the Oak Ridge Office of Environmental Management) continued to collect and analyze samples from the off-site groundwater monitoring well array west of the Clinch River adjacent to Melton Valley. Currently, no water is consumed from these off-site groundwater wells.

7.2.2 Fish Consumption

Chemicals in water can be accumulated by aquatic organisms that may be consumed by humans. To evaluate the potential health effects from the fish consumption pathway, HQs were estimated for the consumption of noncarcinogens, and risk values were estimated for the consumption of carcinogens detected in sunfish and catfish collected both upstream and downstream of ORR discharge points. Based on a nationwide food consumption survey (EPA 2011) and weighted based on the combined population of Anderson, Knox, Loudon, and Roane counties, it was assumed that avid fish consumers would have eaten 27 kg (60 lb) of fish during 2018. This fish consumption rate of 74 g/day (27 kg/year) is assumed for both the noncarcinogenic and carcinogenic pollutants. This is the same fish consumption rate used in the estimation of the radiological dose from consumption of fish.

As shown in Table 7.10, for consumption of sunfish and catfish, HQ values of less than 1 were calculated for all detected analytes except for Aroclor-1260, a polychlorinated biphenyl (PCB), also referred to as PCB-1260. An HQ greater than 1 for Aroclor-1260 was estimated in catfish at all three locations (CRKs 16, 32, and 70).

For carcinogens, risk values at or greater than 10^{-6} were calculated for the intake of arsenic, chromium (as Cr^{+6}), and Aroclor-1260 for sunfish and catfish collected at all three locations. The concentrations for arsenic and chromium were estimated at or below the analytical detection limit. For chromium in catfish at CRK32 and CRK16 concentrations were not quantifiable at the analytical detection limit. The Tennessee Department of Environment and Conservation (TDEC) has issued a fish advisory that states that catfish should not be consumed from Melton Hill Reservoir (in its entirety) because of PCB contamination (TDEC 2017). TDEC has issued a precautionary fish consumption advisory for catfish in the Clinch River arm of Watts Bar Reservoir (TWRA 2018b).

Table 7.10. Chemical hazard quotients and estimated risks for carcinogens in fish caught and consumed from locations on ORR, 2018[a]

Carcinogen	Sunfish			Catfish		
	CRK 70[b]	CRK 32[c]	CRK 16[d]	CRK 70[b]	CRK 32[c]	CRK 16[d]
			Hazard quotients for metals			
Aluminum	J0.001	J0.001	<0.0006	J0.0006	J0.0009	J0.0007
Antimony	J0.3	J0.3	J0.3	J0.4	J0.2	J0.6
Arsenic	J0.3	J0.3	J0.3	J0.06	J0.05	J0.2
Barium	J0.001	0.002	J0.001	J0.0002	J0.0002	J0.0001
Cadmium	J0.01	0.05	<0.008	J0.01	<0.008	J0.01
Chromium	J0.03	J0.03	J0.04	J0.04	<0.02	J0.02
Cobalt	J0.02	0.03	J0.02	J0.01	<0.008	<0.008
Copper	0.01	0.006	J0.004	0.02	0.005	0.007

Table 7.10. Chemical hazard quotients and estimated risks for carcinogens in fish caught and consumed from locations on ORR, 2018 (continued)[a]

Carcinogen	Sunfish			Catfish		
	CRK 70[b]	CRK 32[c]	CRK 16[d]	CRK 70[b]	CRK 32[c]	CRK 16[d]
Iron	0.005	0.006	0.006	0.007	0.004	0.009
Lead	J0.1	1.1	J0.2	J0.1	<0.04	J0.1
Lithium	0.04	J0.04	J0.04	J0.05	J0.04	J0.04
Manganese	0.008	0.008	0.005	0.002	0.001	0.001
Mercury	J0.04	0.08	0.2	0.1	0.2	0.1
Nickel		J0.003	<0.002		<0.002	J0.005
Selenium	0.2	0.2	0.2	0.1	0.1	0.1
Strontium	0.005	0.004	0.003	J0.0001	J0.0002	J0.0001
Thallium	0.3	0.3	0.2	J0.1	J0.1	0.2
Uranium	J0.0009	J0.0009	J0.0009	<0.0009	J0.0009	J0.0008
Vanadium	J0.002		J0.004	J0.001		<0.0009
Zinc	0.05	0.04	0.05	0.02	0.01	0.02
Hazard quotients for Aroclors						
Aroclor-1260	J0.4	J0.3	J0.5	2	2	2
Risks for carcinogens						
Arsenic	J4E-5	J5E-5	J5E-5	J9E-6	J9E-6	J4E-5
Chromium	J2E-5	J2E-5	J2E-5	J2E-5	<1E-5	J1E-5
Lead	J6E-8	6E-7	J9E-8	J5E-8	<2E-8	J6E-8
Aroclor-1260	J6E-6	J4E-6	J8E-6	3E-5	2E-5	3E-5
PCBs (mixed)[e]	J6E-6	J4E-6	J8E-6	3E-5	2E-5	3E-5

[a] A blank space for a location indicates that the parameter was undetected. A prefix "J" indicates that the concentration was estimated at or below the analytical detection limit by the laboratory and "< "indicates that the concentration was not quantifiable at the analytical detection limit.
[b] Melton Hill Reservoir, above the City of Oak Ridge Water Plant.
[c] Clinch River downstream of Oak Ridge National Laboratory.
[d] Clinch River downstream of all US Department of Energy inputs.
[e] Mixed polychlorinated biphenyls (PCBs) consist of the summation of Aroclors detected or estimated.

Acronyms
CRK = Clinch River kilometer
ORR = Oak Ridge Reservation

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Appendix A:
Glossary

Appendix
A. Glossary

accuracy—The closeness of the result of a measurement to the true value of the quantity.

aliquot—The quantity of a sample being used for analysis.

alkalinity—The capacity of an aqueous solution to neutralize an acid. Alkalinity measurements are important in determining the sensitivity of a body of water to acid inputs such as acidic pollution from rainfall or wastewater.

alpha particle—A positively charged particle emitted from the nucleus of an atom; it has the same charge and mass as that of a helium nucleus (two protons and two neutrons).

ambient air—The surrounding atmosphere as it exists around people, plants, and structures.

analyte—A constituent or parameter that is being analyzed.

analytical detection limit—The lowest reasonably accurate concentration of an analyte that can be detected; this value varies depending on the method, instrument, and dilution used.

anion—A negatively charged ion.

aquifer—A saturated, permeable geologic unit that can transmit significant quantities of water under ordinary hydraulic gradients.

aquitard—A geologic unit that inhibits the flow of water.

beta particle—A negatively charged particle emitted from the nucleus of an atom. It has a mass and charge equal to those of an electron.

biota—The animal and plant life of a particular region considered as a total ecological entity.

blank—A control sample that is identical in principle to the sample of interest, except the substance being analyzed is absent. In such cases, the measured value or signal for the substance being analyzed is believed to be a result of artifacts. Under certain circumstances, that value may be subtracted from the measured value to give a net result reflecting the amount of the substance in the sample. EPA does not permit the subtraction of blank results in EPA-regulated analyses.

calibration—Determination of variance from a standard of accuracy of a measuring instrument to ascertain necessary correction factors.

CERCLA Off-site Rule—Requires that CERCLA wastes be placed only in a facility operating in compliance with the Resource Conservation and Recovery act or other applicable federal or state requirements. The regulatory citation is 40 *CFR* 300.440.

CERCLA-reportable release—A release to the environment that exceeds reportable quantities as defined by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

chemical oxygen demand—Indicates the quantity of oxidizable materials present in water and varies with water composition, concentrations of reagent, temperature, period of contact, and other factors.

closure—Specifically, closure of a hazardous waste management facility under Resource Conservation and Recovery Act (RCRA) requirements.

compliance—Fulfillment of applicable requirements of a plan or schedule ordered or approved by government authority.

concentration—The amount of a substance contained in a unit volume or mass of a sample.

conductivity—A measure of water's capacity to convey an electric current. This property is related to the total concentration of the ionized substances in water and the temperature at which the measurement is made.

confluence—The point at which two or more streams meet; the point where a tributary joins the main stream.

contamination—Deposition of unwanted material on the surfaces of structures, areas, objects, or personnel.

cosmic radiation—Ionizing radiation with very high energies, originating outside the earth's atmosphere. Cosmic radiation is one source contributing to natural background radiation.

count—A measure of the radiation from an object or device; the signal that announces an ionization event within a counter.

curie (Ci)—A unit of radioactivity. One curie is defined as 3.7×10^{10} (37 billion) disintegrations per second. Several fractions and multiples of the curie are commonly used:

> **kilocurie (kCi)**—10^{3} Ci, one thousand curies; 3.7×10^{13} disintegrations per second.
>
> **millicurie (mCi)**—10^{-3} Ci, one-thousandth of a curie; 3.7×10^{7} disintegrations per second.
>
> **microcurie (μCi)**—10^{-6} Ci, one-millionth of a curie; 3.7×10^{4} disintegrations per second.
>
> **picocurie (pCi)**—10^{-12} Ci, one-trillionth of a curie; 0.037 disintegrations per second.

daughter—A nuclide formed by the radioactive decay of a parent nuclide.

decay, radioactive—The spontaneous transformation of one radionuclide into a different radioactive or nonradioactive nuclide, or into a different energy state of the same radionuclide.

dense nonaqueous phase liquid (DNAPL)—The liquid phase of chlorinated organic solvents. These liquids are denser than water and include commonly used industrial compounds such as tetrachloroethene and trichloroethene.

derived concentration guide (DCG)—The concentration of a radionuclide in air or water that, under conditions of continuous exposure for 1 year by one exposure mode (i.e., ingestion of water, submersion in air, or inhalation), would result in either an effective dose equivalent of 0.1 rem (1 mSv) or a dose equivalent of 5 rem (50 mSv) to any tissue, including skin and lens of the eye. The guides for radionuclides in air and water are given in DOE Order 5400.5.

derived concentration standard (DCS)—Quantities used in the design and conduct of radiological environmental protection programs at US Department of Energy facilities and sites. These quantities represent the concentration of a given radionuclide in either water or air that results in a member of the public receiving a 1 mSv (100 mrem) effective dose following continuous exposure for 1 year for each of the following pathways: ingestion of water, submersion in air, and inhalation.

disintegration, nuclear—A spontaneous nuclear transformation (radioactivity) characterized by the emission of energy and/or mass from the nucleus of an atom.

dissolved oxygen—A measurement of the amount of gaseous oxygen in an aqueous solution. Adequate dissolved oxygen is necessary for good water quality.

dose—A general term for absorbed dose, equivalent dose, or effective dose.

> **absorbed dose**—The average energy imparted by ionizing radiation to the matter in a volume element per unit mass of irradiated material. The absorbed dose is expressed in units of rad (or gray) (1 rad = 0.01 gray).
>
> **collective dose/collective effective dose**—The sum of the total effective dose to all persons in a specified population received in a specified period of time. It can be approximated by the sum of the average effective dose for a given subgroup i, and Ni is the number of individuals in this subgroup. Collective dose is expressed in units of person-rem (or person-sievert).
>
> **effective dose (E or ED)**—The summation of the products of the equivalent dose (HT) received by specified tissues or organs of the body and the appropriate tissue weighting factor (wT). It includes the dose from radiation sources internal and/or external to the body. The effective dose is expressed in units of rems (or sieverts).
>
> **equivalent dose (HT)**—The product of average absorbed dose (DT,R) in rad (or gray) in a tissue or organ (T) and a radiation (R) weighting factor (wR).

dosimetry—Measurement and calculation of radiation doses from exposure to ionizing radiation.

drinking water standard (DWS)—Federal primary drinking water standards, both proposed and final, as set forth by the US Environmental Protection Agency.

duplicate samples—Two or more samples collected simultaneously into separate containers.

effluent—A liquid or gaseous waste discharge to the environment.

effluent monitoring—The collection and analysis of samples or measurements of liquid and gaseous effluents for purposes of characterizing and quantifying the release of contaminants, assessing radiation exposures of members of the public, and demonstrating compliance with applicable standards.

energy intensity—Energy consumption per square foot of building space, including industrial or laboratory facilities [EO 13514, Section 19(f)].

Environmental Management—A US Department of Energy program that directs the assessment and cleanup (remediation) of its sites and facilities contaminated with waste as a result of nuclear-related activities.

exposure (radiation)—The incidence of radiation on living or inanimate material by accident or intent. Background exposure is the exposure to natural background ionizing radiation. Occupational exposure is the exposure to ionizing radiation that takes place during a person's working hours. Population exposure is the exposure to the total number of persons who inhabit an area.

external radiation—Exposure to ionizing radiation when the radiation source is located outside the body.

flux—A flow or discharge of a substance (in units of mass, radioactivity, etc.) per unit of time.

gamma ray—High-energy, short-wavelength electromagnetic radiation emitted from the nucleus of an excited atom. Gamma rays are identical to x-rays except for the source of the emission.

grab sample—A sample collected instantaneously with a glass or plastic bottle placed below the water surface to collect surface water samples (also called dip samples).

greenhouse gas (GHG)—Gas that traps heat in the atmosphere. The four major greenhouses gases are carbon dioxide, methane, nitrous oxide, and fluorinated gases.

groundwater—The water located beneath the earth's surface in soil pore spaces and in the fractures of rock formations.

hardness—Water hardness is caused by polyvalent metallic ions dissolved in water. In fresh water, these are mainly calcium and magnesium, although other metals such as iron, strontium, and manganese may contribute to hardness.

hectare—A metric unit of area equal to 10,000 square meters or 2.47 acres.

hydrology—The science dealing with the properties, distribution, and circulation of natural water systems.

internal radiation—Internal radiation occurs when radionuclides enter the body by ingestion of foods, milk, and water, and by inhalation. Radon is the major contributor to the annual dose equivalent for internal radionuclides.

ion—An atom or compound that carries an electrical charge.

irradiation—Exposure to radiation.

isotopes—Forms of an element having the same number of protons in their nuclei but differing in the number of neutrons.

Leadership in Energy and Environmental Design (LEED)—A suite of rating systems for the design, construction, operation, and maintenance of green buildings, homes, and neighborhoods. LEED is intended to help building owners and operators find and implement ways to be environmentally responsible and resource-efficient.

maximally exposed individual (MEI)—A hypothetical individual who, because of proximity, activities, or living habits, could potentially receive the maximum possible dose of radiation from a given event or process.

microbes—Microscopic organisms.

migration—The transfer or movement of a material through the air, soil, or groundwater.

millirem (mrem)—The dose equivalent that is one one-thousandth of a rem.

milliroentgen (mR)—A measure of x-ray or gamma radiation. The unit is one-thousandth of a roentgen.

minimum detectable activity (MDA)—The smallest activity of a radionuclide that can be distinguished in a sample by a given measurement system at a preselected counting time and at a given confidence level.

monitoring—A process whereby the quantity and quality of factors that can affect the environment and/or human health are measured periodically to regulate and control potential impacts.

natural radiation—Radiation arising from cosmic and other naturally occurring radionuclide sources (such as radon) present in the environment.

nuclide—An atom specified by its atomic weight, atomic number, and energy state. A radionuclide is a radioactive nuclide.

outfall—The point of conveyance (e.g., drain or pipe) of wastewater or other effluents into a ditch, pond, or river.

ozone—A gas made up of three oxygen atoms that occurs both in earth's upper atmosphere and at ground level. Ozone can be "good" or "bad" for human health and the environment, depending on its location in the atmosphere. Ozone acts as a protective layer high above the earth, but it can be harmful to breathe.

parts per billion (ppb)—A unit measure of concentration equivalent to the weight/volume ratio expressed as micrograms per liter or nanograms per milliliter.

parts per million (ppm)—A unit measure of concentration equivalent to the weight/volume ratio expressed as milligrams per liter or milligrams per kilogram.

person-rem—Collective dose to a population group. For example, a dose of 1 rem to 10 individuals results in a collective dose of 10 person-rem.

pH—A measure of the hydrogen ion concentration in an aqueous solution. Acidic solutions have a pH from 0 through < 7, basic solutions have a pH > 7, and neutral solutions have a pH = 7.

precision—The degree to which repeated measurements under unchanged conditions show the same results (also called reproducibility or repeatability).

quality assurance (QA)—Any action in environmental monitoring to ensure the reliability of monitoring and measurement data.

quality control (QC)—The routine application of procedures within environmental monitoring to obtain the required standards of performance in monitoring and measurement processes.

rad—The unit of absorbed dose deposited in a volume of material.

radioactivity—The spontaneous emission of radiation, generally alpha or beta particles or gamma rays, from the nucleus of an unstable isotope.

radioisotopes—Radioactive isotopes.

radionuclide—An unstable nuclide capable of spontaneous transformation into other nuclides by changing its nuclear configuration or energy level. This transformation is accompanied by the emission of photons or particles.

reclamation—Recovery of wasteland, desert, etc. by ditching, filling, draining, or planting.

reference material—A material or substance with one or more properties that is sufficiently well established and is used to calibrate an apparatus, to assess a measurement method, or to assign values to materials.

release—Any discharge to the environment. "Environment" is broadly defined as any water, land, or ambient air.

rem—The unit of dose equivalent (absorbed dose in rads × the radiation quality factor). Dose equivalent is frequently reported in units of millirem (mrem), which is one one-thousandth of a rem.

remediation—The correction of a problem. On the Oak Ridge Reservation remediation efforts focus on the safe cleanup of the environmental legacy resulting from research activities and weapons production over the past 5 decades.

remedial investigation/feasibility study (RI/FS)—An in-depth study designed to gather data needed to determine the nature and extent of contamination at a Superfund site; establish site cleanup criteria; identify preliminary alternatives for remedial action; and support technical and cost analyses of alternatives. The remedial investigation is usually done with the feasibility study. Together they are usually referred to as the "RI/FS."

roentgen—A unit of radiation exposure equal to the quantity of ionizing radiation that will produce one electrostatic unit of electricity in one cubic centimeter of dry air at 0°C and standard atmospheric pressure. One roentgen equals 2.58×10^{-4} coulombs per kilogram of air. [Note: A coulomb is a unit of electric charge—the SI (International System of Units) unit of electric charge equal to the amount of charge transported by a current of one ampere in one second.]

sensitivity—The capability of a methodology or an instrument to discriminate among samples with differing concentrations or containing varying amounts of analyte.

sievert (Sv)—The SI (International System of Units) unit of dose equivalent; 1 Sv = 100 rem.

spike—The addition of a known amount of reference material containing the analyte of interest to a blank sample.

spiked sample—A sample to which a known amount of some substance has been added.

stable—Not radioactive or not easily decomposed or otherwise modified chemically.

stack—A vertical pipe or flue designed to exhaust airborne gases and suspended particulate matter.

standard reference material (SRM)—A reference material distributed and certified by the National Institute of Standards and Technology.

storm water runoff—Rainfall that flows over the ground surface.

stratospheric ozone—The stratosphere or "good" ozone layer extends upward from about 6 to 30 miles above the earth's surface and protects the earth from the sun's harmful ultraviolet rays.

substrate—The substance, base, surface, or medium in which an organism lives and grows.

Superfund—The Superfund Amendments and Reauthorization Act amended the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) in 1986. CERCLA, the federal program to clean up the nation's uncontrolled hazardous waste, is now known as Superfund.

surface water—All water on the surface of the earth, as distinguished from groundwater.

terrestrial radiation—Ionizing radiation emitted from radioactive materials, primarily potassium-40, thorium, and uranium, in the earth's soils. Terrestrial radiation contributes to natural background radiation.

total activity—The total number of atoms of a radioactive substance that decay per unit of time.

total dissolved solids—Dissolved solids and total dissolved solids (generally associated with freshwater systems) consist of inorganic salts, small amounts of organic matter, and dissolved materials.

transect—A line across an area being studied. The line is composed of points where specific measurements or samples are taken.

transuranic (or transuranium)—Of or relating to elements with higher atomic weights than uranium; all 13 known transuranic elements are radioactive and are produced artificially.

transuranic waste—Solid radioactive waste containing primarily alpha-emitting elements heavier than uranium.

trip blank—A sample container of deionized water that is transported to a sampling location, treated as a sample, and sent to the laboratory for analysis; trip blanks are used to check for contamination resulting from transport, shipping, and site conditions.

turbidity—A measure of the concentration of sediment or suspended particles in solution.

volatile organic compounds—Organic chemicals that have a high vapor pressure at ordinary conditions. They include both human-produced and naturally occurring chemical compounds and are used in many industrial processes. Common examples include trichloroethane, tetrachloroethene, and trichloroethene.

watershed—The region draining into a river, river system, or body of water. Large watersheds may be subdivided into smaller units called **subwatersheds**, which collectively flow together to form larger sub-basins and river basins.

wetlands—Lowland areas, such as a marshes or swamps, sufficiently inundated or saturated by surface water or groundwater to support aquatic vegetation or plants adapted for life in saturated soils. Wetlands are those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands include swamps, marshes, bogs, and similar areas.

wind rose—A diagram that summarizes statistical information concerning wind direction and speed at a specific location.

Appendix B:
Climate Overview of the Oak Ridge Area

Appendix
B. Climate Overview of the Oak Ridge Area

B.1 Regional Climate

The climate of the Oak Ridge area and its surroundings may be broadly classified as humid subtropical. The term “humid” indicates that the region receives an overall surplus of precipitation compared to the level of evaporation and transpiration that is normally experienced throughout the year. The “subtropical” designation indicates that the region experiences a wide range of seasonal temperatures. Such areas are typified by significant differences in temperature between summer and winter. More specifically, the coldest month’s average temperature is above –3°C (27°F), and at least one summer month has an average temperature above 22°C (72°F). Also, the definition of the humid subtropical climate means that at least 4 months have an average temperature above 10°C (50°F). There are no major differences in monthly precipitation throughout the year, but the sources of precipitation may vary.

Oak Ridge winters are characterized by synoptic midlatitude cyclones that produce significant precipitation events roughly every 3 to 5 days. These wet periods are occasionally followed by arctic air outbreaks. Although snow and ice are not associated with many of these systems, occasional snowfall does result. Winter cloud cover tends to be enhanced by the regional terrain (due to cold air wedging and moisture trapping).

Severe thunderstorms, which can occur at any time of the year, occur most frequently during spring and rarely during winter. The Cumberland Mountains and Cumberland Plateau frequently inhibit the intensity of severe systems that traverse the region, particularly those moving from west to east, due to the downward momentum created as the storms move off higher terrain into the Great Valley. Summers are characterized by very warm, humid conditions. Occasional frontal systems may produce organized lines of thunderstorms (and rare damaging tornados). More frequently, however, summer precipitation results from “air mass” thundershowers that form as a consequence of daytime heating, rising humid air, and local terrain features. Although adequate precipitation usually occurs during the fall, August through October often are the driest months of the year. The occurrence of precipitation during the fall tends to be less cyclical than for other seasons but is occasionally enhanced by decaying tropical cyclones moving north from the Gulf of Mexico. During November, midlatitude cyclones again begin to dominate the weather and typically continue to do so until May.

Decadal-scale climate change regularly affects the East Tennessee region. Most of these changes appear related to the hemispheric temperature and precipitation effects caused by the frequency and phase of the El Niño–Southern Oscillation (ENSO), the Pacific Decadal Oscillation (PDO), and the Atlantic Multidecadal Oscillation (AMO). The ENSO and PDO patterns, with cycles of 3 to 7 years and about 60 years, respectively, affect Pacific Ocean sea surface temperature patterns. The AMO, with a cycle of 40 to 70 years, affects Atlantic sea surface temperature similar to the PDO. These medium- and long-range sea surface temperature patterns collectively modulate decadal-scale and longer regional temperature and precipitation trends in eastern Tennessee. The AMO shifted from a cold to a warm sea surface temperature phase in the mid-1990s and may continue in its present state for another decade or so. The PDO entered an either cool or transitional sea surface temperature state around 2000. Also, the ENSO pattern had frequently brought about warmer Eastern Pacific sea surface temperatures during the 1990s, but that phenomenon had subsided somewhat in the 2000s. A very strong El Niño occurred in 2015–2016, leading to above-normal temperatures, both locally and across much of the globe by 2016. Additionally, some evidence exists that human-induced climate change may be producing some effect on local temperatures via an array of first-order influences such as well-mixed greenhouse gases, land cover change, carbon soot, aerosols, and other effects. Solar influences on the jet stream, via changes to the stratospheric temperature gradient with respect to the 11-year solar cycle (and perhaps longer cycles), also play a role in inter-annual climate variability (Ineson et al. 2011). Perhaps in part due to the effects of the AMO and ENSO, the Oak Ridge climate warmed about 1.2°C from the 1970s to the 1990s but has remained within 0.2°C of the 1990s observed value. The late-20th-century warming appears to have lengthened the growing season (i.e., the period with temperatures above 0°C, or 32°F) by about 2 to 3 weeks over the last 30 years. This warming has primarily affected minimum temperature over the last 30 years; the effect is presumably related to changes in the interaction of the surface boundary layer with greenhouse gases and/or aerosol concentration changes. The effects of greenhouse gases on the nocturnal inversion layer (and thus on minimum temperatures) represent a redistribution of heat in the lower portion of the surface atmospheric layer. Temperature averages for individual years may vary significantly, as noted by the recent contrast of greater than 1°C between 2014 (14.8°C average) and 2015 (16.0°C average), largely the result of the recent strong El Niño. During the post–El Niño years of 2017 and 2018, the annual average temperature at ORNL returned to approximately the same level as in 2014 (14.5°C in 2018).

B.2 Winds

Five major terrain-related wind regimes regularly affect the Great Valley of eastern Tennessee:

- pressure-driven channeling
- downward-momentum transport or vertically coupled flow
- forced channeling
- along-valley and mountain-valley thermal circulations
- down sloping

Pressure-driven channeling and vertically coupled flow affect winds on scales comparable to those of the Great Valley (hundreds of kilometers). Forced channeling occurs on similar scales but is also quite important at small spatial scales, such as those characterizing the ridge-and-valley terrain on ORR (Birdwell 2011). Along-valley and mountain-valley circulations are thermally driven and occur within a large range of spatial scales. Thermally driven flows are more prevalent under conditions of clear skies and low humidity, favoring summer and especially fall months. Down sloping frequently is responsible for a slight temperature elevation when the Cumberland Mountains are on the windward side of ORR. Such windward flow also favors reduced wind speeds.

Forced channeling is defined as the direct deflection of wind by terrain. This form of channeling necessitates some degree of vertical motion transfer, implying that the mechanism is less pronounced during strong temperature-inversion conditions. Although forced channeling may result from interactions between large valleys and mountain ranges (such as the Great Valley and the surrounding mountains), the mechanism is especially important in narrow, small valleys such as those on ORR (Kossman and Sturman 2002).

Forced channeling within the Central Great Valley represents the dominant large-scale wind mechanism, influencing 50 to 60 percent of all winds observed in the area. For up-valley (southwest to northeast) flow cases, these winds are frequently associated with large wind shifts when they initiate or terminate (45°–90°). At small scales, ridge-and-valley terrain usually produces forced-channeled local flow (more than 90 percent of cases). Most forced-channeled winds prefer weak to moderate synoptic pressure gradients of less than 0.010 mb/km (Birdwell 2011).

Large-scale forced channeling occurs regularly within the Great Valley when northwest to north winds (perpendicular to the axis of the central Great Valley) coincide with vertically coupled flow. The phenomenon sometimes results in a split-flow pattern (winds southwest of Knoxville moving down-valley and those east of Knoxville moving up-valley). The causes of such a flow pattern may include the shape characteristics of the Great Valley (Kossman and Sturman 2002) but also may be associated with the specific location of the Cumberland and Smoky Mountains relative to upper-level wind flow (Eckman 1998). The convex shape of the Great Valley with respect to a northwest wind flow may lead to a divergent wind flow pattern in the Knoxville area, resulting in downward air motion. Additionally, horizontal flow is reduced by the windward mountain range (Cumberland Mountains), which increases buoyancy and Coriolis effects (also known as Froude and Rossby ratios). Consequently, the leeward mountain range (Smoky Mountains) becomes more effective at blocking or redirecting the winds.

Vertically coupled winds tend to occur when the atmosphere is unstably or neutrally buoyant. When a strong horizontal wind component is present, as in conditions behind a winter cold front or during strong regional cold air advection, winds tend to override the terrain, flowing roughly in the same direction as the winds aloft. This phenomenon is a consequence of the horizontal transport and momentum aloft being transferred to the surface. However, Coriolis effects may turn the winds by up to 40° to the left (Birdwell 1996).

In the Central Valley, vertically coupled winds dominate about 25 to 35 percent of the time; however, most such winds are turned toward an up-valley or down-valley direction when small-scale ridge-and-valley terrain is factored in. Wintertime vertically coupled flow is typically dominated by strong, large-scale pressure forces, whereas the summertime cases tend to be associated with a deep mixing depth (greater than 500 m). Most vertically coupled flows are associated with major wind shifts (90°–135°) when they begin or terminate (Birdwell 2011).

Another wind mechanism, pressure-driven channeling, is the redirection of synoptically induced wind flow through a valley channel. The direction of wind flow through the valley is determined by the axis of the pressure gradient superimposed on a valley axis (Whiteman 2000). The process is affected by Coriolis forces, a leftward deflection of winds in the Northern Hemisphere. Eckman (1998) suggested that pressure-driven channeling plays a significant role in the Great Valley. Winds driven purely by such a process shift from up-valley to down-valley flow or conversely as large-scale pressure systems induce reversals in air pressure gradients across the axis of the Great Valley. Since the processes involved in pressure-driven flow primarily affect the horizontal motion of air, the presence of a temperature inversion enhances this pattern significantly. Weak vertical air motion and momentum associated with such inversions allow different layers of air to slide over each other with varied direction of movement (Monti et al. 2002).

Within the Central Great Valley, and especially ORR, winds dominated by down-valley pressure-driven channeling range in frequency from 2 to 10 percent, with the lowest values in summer and the highest in winter. Up-valley pressure-driven channeling usually does not dominate winds in the Central Great Valley but co-occurs with forced-channeled winds 50 percent of the time. Winds dominated by pressure-driven channeling often result in large wind shifts (90°–180°) before and after the occurrence of the wind pattern. These wind shifts occur about twice as frequently within and near ORR when compared with wind shifts that take place in other parts of the Great Valley (Birdwell 2011). Most pressure-driven channeled winds occur in association with moderate (0.006–0.016 mb/km) synoptic pressure gradients.

Thermally driven winds are common in areas of significant complex terrain. These winds occur as a result of pressure and temperature differences caused by varied surface-air energy exchange at similar altitudes along a valley's axis, sidewalls, or slopes. Thermal flows operate most effectively when synoptic winds are light and when thermal differences are exacerbated by clear skies and low humidity (Whiteman 2000).

Ridge-and-valley terrain may be responsible for enhancing or inhibiting such flow, depending on ambient weather conditions. Large-scale thermally driven wind frequency varies from 2 percent to 20 percent with respect to season in the Central Great Valley. Frequencies are highest during summer and especially fall, when intense surface heating and/or low humidity help drive flow patterns (Birdwell 2011).

Annual wind roses have been compiled for 2018 for each of the 10 DOE-managed ORR meteorological towers (towers MT2, MT3, MT4, MT6, MT7, MT9, MT10, MT11, MT12, and MT13). These, along with other annual wind rose data, may be viewed online **here**. The wind roses represent large-scale trends and should be used with caution for estimates involving short-term variations.

A wind rose depicts the typical distribution of wind speed and direction for a given location. The winds are represented in terms of the direction from which they originate. The rays emanating from the center correspond to points of the compass. The length of each ray is related to the frequency at which winds blow from the given direction. The concentric circles represent increasing frequencies from the center outward, given in percentages. Precipitation wind roses display similar information except that wind speed frequencies are replaced with data associated with the rate of hourly precipitation. Likewise, wind direction stability and wind direction mixing height roses replace wind speeds with data on stability class and mixing height, respectively. Wind direction peak gust roses reflect the frequency of peak 1 to 10 s wind gusts for various wind directions.

B.3 Temperature and Precipitation

Temperature and precipitation normals (1981–2010) and extremes (1948–2018) and their durations for the city of Oak Ridge and ORNL are summarized in Table B.1. Decadal temperature and precipitation averages for the nearly five decades of the 1970s to 2010s are provided in Table B.2. Hourly freeze data (1985–February 2019) are given in Table B.3. Overall, at ORNL, 2018 was 0.1°C below normal with regard to temperatures compared to the 1981–2010 Oak Ridge base period, and precipitation was about 20 percent above normal compared to the 1981–2010 mean. ORNL became the official reporting site for the purposes of ORNL and this report in 2015 instead of the Oak Ridge townsite. This change was made in response to the implementation of climate data quality measurements initiated at ORNL in 2014 and in response to siting problems at the Oak Ridge townsite (KOQT).

B.3.1 Recent Climate Change with Respect to Temperature and Precipitation

Table B.2 presents a decadal analysis of temperature patterns for the decades of the 1970s to the 2010s. In general, temperatures in the Oak Ridge area rose from the 1970s to the 1990s and then nearly stabilized since the 1990s. Based on these average decadal temperatures, temperatures have risen 1.2°C between the decades of the 1970s and the 1990s, from 13.8°C to 15.0°C (56.8°F to 59.0°F). The warmest decade of the last five was the 2000s at 15.2°C (59.3°F). More detailed analysis reveals that these temperature changes have been neither linear nor equal with respect to the seasons.

From the 1970s to the 1990s, January and February average temperatures have seen increases of about 2.5°C, followed by a decline of just over 1°C since the 1990s. The observed peak in the 1990s may be associated with the effects of the AMO, though this climate response may include both natural and anthropogenic effects. The Arctic has seen the largest increase in temperatures anywhere in the Northern Hemisphere over the last 30 years, and this has an effect on Oak Ridge temperatures in winter due to the presence of Arctic air masses during that season.

During the winter months of January and February, much of the air entering eastern Tennessee comes from the Arctic. As a result, Oak Ridge temperatures have warmed more dramatically during those months in which Arctic air dominates. However, the changes affecting the months of January and

February do not seem to be the case for December temperature averages. December averages were relatively warm in the 1970s (4.6°C), bottomed out in the 1980s (3.1°C), returned to approximately 1970s levels in the 1990s and 2000s, and finally warmed (to about 6.1°C) by the 2010s.

Compared to the 1970s, temperatures have warmed 1.2°C, 1.6°C, and 2.1°C during the climatological spring months of March, April, and May, respectively. However, most of that warming did not occur until the 2000s for the months of March and April. The tendency toward warmer springs has had the effect of slightly lengthening the growing season.

Summer months (June, July, and August) were 2.0°C, 1.5°C, and 0.9°C warmer on average in the 2010s versus the 1970s; however, most observed warming during summer can be attributed to a rise in minimum temperatures. In fact, August maximum temperatures have declined about 0.7°C since the 2000s. Warming for June and July has slowed since the 2000s.

Climatological fall months (September, October, November) generally had the weakest average temperature increases (of 0.7°C, 1.2°C, and 0.4°C) since the 1970s. In fact, September and October have seen virtually no change in average temperature since the 1990s, while November has not shown a clear trend across the decades since the 1970s.

Considering annual mean temperatures only, the mean annual temperature increased by 1.4°C between the 1970s and the 2000s and then remained about the same in the 2010s (1.3°C warming compared to the 1970s). About 90 percent of the observed increase occurred between the 1980s and 1990s. Mean annual decadal-averaged temperatures have varied by only 0.2°C since the 1990s.

Table B.1. Climate normals (1981–2010) and extremes (1948–2018) for Oak Ridge National Laboratory, Oak Ridge, Tennessee

Monthly variables	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Temperature, °C (°F)													
30-Year Average Max	8.3 (46.9)	11.2 (52.1)	16.4 (61.6)	21.6 (70.8)	25.9 (78.6)	29.8 (85.7)	31.4 (88.5)	31.2 (88.1)	27.7 (81.9)	22.0 (71.6)	15.7 (60.2)	9.4 (49.0)	20.9 (69.6)
2018 Average Max	6.6 (43.8)	14.4 (58.0)	14.2 (57.5)	19.2 (66.5)	28.8 (83.8)	30.4 (86.8)	31.2 (88.2)	29.6 (85.2)	29.3 (84.7)	21.7 (71.0)	11.8 (53.3)	10.5 (50.9)	20.6 (69.1)
71-Year Record Max	25 (77)	27 (80)	30 (86)	33 (92)	35 (95)	41 (105)	41 (105)	39 (103)	39 (102)	32 (90)	28 (83)	26 (78)	41 (105)
30-Year Average Min	-2.2 (28.0)	-0.6 (30.9)	3.1 (37.5)	7.4 (45.4)	12.6 (54.7)	17.3 (63.1)	19.7 (67.5)	18.9 (66.1)	15.2 (59.3)	8.4 (47.2)	3.1 (37.6)	-0.9 (30.4)	8.5 (47.3)
2018 Average Min	-5.3 (22.5)	4.7 (40.4)	3.3 (37.9)	5.1 (41.3)	15.7 (60.3)	18.2 (64.7)	19.6 (67.3)	19.2 (66.6)	19.3 (66.7)	15.4 (59.8)	3.8 (38.7)	2.0 (35.6)	10.0 (50.0)
71-Year Record Min	-27 (-17)	-25 (-13)	-17 (1)	-7 (20)	-1 (30)	4 (39)	9 (49)	10 (50)	1 (33)	-6 (21)	-16 (3)	-22 (-7)	-27 (-17)
30-Year Average	3.1 (37.5)	5.3 (41.5)	9.8 (49.6)	14.6 (58.3)	19.3 (66.7)	23.6 (74.5)	25.6 (78.1)	25.2 (77.4)	21.5 (70.7)	15.2 (59.4)	9.4 (48.9)	4.3 (39.7)	14.7 (58.5)
2018 Average	0.4 (32.8)	9.5 (49.1)	12.0 (53.6)	12.0 (53.6)	21.6 (70.9)	23.5 (74.3)	24.7 (76.5)	23.5 (74.4)	23.3 (73.9)	15.4 (59.8)	6.6 (43.9)	5.9 (42.7)	14.6 (58.3)
2018 Departure from Average	-2.7 (-4.7)	4.2 (7.6)	-2.6 (-4.7)	-2.6 (-4.7)	2.3 (4.2)	-0.1 (-0.2)	-0.9 (-1.6)	-1.7 (-3.0)	1.8 (3.2)	0.2 (0.4)	-2.8 (-5.0)	1.6 (3.0)	-0.1 (-0.2)
30-year average heating degree days, °C (°F)[a]													
	332 (598)	273 (491)	243 (473)	49(88)	42(75)	0	0	0	14 (25)	107 (192)	224 (403)	428 (770)	1711 (3079)
30-year average cooling degree days, °C (°F)[a]													
	0	0	2 (4)	16 (29)	68 (122)	164 (296)	228 (410)	217 (390)	108 (194)	18 (32)	1 (2)	0	822 (1479)
Precipitation, mm (in.)													
30-Year Average	120.9 (4.76)	124.2 (4.89)	120.9 (4.76)	112.6 (4.43)	116.6 (4.59)	98.3 (3.87)	134.4 (5.29)	82.1 (3.23)	98.1 (3.86)	76.0 (2.99)	122.2 (4.81)	131.1 (5.16)	1337.5 (52.64)
2018 Totals	47.5 (1.87)	242.4 (9.54)	112.3 (4.42)	110.0 (4.33)	102.6 (4.04)	116.9 (460)	131.4 (5.17)	95.3 (3.75)	193.4 (7.61)	66.8 (2.63)	149.1 (5.87)	192.1 (7.56)	1559.8 (61.39)
2018 Departure from Average	-73.4 (-2.89)	118.1 (4.65)	-8.6 (-0.34)	-2.5 (-0.10)	-14.0 (-0.55)	18.5 (0.73)	-3.0 (-0.12)	13.2 (0.52)	95.3 (3.75)	-9.1 (-0.36)	26.9 (1.06)	61.0 (2.40)	222.3 (8.75)
71-Year Max Monthly	337.2 (13.27)	324.7 (12.78)	311.0 (12.24)	356.5 (14.03)	271.9 (10.70)	283.0 (11.14)	489.6 (19.27)	265.8 (10.46)	257.4 (10.14)	176.6 (6.95)	310.5 (12.22)	321.2 (12.64)	1939.4 (76.33)
71-Year Max 24-h	108.0 (4.25)	131.6 (5.18)	120.4 (4.74)	158.5 (6.24)	112.0 (4.41)	94.0 (3.70)	124.8 (4.91)	190.1 (7.48)	160.1 (6.30)	67.6 (2.66)	130.1 (5.12)	130.1 (5.12)	190.1 (7.48)
71-Year Min Monthly	23.6 (0.93)	21.3 (0.84)	54.1 (2.13)	46.2 (1.82)	20.3 (0.80)	13.5 (0.53)	31.3 (1.23)	13.7 (0.54)	Trace	Trace	34.8 (1.37)	17.0 (0.67)	911.4 (35.87)
Snowfall, cm (in.)													
30-Year Average	7.4 (2.9)	6.6 (2.6)	2.5 (1.0)	7.6 (0.3)	0	0	0	0	0	0	Trace	4.1 (1.6)	21.3 (8.4)
2018 Totals	40.7 (1.6)	Trace	0.2 (0.1)	0	0	0	0	0	0	0	Trace	2.5 (1.0)	6.8 (2.7)
71-Year Max Monthly	24.4 (9.6)	43.7 (17.2)	53.4 (21.0)	15.0 (5.9)	Trace	0	0	0	0	Trace	16.5 (6.5)	53.4 (21.0)	105.2 (41.4)
71-Year Max 24-h	21.1 (8.3)	28.7 (11.3)	30.5 (12.0)	13.7 (5.4)	Trace	0	0	0	0	Trace	16.5 (6.5)	30.5 (12.0)	30.5 (12.0)
Days w/temp													
30-Year Max ≥ 32°C	0	0	0	0.2	0.8	8.0	14.5	13.1	3.9	0	0	0	40.5
2018 Max ≥ 32°C	0	0	0	0	1	9	12	4	9	0	0	0	35
30-Year Min ≤ 0°C	21.6	16.6	10.7	2.7	0	0	0	0	0	1.7	10.4	18.8	82.5
2018 Min ≤ 0°C	22	7	8	6	0	0	0	0	0	0	10	12	65
30-Year Max ≤ °C	2.8	0.9	0.1	0	0	0	0	0	0	0	0	1.6	5.4
2018 Max ≤ 0°C	8	0	0	0	0	0	0	0	0	0	0	0	8
Days w/precipitation													
30-Year Avg ≥ 0.01 in.	11.5	11.0	11.7	10.4	11.7	11.1	12.4	9.6	8.4	8.4	9.6	12.0	127.8
2018 Days ≥ 0.01 in.	7	17	12	13	12	9	7	11	11	10	15	14	138
30-Year Avg ≥ 1.00 in.	1.3	1.4	1.2	1.2	1.3	1.0	1.4	0.8	1.3	1.0	1.5	1.6	15.0
2018 Days ≥ 1.00 in.	0	2	1	1	0	1	2	1	3	0	0	0	11

Table B.2. Decadal climate change (1970–2018) for City of Oak Ridge / ORNL, Tennessee, with 2018 comparisons

Monthly variables	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Temperature, °C (°F)													
1970–1979 Avg Max	6.6 (43.8)	9.7 (49.5)	15.6 (60.1)	21.4 (70.6)	24.8 (76.7)	28.5 (83.3)	30.0 (85.9)	29.7 (85.5)	26.8 (80.2)	20.8 (69.4)	14.5 (58.2)	10.0 (49.9)	19.9 (67.8)
1980–1989 Avg Max	6.9 (44.4)	10.2 (50.3)	15.9 (60.7)	21.0 (69.8)	25.6 (78.1)	29.8 (85.7)	31.6 (88.8)	30.7 (87.3)	27.1 (80.8)	21.3 (70.3)	15.6 (60.2)	8.6 (47.5)	20.3 (68.6)
1990–1999 Avg Max	9.4 (48.8)	12.3 (54.1)	16.2 (61.2)	21.9 (71.3)	26.2 (79.1)	29.7 (85.5)	32.1 (89.8)	31.4 (88.6)	28.4 (83.2)	22.6 (72.8)	15.2 (59.4)	10.4 (50.8)	21.3 (70.4)
2000–2009 Avg Max	8.8 (47.9)	11.2 (52.1)	17.0 (62.7)	21.4 (70.6)	25.8 (78.4)	29.8 (85.6)	30.8 (87.5)	31.4 (88.5)	27.6 (81.8)	21.8 (71.2)	15.9 (60.6)	9.8 (49.6)	21.0 (69.7)
2010–2018 Avg Max	8.1 (46.7)	11.4 (51.7)	16.4 (61.6)	22.6 (72.7)	26.7 (80.0)	30.4 (86.8)	31.3 (88.5)	30.7 (87.3)	28.1 (82.6)	22.1 (71.9)	15.3 (59.6)	11.1 (51.1)	21.1 (70.0)
1980s vs. 2010s	1.2 (2.2)	0.8 (1.4)	0.5 (1.0)	1.6 (2.8)	1.0 (1.9)	0.6 (1.1)	-0.2 (-0.3)	0.0 (0.0)	1.0 (1.8)	0.9 (1.6)	-0.3 (-0.6)	2.1 (3.7)	0.8 (1.4)
2000s vs. 2010s	-0.7 (-1.2)	-0.2 (-0.4)	-0.6 (-1.0)	1.2 (2.1)	0.9 (1.5)	0.6 (1.2)	0.6 (1.0)	-0.7 (-1.2)	0.5 (0.8)	0.4 (0.7)	-0.6 (-1.0)	0.9 (1.6)	0.2 (0.3)
2018 Avg Max	6.6 (43.8)	14.4 (58.0)	14..2 (57.5)	19.2 (66.5)	28.8 (83.8)	30.4 (86.8)	31.2 (88.2)	29.5 (85.2)	29.2 (84.7)	21.7 (71.0)	11.9 (53.3)	10.5 (50.9)	20.7 (69.1)
1970–1979 Avg Min	-3.4 (25.8)	-2.4 (27.6)	3.0 (37.4)	6.7 (44.1)	11.6 (52.8)	15.7 (60.2)	18.3 (64.9)	18.1 (64.6)	15.5 (59.9)	7.5 (45.5)	2.6 (36.8)	-0.8 (30.5)	7.7 (45.8)
1980–1989 Avg Min	-4.1 (24.7)	-2.1 (28.3)	1.7 (35.0)	6.0 (42.9)	11.4 (52.4)	16.2 (61.2)	19.0 (66.2)	18.4 (65.1)	14.4 (57.9)	7.5 (45.4)	3.1 (37.5)	-2.3 (27.8)	7.4 (45.3)
1990–1999 Avg Min	-0.9 (30.3)	0.0 (32.0)	2.9 (37.1)	7.2 (45.0)	12.5 (54.5)	17.2 (63.0)	20.0 (67.9)	18.9 (66.1)	15.1 (59.2)	8.2 (46.8)	2.2 (36.0)	0.1 (32.2)	8.6 (47.6)
2000–2009 Avg Min	-1.4 (29.5)	0.0 (32.0)	4.4 (39.9)	8.6 (47.5)	13.6 (56.4)	18.0 (64.3)	20.0 (67.9)	20.0 (68.0)	16.1 (61.0)	9.5 (49.0)	3.9 (39.0)	-0.4 (31.4)	9.4 (48.9)
2010–2018 Avg Min	-2.0 (28.3)	0.2 (32.4)	4.4 (39.9)	8.8 (47.8)	14.0 (57.2)	18.4 (65.2)	20.4 (68.7)	19.5 (67.2)	16.3 (61.3)	9.3 (48.8)	3.0 (37.3)	1.2 (34.2)	9.5 (49.1)
1980s vs. 2010s	2.0 (3.6)	2.3 (4.2)	2.7 (4.8)	2.7 (4.9)	2.7 (4.8)	2.2 (4.0)	1.4 (2.5)	1.2 (2.1)	1.8 (3.3)	1.9 (3.4)	-0.1 (-0.3)	3.5 (6.4)	2.1 (3.8)
2000s vs. 2010s	-0.7 (-1.2)	0.2 (0.4)	0.0 (0.0)	0.1 (0.3)	0.4 (0.8)	0.5 (0.9)	0.4 (0.8)	-0.5 (-0.9)	0.2 (0.3)	-0.1 (-0.2)	-1.0 (-1.7)	1.6 (2.8)	0.1 (0.2)
2018 Avg Min	-5.3 (22.5)	4.6 (40.4)	3.3 (37.9)	5.2 (41.3)	15.6 (60.3)	18.1 (64.7)	19.6 (67.3)	19.2 (66.6)	19.6 (66.7)	10.5 (50.9)	1.9 (35.3)	2.0 (51.6)	10.0 (50.0)
1970–1979 Avg	1.6 (34.9)	3.7 (38.6)	9.3 (48.8)	14.1 (57.4)	18.1 (64.7)	22.1 (71.8)	24.1 (75.4)	23.9 (75.0)	21.1 (70.0)	14.2 (57.5)	8.6 (47.5)	4.6 (40.3)	13.8 (56.8)
1980–1989 Avg	1.4 (34.6)	4.1 (39.3)	8.8 (47.9)	13.5 (56.4)	18.5 (65.3)	23.0 (73.4)	25.3 (77.5)	24.6 (76.2)	20.8 (69.4)	14.4 (57.9)	9.4 (48.8)	3.1 (37.7)	13.9 (57.0)
1990–1999 Avg	4.2 (39.6)	6.2 (43.1)	9.6 (49.2)	14.5 (58.2)	19.4 (66.8)	23.5 (74.3)	26.0 (78.9)	25.2 (77.4)	21.9 (71.4)	15.5 (59.8)	8.8 (47.8)	5.3 (41.5)	15.0 (59.0)
2000–2009 Avg	3.7 (38.7)	5.6 (42.1)	10.7 (51.3)	15.3 (59.6)	19.7 (67.5)	23.9 (75.1)	25.4 (77.7)	25.7 (78.3)	21.9 (71.4)	15.6 (60.1)	9.9 (49.8)	4.7 (40.5)	15.2 (59.3)
2010–2018 Avg	3.0 (37.3)	5.1 (42.1)	10.5 (50.9)	15.7 (60.1)	20.2 (68.3)	24.1 (75.5)	25.6 (78.0)	24.8 (76.6)	21.8 (71.2)	15.4 (59.7)	9.0 (48.1)	6.3 (42.5)	15.1 (59.2)
1980s vs. 2010s	1.5 (2.8)	1.5 (2.8)	1.7 (3.0)	2.1 (3.8)	1.7 (3.0)	1.1 (2.0)	0.2 (0.4)	0.2 (0.4)	1.0 (1.8)	1.0 (1.8)	-0.4 (-0.8)	2.7 (4.8)	1.2 (2.2)
2000s vs. 2010s	-0.7 (-1.3)	0.0 (0.0)	-0.2 (-0.4)	0.3 (0.6)	0.5 (0.9)	0.2 (0.4)	0.1 (0.2)	-0.9 (-1.7)	-0.1 (-0.2)	-0.3 (-0.5)	-1.0 (-1.8)	1.1 (2.0)	-0.1 (-0.1)
2018 Avg	0.4 (32.8)	9.5 (49.1)	8.8 (47.8)	17.3 (53.6)	21.6 (70.9)	23.5 (74.3)	24.6 (76.5)	23.5 (74.4)	23.2 (73.9)	15.4 (59.8)	6.6 (43.9)	6.4 (42.7)	14.6 (58.3)
Precipitation, mm (in.)													
1970–1979 Avg	143.4 (5.65)	94.6 (3.72)	169.4 (6.67)	118.3 (4.66)	149.8 (5.89)	120.5 (4.74)	130.4 (5.13)	109.8 (4.32)	107.2 (4.22)	99.8 (3.93)	129.6 (5.10)	145.3 (5.72)	1516.4 (59.68)
1980–1989 Avg	100.4 (3.95)	109.1 (4.29)	112.6 (4.43)	88.8 (3.49)	110.6 (4.35)	84.1 (3.31)	120.4 (4.74)	82.6 (3.25)	108.9 (4.29)	79.8 (3.14)	128.0 (5.04)	107.6 (4.23)	1236.2 (48.66)
1990–1999 Avg	141.4 (5.57)	136.5 (5.37)	149.0 (5.86)	126.3 (4.97)	113.4 (4.47)	110.0 (4.33)	134.8 (5.31)	83.6 (3.29)	71.9 (2.83)	67.3 (2.65)	109.8 (4.32)	161.0 (6.34)	1429.4 (56.26)
2000–2009 Avg	116.9 (4.60)	121.8 (4.80)	115.6 (4.55)	125.0 (4.92)	117.8 (4.64)	95.2 (3.75)	138.9 (5.47)	78.4 (3.09)	108.8 (4.28)	74.0 (2.91)	121.4 (4.78)	124.4 (4.90)	1333.4 (52.48)
2010–2018 Avg	130.1 (5.12)	147.6 (5.81)	117.6 (4.63)	135.4 (5.33)	91.2 (3.59)	124.2 (4.89)	158.3 (6.23)	86.1 (3.39)	126.8 (4.99)	78.5 (3.09)	127.5 (5.02)	152.7 (6.01)	1437.1 (56.56)
1980s vs. 2010s	29.5 (1.16)	38.4 (1.51)	5.0 (0.20)	46.5 (1.83)	-19.3 (-0.76)	40.1 (1.58)	37.9 (1.49)	3.6 (0.14)	17.9 (0.70)	-1.3 (-0.05)	-0.5 (-0.02)	45.1 (1.77)	198.3 (7.80)
2000s vs. 2010s	13.2 (0.52)	25.7 (1.01)	2.1 (0.08)	10.4 (0.41)	-26.7 (-1.05)	29.0 (1.14)	19.3 (0.76)	7.6 (0.30)	17.9 (0.70)	4.4 (0.17)	6.1 (0.24)	28.2 (1.11)	105.8 (4.16)
2018 Totals	47.5 (1.87)	242.4 (9.54)	112.3 (4.42)	112.5 (4.43)	102.6 (4.04)	116.8 (4.60)	131.4 (5.17)	95.3 (3.75)	193.4 (7.61)	66.8 (2.63)	149.1 (5.87)	192.1 (7.56)	1559.8 (61.39)
Snowfall, cm (in.)													
1970–1979 Avg	11.1 (4.4)	12.5 (4.9)	4.2 (1.7)	0.2 (0.1)	0	0	0	0	0	0	0.5 (0.2)	4.4 (1.8)	35.1 (13.8)
1980–1989 Avg	11.4 (4.5)	8.8 (3.5)	2.2 (0.9)	2.2 (0.9)	0	0	0	0	0	0	0	7.5 (3.0)	32.8 (12.9)
1990–1999 Avg	6.9 (2.7)	7.8 (3.1)	8.1 (3.2)	Trace	0	0	0	0	0	0	0.3 (0.1)	3.1 (1.2)	10.9 (4.3)
2000–2009 Avg	2.1 (0.8)	4.5 (1.8)	Trace	Trace	0	0	0	0	0	0	Trace	1.7 (0.7)	8.3 (3.3)
2010–2018 Avg	5.3 (2.1)	6.4 (2.5)	0.3 (0.1)	Trace	0	0	0	0	0	0	0.3 (0.1)	2.3 (0.9)	14.0 (5.5)
1980s vs. 2010s	-516 (-2.0)	-1.8 (-0.7)	-1.0 (-0.4)	-1.5 (-0.6)	0	0	0	0	0	0	0.3 (0.1)	-5.3 (-2.1)	-2.5 (-4.6)
2000s vs. 2010s	3.6 (1.4)	2.8 (1.1)	0.3 (0.1)	0.0 (0.0)	0	0	0	0	0	0	0.3 (0.1)	0.5 (0.2)	1.6 (2.9)
2018 Totals	4.1 (1.6)	Trace	Trace	Trace	0	0	0	0	0	0	Trace	2.5 (1.0)	6.9 (2.7)

Table B.3. Hourly subfreezing temperature data for Oak Ridge, Tennessee, January 1985–April 2019[a]

(Hours at or below 0, −5, −10, and −15°C)

Year	January				February				March			April		May		October		November			December				Annual			
	≤0	<-5	<-10	<-15	≤0	<-5	<-10	<-15	≤0	<-5	<-10	≤0	<-5	≤0	<-5	≤0	<-5	≤0	<-5	<-10	≤0	<-5	<-10	<-15	≤0	<-5	<-10	<-15
1985	467	195	103	39	331	127	26	0	105	6	0	43	3	0	0	0	0	22	0	0	431	201	66	2	1399	532	195	41
1986	308	125	38	10	161	29	3	0	124	28	0	17	0	0	0	0	0	32	10	0	232	34	0	0	874	226	41	10
1987	302	53	7	0	111	19	3	0	95	0	0	55	4	0	0	36	0	103	18	0	151	16	0	0	853	110	10	0
1988	385	182	43	0	294	102	19	0	97	9	0	6	0	0	0	45	0	62	3	0	301	55	0	0	1190	351	62	0
1989	163	27	0	0	190	66	10	0	35	0	0	18	0	3	0	7	0	125	14	0	421	188	71	30	962	295	81	30
1990	142	13	0	0	115	5	0	0	35	0	0	35	0	0	0	19	0	62	1	0	172	43	5	0	580	62	5	0
1991	186	44	0	0	158	47	15	0	49	0	0	0	0	0	0	4	0	148	16	0	192	38	0	0	737	145	15	0
1992	230	65	8	0	116	22	0	0	116	4	0	27	2	0	0	7	0	100	0	0	166	9	0	0	762	102	8	0
1993	125	11	0	0	245	47	8	0	124	32	9	3	0	0	0	0	0	152	2	0	223	44	0	0	872	136	17	0
1994	337	191	85	26	196	46	3	0	66	0	0	18	0	0	0	0	0	53	1	0	142	0	0	0	812	238	88	26
1995	240	45	6	0	217	84	18	0	37	0	0	0	0	0	0	0	0	142	3	0	288	84	10	0	924	216	34	0
1996	301	91	0	0	225	110	62	27	182	49	6	23	0	0	0	3	0	101	0	0	194	40	4	0	1029	290	72	27
1997	254	101	24	0	67	0	0	0	25	0	0	6	0	0	0	6	0	96	10	0	232	14	0	0	686	125	24	0
1998	97	10	7	0	25	0	0	0	74	20	0	0	0	0	0	0	0	38	0	0	132	4	0	0	366	34	7	0
1999	181	68	0	0	113	14	0	0	62	0	0	0	0	0	0	4	0	41	0	0	177	23	0	0	578	105	0	0
2000	273	62	5	0	127	30	0	0	18	0	0	8	0	0	0	11	0	94	11	0	345	124	7	0	876	227	12	0
2001	281	60	5	0	79	9	0	0	53	0	0	2	0	0	0	18	0	28	0	0	137	35	0	0	598	104	5	0
2002	185	28	0	0	121	16	0	0	91	17	0	2	0	0	0	0	0	41	0	0	82	6	0	0	522	67	0	0
2003	345	123	26	0	117	12	0	0	19	0	0	0	0	0	0	0	0	37	0	0	102	9	0	0	620	144	26	0
2004	285	50	2	0	76	0	0	0	18	0	0	0	0	0	0	0	0	9	0	0	247	41	4	0	635	91	6	0
2005	151	65	6	0	52	1	0	0	81	1	0	0	0	0	0	1	0	55	0	0	176	28	0	0	516	95	6	0
2006	70	0	0	0	169	19	0	0	44	0	0	0	0	0	0	15	0	37	0	0	126	41	1	0	461	60	1	0
2007	189	30	5	0	283	70	0	0	29	0	0	32	0	0	0	0	0	60	0	0	83	8	0	0	673	111	5	0
2008	242	86	11	0	114	7	0	0	69	6	0	0	0	0	0	15	0	89	18	0	157	34	5	0	686	151	16	0
2009	238	93	29	0	178	64	5	0	55	15	0	5	0	0	0	0	0	8	0	0	178	22	0	0	662	194	34	0
2010	384	181	14	0	289	32	0	0	40	2	0	0	0	0	0	0	0	46	0	0	364	109	11	0	1123	324	25	0
2011	300	61	0	0	108	14	0	0	2	0	0	0	0	0	0	5	0	29	0	0	91	0	0	0	535	75	0	0
2012	169	27	0	0	78	19	0	0	9	0	0	1	0	0	0	0	0	46	0	0	76	0	0	0	379	46	0	0
2013	245	49	0	0	120	12	0	0	95	7	0	0	0	0	0	11	0	121	0	0	173	6	0	0	765	74	0	0
2014	371	208	76	12	109	5	0	0	68	0	0	5	0	0	0	0	0	122	10	0	94	1	0	0	769	224	76	12
2015	228	52	16	0	371	120	31	6	52	16	0	0	0	0	0	0	0	11	0	0	41	0	0	0	703	188	47	6
2016[a]	333	82	12	0	211	17	0	0	35	0	0	9	0	0	0	0	0	44	3	0	163	32	0	0	795	134	12	0
2017	130	47	11	1	64	5	0	0	82	8	0	0	0	0	0	8	0	67	0	0	252	20	0	0	603	44	10	0
2018	362	199	86	4	67	7	0	0	49	2	0	11	0	0	0	0	0	89	6	0	102	11	0	0	680	225	86	4
2019[b]	146	46	1	0	46	0	0	0	80	9	0	5	0															
Avg.	247	79	18	3	153	34	6	1	63	7	0	9	0	0	0	6	0	68	4	0	190	39	5	1	729	161	29	4

[a] Source: 1985–2015 National Oceanic and Atmospheric Administration, Atmospheric Turbulence and Diffusion Division, KOQT Station, Automated Surface Observing System; 2016–2019 Oak Ridge National Laboratory, Tower "D"

[b] 2019 values through April 30, 2019

Decadal precipitation averages suggest some important changes in precipitation patterns in Oak Ridge over the period from the 1970s to 2010s. Although overall decadal precipitation averages have remained within a window of about 48 to 60 in. annually, there have been some decadal shifts in the patterns of rainfall on a monthly and seasonal scale. During winter (December, January, and February), precipitation declined slightly overall since the 1970s, but there has been a significant increase in February precipitation in the 2010s. Spring precipitation (March, April, and May) has declined about 20 percent since the 1970s but has remained relatively constant compared to the 1990s and especially the 2000s. For summer precipitation (June, July, and August), changes in precipitation are mixed. June values have changed little in the 2010s versus the 1970s, but July values have increased about 20 percent, and August values declined about 20 percent. Similar patterns are revealed for the fall months. September in the 2010s shows about a 20 percent increase compared to the 1970s while October shows about a 20 percent decrease. There was little change in precipitation for November. Overall, annual average precipitation in the 2010s is only about 6 percent less than in the 1970s (59.68 versus 56.56 in.). Also, both the 1980s and 2000s were 10 percent to 20 percent drier than the 2010s while the 1990s exhibited similar precipitation. The most recent calendar year (2018) yielded precipitation totals about 20 percent above the 30-year mean, with a total of 1,560 mm (61.39 in.). The total period of observed precipitation for Oak Ridge covers the period from 1948 to 2018.

The previously discussed increase in winter temperatures by the 2000s and 2010s has affected monthly and annual snowfall amounts until recently. During the 1970s and 1980s, snowfall averaged about 25.4 to 28 cm (10 to 11 in.) annually in Oak Ridge. However, during the most recent two decades (2000s and 2010s), snowfall has averaged only 9.6 cm (3.8 in) per year. This decrease seems to have occurred largely since the mid-1990s. There has been a slight cooling of January and February temperatures in the 2010s compared to the 2000s, which seems to have reversed the decrease in snowfall slightly, with annual averages of 14.0 cm (5.5 in.). Concurrent with the overall decrease in snowfall, the annual number of hours of subfreezing weather has generally declined since the 1980s (see Table B.3). However, the number of subfreezing hours during 2010 (1,123 h) was the highest recorded since 1988. January 2014 was the coldest January since 1985, with 371 subfreezing hours, and February 2015 was the coldest February since 1978, also with 371 subfreezing hours.

Selected wind roses for ORR towers that show wind direction for hours with precipitation and other relevant meteorological parameters have been compiled for 2018 and may be reviewed **here**.

Hourly values of subfreezing temperatures in Oak Ridge are presented in Table B.3 for January 1985 through February 2019. During the middle to late 1980s, a typical year experienced about 900–1,000 hours of subfreezing temperatures. In recent years, the value has fallen to about 600–700 hours, though higher values have occurred relatively recently (2010 at 1,123 hours). Other statistics on winter precipitation may be found **here**.

B.4 Moisture

ORR's humid environment results in frequent saturation of the surface layer, especially at night. Average annual humidity at ORNL (Tower MT2) is 74.7 percent (2015–2018) at 2 m above ground level and 71.8 percent at 15 m above the ground. In terms of absolute humidity (grams per cubic meter), the average annual humidity for the same location is 10.3 g/m^3 and 10.2 g/m^3, respectively. This value varies greatly throughout the annual cycle, ranging from a monthly minimum of about 4.6 g/m^3 during winter to a maximum of about 17.2 g/m^3 during summer. These data are summarized for absolute and relative humidity and dew point **here**.

B.5 Severe Weather

On average, thunderstorms and associated lightning occur in the Oak Ridge area at a rate of 48.3 days per year, with a monthly maximum between 10 and 11 days occurring in July. About 41 of these thunderstorm days occur during the 7-month period from April through October, with the remainder spread evenly throughout the late fall and winter. The highest number of thunderstorm days at ORNL (65) was observed during 2012; the lowest (34) was observed during 2007. Monthly and annual average numbers of thunderstorm days for ORNL and Knoxville McGhee-Tyson Airport, respectively, during 2001–2018 can be viewed **here**.

Hailstorms are infrequent on ORR and typically occur in association with severe thunderstorms. The phenomenon usually occurs as a result of high-altitude thunderstorm updrafts, which propel water droplets above the freezing level. Some hail events have been known to occur in association with non-thunder rain showers and low freezing levels (particularly during winter or spring). Most hailstorm occurrences (77 percent) do not produce hailstones larger than 2 cm (about ¾ in.). During the period from 1961 through 1990, about six hail events (with hailstones larger than about 2 cm) were documented to have occurred at locations within 40 km (25 miles) of ORNL. Nearly all of these events occurred during the summer and fall seasons. During the 2011 significant tornado outbreak in East Tennessee, large hail (greater than 2 cm) was observed in Farragut, Tennessee, about 15 km (9 miles) southeast of ORNL.

East Tennessee experiences a tornado "outbreak" about once every 3 to 6 years on average. Tornadoes occur more frequently in Middle and West Tennessee. Tornado indices from the National Weather Service in Morristown show that since 1950, three tornadoes have been documented within 10 km (6 miles) of ORNL, represented by two F0 (Fujita Scale) tornadoes and one F3 tornado. A moderately strong F3 tornado occurred in February 1993 and moved through Bear Creek Valley near the Y-12 National Security Complex, with winds damaging the roofs of several buildings along Union Valley Road. To date, the February 1993 tornado has been the only documented tornado to occur within ORR.

Nine additional tornadoes have been documented since 1950 within 20 km (12 miles) of ORNL, ranging in intensity from F0/EF0 (Enhanced Fujita Scale) to F2/EF2. The most recent of these were three EF0–EF1 tornadoes that occurred during the April 27, 2011 tornado outbreak and an EF0 tornado near Kingston, Tennessee on June 10, 2014. The storm system that produced the latter tornado brought a squall line through ORNL that produced high winds and some minor damage. The remaining group of tornadoes that were within 20 km (12 miles) of ORNL affected eastern Roane County to the south and the Edgemoor Road area to the northeast of ORR. Another 10 tornadoes, ranging from F0/EF0 to F3/EF3 in intensity, have occurred within 35 km (22 miles) of ORNL since 1950. Most of them occurred to the east and south of ORR in Knox and Roane Counties; however, a few occurred in the Rocky Top and Norris areas. Tornado statistics relevant to ORR are provided **here** for Anderson, Knox, Loudon, and Roane Counties.

The annual probability that a tornado will strike any location in a grid square may be estimated by multiplying the number of tornadoes per year per square kilometer (in that particular grid square) by the path area of a tornado. The result of such a calculation is seen to be greatly affected by the assumption of the size of the path area of a tornado. In total, about 22 tornadoes have been documented within 35 km (22 miles) of ORNL since 1950. This represents a surface area of 3,848 km^2 (1,485 $miles^2$) and yields a probability of about 0.006 tornadoes per square kilometer per 50-year period.

B.6 Stability

The local ridge-and-valley terrain plays a role in the development of stable surface air under certain conditions and influences the dynamics of airflow. Although ridge-and-valley terrain creates identifiable patterns of association during unstable conditions as well, strong vertical mixing and momentum tend to reduce these effects. “Stability” describes the tendency of the atmosphere to mix (especially vertically) or overturn. Consequently, dispersion parameters are influenced by the stability characteristics of the atmosphere. Stability classes range from A (very unstable) to G (very stable), with D being a neutral state.

The suppression of vertical motions during stable conditions increases the effect of local terrain on air motion. Conversely, stable conditions isolate wind flows within the ridge-and-valley terrain from the effects of more distant terrain features and from winds aloft. These effects are particularly significant with respect to mountain waves. Deep, stable layers of air tend to reduce the vertical space available for oscillating vertical air motions caused by local mountain ranges (Smith et al. 2002). This effect on mountain wave formation may be important to the impact that the nearby Cumberland Mountains may have on local airflow.

A second factor that may decouple large-scale wind flow effects from local ones (and thus produce stable surface layers) occurs with overcast sky conditions. Clouds overlying the Great Valley may warm due to direct insolation on the cloud tops. Warming may also occur within the clouds as latent energy, which is released due to the condensation of moisture. Surface air underlying the clouds may remain relatively cool as the layer remains cut off from direct exposure to the sun. Consequently, the vertical temperature gradient associated with the air mass becomes more stable (Lewellen and Lewellen 2002). Long wave cooling of fog decks has also been observed to help modify stability in the surface layer (Whiteman et al. 2001).

Stable boundary layers typically form as a result of radiational cooling processes near the ground (Van De Weil et al. 2002); however, they are also influenced by the mechanical energy supplied by horizontal wind motion, which is in turn influenced by the synoptic-scale weather-related pressure gradient. Ridge-and-valley terrain may have significant ability to block such winds and their associated mechanical energy (Carlson and Stull 1986). Consequently, radiational cooling at the surface is enhanced since there is less wind energy available to remove chilled air.

Stable boundary layers also exhibit intermittent turbulence, which has been associated with the above factors. The process results from a give-and-take between the effects of friction and radiational cooling. As a stable surface layer intensifies via a radiational cooling process, it tends to decouple from air aloft, thereby reducing the effects of surface friction. The upper air layer responds with an acceleration in wind speed. Increased wind speed aloft results in an increase in mechanical turbulence and wind shear at the boundary with the stable surface layer. Eventually, the turbulence works into the surface layer and weakens it. As the inversion weakens friction again increases, reducing wind speeds aloft. The reduced wind speeds aloft allow enhanced radiation cooling at the surface, which reintensifies the inversion and allows the process to start again. Van De Weil et al. (2002) have shown that cyclical temperature oscillations up to 4°C (7°F) may result from these processes. Since these intermittent processes are driven primarily by large-scale horizontal wind flow and radiational cooling of the surface, ridge-and-valley terrain significantly affects the intensity of these oscillations.

Wind roses for stability and mixing depth have been compiled for all ORR tower sites for 2018. They may be viewed **here**. The wind roses in general reveal that both unstable conditions and/or deep mixing depths are associated with less channeling of winds and that stable conditions and/or shallow mixing depths tend to promote channeled flow. Associated mixing height tables for 2018 can be accessed **here**.

B.7 References

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Appendix C:
Reference Standards and Data for Water

Appendix
C. Reference Standards and Data for Water

Table C.1. Reference standards for radionuclides in water

Parameter[a]	National primary drinking water	DCS[c]
^{241}Am		170
^{214}Bi		260,000
^{109}Cd		16,000
^{143}Ce		26,000
^{60}Co		7,200
^{51}Cr		790,000
^{137}Cs		3,000
^{155}Eu		87,000
Gross alpha[d]		15
Gross beta (mrem/year)		4
^{3}H		1,900,000
^{131}I		1,300
^{40}K		4,800
^{237}Np		320
^{234m}Pa		71,000
^{238}Pu		150
$^{239/240}Pu$		140
^{226}Ra		87
^{228}Ra		25
^{106}Ru		4,100
^{90}Sr		1,100
^{99}Tc		44,000
^{228}Th		340
^{230}Th		160
^{232}Th		140
^{234}Th		8,400
^{234}U		680
^{235}U		720
^{236}U		720
^{238}U		750

[a]Only the radionuclides included in the Oak Ridge Reservation monitoring programs are listed. Unless labeled otherwise, units are pCi/L.
[b]40 *CFR* Part 141, *National Primary Drinking Water Regulations*, Subparts B and G. The drinking water standards are presented strictly for reference purposes and have regulatory applicability only for public water supplies.
[c]DOE. "Derived Concentration Technical Standard, DOE-STD-1196-2011, April 2011."
[d]Excludes radon and uranium.
[e]These values are not maximum contaminant levels but are concentrations that result in the effective dose equivalent of the maximum contaminant level for gross beta emissions, which is 4 mrem/year.
[f]Applies to combined ^{226}Ra and ^{228}Ra.
[g]Minimum of uranium isotopes.

Table C.2. TDEC and EPA nonradiological water quality standards and criteria (μg/L)

Chemical	TDEC and EPA Drinking Water Standards[a]	TDEC Fish and Aquatic Life Criteria		TDEC recreation criteria water + organisms, organisms only[b]
		Maximum	Continuous	
Acenaphthene				670, 990
Acrolein				6, 9
Acrylonitrile (c)				0.51, 2.5
Alachlor	2 (E1, T)			
Aldrin (c)		3.0	–	0.00049, 0.00050
Aldicarb	3 (E1)			
Aldicarb sulfoxide	4 (E1)			
Aldicarb sulfone	2 (E1)			
Aluminum	200 (E2)			
Anthracene				8300, 40,000
Antimony	6 (E1, T)			5.6, 640
Arsenic (c)	10 (E1, T)			10.0, 10.0
Arsenic(III)[c]		340[c]	150[c]	
Asbestos	7 million fibers/L (MFL) (E1)			
Atrazine	3 (E1, T)			
Barium	2000 (E1, T)			
Benzene (c)	5 (E1, T)			22, 510
Benzidine (c)				0.00086, 0.0020
Benzo(a)anthracene (c)				0.038, 0.18
Benzo(a)pyrene (c)	0.2 (E1, T)			0.038, 0.18
Benzo(b)fluoranthene (c)				0.038, 0.18
Benzo(k)fluoranthene (c)				0.038, 0.18
Beryllium	4 (E1, T)			
a-BHC (c)				0.026, 0.049
b-BHC (c)				0.091, 0.17
g-BHC (Lindane)	0.2 (E1, T)	0.95	–	0.98, 1.8
Bis(2-chloroethyl)ether (c)				0.30, 5.3
Bis(2-chloro-isopropyl) ether				1400, 65,000
Bis(2-ethylhexyl) phthalate (c)				12, 22
Bis (Chloromethyl) ether (c)				12, 22
Bromate	10 (E1)			
Bromoform (c)				43, 1400
Butylbenzyl phthalate				1500, 1900
Cadmium	5 (E1, T)	2.0[d]	0.25[d]	
Carbofuran	40 (E1, T)			
Carbon tetrachloride (c)	5 (E1, T)			2.3, 16
Chlordane (c)	2 (E1, T)	2.4	0.0043	0.0080, 0.0081
Chloride	250,000 (E2)			
Chlorine (TRC)	4000 (E1)	19	11	
Chlorite	1000 (E1)			
Chlorobenzene				130, 1600
Chlorodibromomethane (c)				4.0, 130
Chloroform (c)				57, 4700
Chloromines (as Cl2)	4000 (E1)			
Chlorine dioxide (as Cl2)	800 (E1)			

Table C.2. TDEC and EPA nonradiological water quality standards and criteria (µg/L) (continued)

Chemical	TDEC and EPA Drinking Water Standards[a]	TDEC Fish and Aquatic Life Criteria		TDEC recreation criteria water + organisms, organisms only[b]
		Maximum	Continuous	
2-Chloronaphthalene				1000, 1600
2-Chlorophenol				81, 150
Chromium (total)	100 (E1, T)			
Chromium(III)		570[d]	74[d]	
Chromium(VI) [c]		16[c]	11[c]	
Chrysene (c)				0.038, 0.18
Coliforms	no more than 5% of samples per month can be positive for total coliforms (E1)	2880/100 mL, *E. coli* (single sample)	630/100 mL, *E. coli* (geometric mean)	126/100 mL, geometric mean, *E. coli* 487, maximum lakes/reservoirs, *E. coli* 941, maximum, other water bodies, *E. coli*
Color	15 color units (E2)			
Copper	1000 (E2) 1300 (E1 "Action Level")	13[d]	9.0[d]	
Cyanide (as free cyanide)	200 (E1, T)	22	5.2	140, 140
2,4-D (Dichlorophennoxyacetic acid)	70 (E1, T)			
4,4'-DDT (c)		1.1	0.001	0.0022, 0.0022
4,4'-DDE (c)				0.0022, 0.0022
4,4'-DDD (c)				0.0031, 0.0031
Dalapon	200 (E1, T)			
Demeton			0.1	
Diazinon		0.1	0.1	
Dibenz(a,h)anthracene (c)				0.038, 0.18
1,2-dibromo-3-chloropropane (DBCP)	0.2 (E1, T)			
1,2-Dichlorobenzene (*ortho-*)	600 (E1, T)			420, 1300
1,3-Dichlorobenzene (*meta-*)				320, 960
1,4-Dichlorobenzene (*para-*)	75 (E1, T)			63, 190
3,3-Dichlorobenzidine (c)				0.21, 0.28
Dichlorobromomethane (c)				5.5, 170
1,2-Dichloroethane (c)	5 (E1, T)			3.8, 370
1,1-Dichloroethylene	7 (E1, T)			330, 7100
Cis-1,2-Dichloroethylene	70 (E1, T)			
trans 1,2-Dichloroethylene	100 (E1, T)			140, 10,000
Dichloromethane	5 (E1, T)			
2,4-Dichlorophenol				77, 290
1,2-Dichloropropane (c)	5 (E1, T)			5.0, 150
1,3-Dichloropropene (c)				3.4, 210
Dieldrin (b)(c)		0.24	0.056	0.00052, 0.00054
Diethyl phthalate				17,000, 44,000
Di (2-ethylhexyl) adipate	400 (E1, T)			
Di (2-ethylhexyl) phthalate	6 (E1, T)			
Dinoseb	7 (E1, T)			
Dimethyl phthalate				270,000, 1,100,000

Table C.2. TDEC and EPA nonradiological water quality standards and criteria (µg/L) (continued)

Chemical	TDEC and EPA Drinking Water Standards[a]	TDEC Fish and Aquatic Life Criteria		TDEC recreation criteria water + organisms, organisms only[b]
		Maximum	Continuous	
Dimethylphenols				380, 850
Di-n-butyl phthalate				2000, 4500
2,4-Dinitrophenol				69, 5300
2,4-Dinitrotoluene (c)				1.1, 34
Dioxin (2,3,7,8-TCDD) (c)	3 E-5 (E1, T)			0.000001, 0.000001
Diquat	20 (E1, T)			
1,2-Diphenylhydrazine (c)				0.36, 2.0
a-Endosulfan		0.22	0.056	62, 89
b-Endosulfan		0.22	0.056	62, 89
Endosulfan sulfate				62, 89
Endothall	100 (E1, T)			
Endrin	2 (E1, T)	0.086	0.036	0.059, 0.06
Endrin aldehyde				0.29, 0.30
Ethylbenzene	700 (E1)			530, 2100
Ethylene dibromide	0.05 (E1, T)			
Fluoranthene				130, 140
Fluorene				1100, 5300
Fluoride	2000 (E2) 4000 (E1,T)			
Foaming agents	500 (E2)			
Glyphosate	700 (E1, T)			
Guthion			0.01	
Haloacetic acids (five)	60 (E1)			
Heptachlor (c)	0.4 (E1, T)	0.52	0.0038	0.00079, 0.00079
Heptachlor epoxide (c)	0.2 (E1, T)	0.52	0.0038	0.00039, 0.00039
Hexachlorobenzene (b)(c)	1 (E1, T)			0.0028, 0.0029
Hexachlorobutadiene (b)(c)				4.4, 180
Hexachlorocyclopentadiene	50 (E1, T)			40, 1100
Hexachloroethane (c)				14, 33
Ideno(1,2,3-cd)pyrene (c)				0.038, 0.18
Iron	300 (E2)			
Isophorone (c)				350, 9600
Lead	15 (E1 “Action Level”)	65[d]	2.5[d]	
Lindane	0.2 (T)			
Malathion			0.1	
Manganese	50 (E2)			
Mercury (inorganic)[c]	2 (E1)	1.4[c]	0.77[c]	0.05, 0.051
Methoxychlor	40 (E1, T)		0.03	
Methyl bromide				47, 1500
2-Methyl-4,6-dinitrophenol				13, 280
Methylene chloride (Dichloromethane) (c)				46, 5900
Mirex (b)			0.001	
Monocholorobenzene	100 (E1, T)			
Nickel	100 (T)	470[d]	52[d]	610, 4600

Table C.2. TDEC and EPA nonradiological water quality standards and criteria (µg/L) (continued)

Chemical	TDEC and EPA Drinking Water Standards[a]	TDEC Fish and Aquatic Life Criteria		TDEC recreation criteria water + organisms, organisms only[b]
		Maximum	Continuous	
Nitrate as N	10,000 (E1,T)			
Nitrite as N	1000 (E1, T)			
Nitrobenzene				17, 690
Nitrosamines				0.0008, 1.24
Nitrolsodibutylamine (c)				0.063, 2.2
Nitrosodiethylamine (c)				0.008, 12.4
Nitrosopyrrolidine (c)				0.16, 340
N-Nitrosodimethylamine (c)				0.0069, 30
N-Nitrosodi-n-propylamine (c)				0.05, 5.1
N-Nitrosodiphenylamine (c)				33, 60
Nonylphenol		28.0	6.6	
Odor	3 threshold odor number (E2)			
Oxamyl (Vydate)	200 (E1, T)			
Parathion		0.065	0.013	
Pentachlorobenzene (b)				1.4, 1.5
Pentachlorophenol (c)	1 (E1, T)	19[e]	15[e]	2.7, 30
pH	6.5 to 8.5 units (E2) 6.0 to 9.0 units (T)		6.0 to 9.0 units, wade-able streams 6.5 to 9.0 units, larger rivers, lakes, etc	6.0 to 9.0 units
Phenol				10,000, 860,000
Picloram	500 (E1,T)			
PCBs, total (c)	0.5 (E1, T)	–	0.014	0.00064, 0.00064
Pyrene				830, 4000
Selenium	50 (E1, T)	20	5	170, 4200
Silver	100 (E2)	3.2[d]	–	
Simazine	4 (E1, T)			
Styrene	100 (E1, T)			
Sulfate	250,000 (E2)			
1,1,2,2-Tetrachloroethane (c)				1.7, 40
1,2,4,5-Tetrachlorobenzene (b)				0.97, 1.1
Tetrachloroethylene (c)	5 (E1, T)			6.9, 33
Thallium	2 (E1, T)			0.24, 0.47
Toluene	1000 (E1, T)			1300, 15,000
Total dissolved solids	500,000 (E2)			
Total Nitrate and Nitrite	10,000 as N (E1,T)			
Total trihalomethanes	80 (E1)			
Toxaphene (b)(c)	3 (E1, T)	0.73	0.0002	0.0028, 0.0028
2,4,5-TP (Silvex)	50 (E1, T)			1800, 3600
Tributyltin (TBT)		0.46	0.072	
1,2,4-Trichlorobenzene	70 (E1, T)			35, 70
1,1,1-Trichloroethane	200 (E1, T)			

Table C.2. TDEC and EPA nonradiological water quality standards and criteria (µg/L) (continued)

Chemical	TDEC and EPA Drinking Water Standards[a]	TDEC Fish and Aquatic Life Criteria		TDEC recreation criteria water + organisms, organisms only[b]
		Maximum	Continuous	
1,1,2-Trichloroethane (c)	5 (E1, T)			5.9, 160
Trichloroethylene (c)	5 (E1, T)			25, 300
2,4,6-Trichlorophenol (c)				14, 24
Vinyl chloride (c)	2 (E1, T)			0.25, 24
Xylenes (total)	10,000 (E1, T)			
Zinc	5000 (E2)	120[d]	120[d]	7400, 26,000

[a]E1 = EPA Primary Drinking Water Standards; E2 = EPA Secondary Drinking Water Standards; T = TDEC domestic water supply criteria.
[b]For each parameter, the first recreational criterion is for “water and organisms” and is applicable on the Oak Ridge Reservation (ORR) only to the Clinch River because the Clinch is the only stream on ORR that is classified for both domestic water supply and for recreation. The second criterion is for “organisms only” and is applicable to the other streams on ORR. TDEC uses a 10^{-5} risk level for recreational criteria for all carcinogenic pollutants (designated as (c) under “Chemical” column). Recreational criteria for noncarcinogenic chemicals are set using a 10^{-6} risk level. (Note: All federal recreational criteria are set at a 10^{-6} risk level.)
[c]Criteria are expressed as dissolved.
[d]Criteria are expressed as dissolved and are a function of total hardness (mg/L). Criteria displayed correspond to a total hardness of 100 mg/L.
[e]Criteria are expressed as a function of pH; values shown correspond to a pH of 7.8.

Abbreviations
TDEC = Tennessee Department of Environment and Conservation
EPA = US Environmental Protection Agency

Appendix D:
National Pollutant Discharge Elimination System Noncompliance Summaries for 2018

Appendix D. National Pollutant Discharge Elimination System Noncompliance Summaries for 2018

D.1 Y-12 National Security Complex

The Y-12 National Security Complex was in full compliance with the National Pollutant Discharge Elimination System (NPDES) permit in 2018. Adequate data points were obtained from sampling required by the NPDES permit. Compliance with permit discharge limits for 2018 was 100 percent.

D.2 East Tennessee Technology Park

The East Tennessee Technology Park program was 100 percent compliant with the numerical permit limits during 2018. The current ETTP NPDES permit was effective on April 1, 2015 and will remain in effect until March 31, 2020.

D.3 Oak Ridge National Laboratory

In 2018, compliance with the Oak Ridge National Laboratory NPDES permit was determined by laboratory analyses and field measurements. The NPDES permit limit compliance rate for all discharge points for 2018 was 100 percent.

Appendix E: Radiation

Appendix
E. Radiation

This appendix presents basic information about radiation. The information is intended as a basis for understanding the potential doses associated with releases of radionuclides from the Oak Ridge Reservation (ORR), not as a comprehensive discussion of radiation and its effects on the environment and on biological systems.

Radiation comes from natural and human sources. People are constantly exposed to naturally occurring radiation. For example, cosmic radiation, radon in air, potassium in food and water, and uranium, thorium, and radium in the earth's crust are all sources of radiation. The following discussion describes important aspects of radiation and its types, sources, and pathways; radiation measurement; and dose information.

E.1 Atoms and Isotopes

All matter is made up of atoms. An atom is "a unit of matter consisting of a single nucleus surrounded by a number of electrons equal to the number of protons in the nucleus" (Alter 1986). The number of protons in the nucleus determines an element's atomic number or chemical identity. With the exception of hydrogen, the nucleus of each type of atom also contains at least one neutron. Unlike protons, the neutrons may vary in number among atoms of the same element. The number of neutrons and protons determines the atomic weight. Atoms of the same element that have different numbers of neutrons are called isotopes. In other words, isotopes have the same chemical properties but different atomic weights (see Figure E.1).

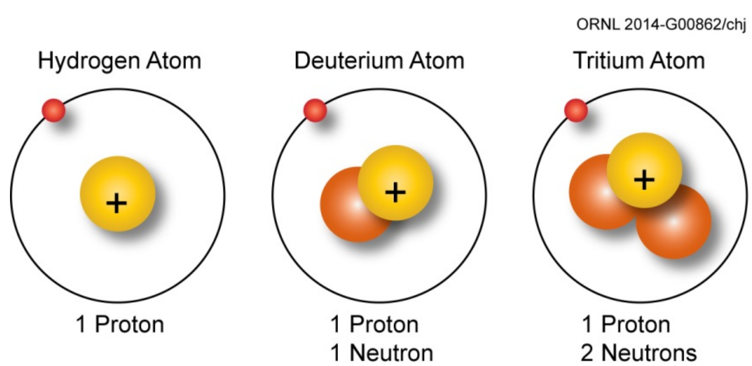

Figure E.1. The hydrogen atom and its isotopes

For example, the element uranium has 92 protons. All isotopes of uranium, therefore, have 92 protons. However, each uranium isotope has a different number of neutrons:

- uranium-238 has 92 protons and 146 neutrons
- uranium-235 has 92 protons and 143 neutrons
- uranium-234 has 92 protons and 142 neutrons

Some isotopes are stable, or nonradioactive; some are radioactive. Radioactive isotopes are called radionuclides or radioisotopes. In an attempt to become stable, radionuclides emit rays or particles. This emission of rays and particles is known as radioactive decay. Each radioisotope has a radioactive half-life, which is the average time required for half of a specified number of atoms to decay. Half-lives can be very short (fractions of a second) or very long (millions of years), depending on the isotope. Table E.1 shows the half-lives of selected radionuclides.

Table E.1. Selected radionuclide half-lives

Radionuclide	Symbol	Half-life (in years unless otherwise noted)	Radionuclide	Symbol	Half-life (in years unless otherwise noted)
Americium-241	^{241}Am	432.2	Plutonium-238	^{238}Pu	87.74
Americium-243	^{243}Am	7.37E+3	Plutonium-239	^{239}Pu	2.411E+4
Argon-41	^{41}Ar	1.827 hours	Plutonium-240	^{240}Pu	6.564E+3
Beryllium-7	^{7}Be	53.22 days	Potassium-40	^{40}K	1.251E+9
Californium-252	^{252}Cf	2.645	Radium-226	^{226}Ra	1.6E+3
Carbon-11	^{11}C	20.39 minutes	Radium-228	^{228}Ra	5.75
Carbon-14	^{14}C	5.70E+3	Ruthenium-103	^{103}Ru	39.26 days
Cerium-141	^{141}Ce	32.508 days	Samarium-153	^{153}Sm	46.5 hours
Cerium-144	^{144}Ce	284.91 days	Strontium-89	^{89}Sr	50.53 days
Cesium-134	^{134}Cs	2.0648	Strontium-90	^{90}Sr	28.79
Cesium-137	^{137}Cs	30.167	Technetium-99	^{99}Tc	2.111E+5
Cesium-138	^{138}Cs	32.41 minutes	Thorium-228	^{228}Th	1.9116
Cobalt-58	^{58}Co	70.86 days	Thorium-230	^{230}Th	7.538E+4
Cobalt-60	^{60}Co	5.271	Thorium-232	^{232}Th	1.405E+10
Curium-242	^{242}Cm	162.8 days	Thorium-234	^{234}Th	24.1 days
Curium-244	^{244}Cm	18.1	Tritium	^{3}H	12.32
Iodine-129	^{129}I	157E+7	Uranium-234	^{234}U	2.455E+5
Iodine-131	^{131}I	8.02 days	Uranium-235	^{235}U	7.04E+8
Krypton-85	^{85}Kr	10.756	Uranium-236	^{236}U	2.342E+7
Krypton-88	^{88}Kr	2.84 hours	Uranium-238	^{238}U	4.468E+9
Lead-212	^{212}Pb	10.64 hours	Xenon-133	^{133}Xe	5.243 days
Manganese-54	^{54}Mn	312.12 days	Xenon-135	^{135}Xe	9.14 hours
Neptunium-237	^{237}Np	2.144E+6	Yttrium-90	^{90}Y	64.1 hours
Niobium-95	^{95}Nb	34.991 days	Zirconium-95	^{95}Zr	64.032 days

Source: ICRP 2008

E.2 Radiation

Radiation, or radiant energy, is energy in the form of waves or particles moving through space. Visible light, heat, radio waves, and alpha particles are examples of radiation. When people feel warmth from sunlight, they are actually absorbing the radiant energy emitted by the sun.

Electromagnetic radiation is radiation in the form of electromagnetic waves. Examples include gamma rays, ultraviolet light, and radio waves. Particulate radiation is radiation in the form of particles. Examples include alpha and beta particles. Radiation also is characterized as ionizing or nonionizing because of the way in which it interacts with matter.

E.2.1 Ionizing Radiation

Normally an atom has an equal number of protons and electrons; however, atoms can lose or gain electrons in a process known as ionization. Some forms of radiation (called ionizing radiation) can ionize atoms by knocking electrons off atoms. Examples of ionizing radiation include alpha and beta particles and gamma and x-rays.

Ionizing radiation is capable of changing the chemical state of matter and subsequently causing biological damage. By this mechanism, it is potentially harmful to human health.

E.2.2 Nonionizing Radiation

Nonionizing radiation is described as a series of energy waves composed of oscillating electric and magnetic fields traveling at the speed of light. Nonionizing radiation includes the spectrum of ultraviolet, visible light, infrared, microwave, radio frequency, and extremely low frequency. Lasers commonly operate in the ultraviolet, visible, and infrared frequencies. Microwave radiation is absorbed near the skin, while radio frequency radiation may be absorbed throughout the body. At high enough intensities, both will damage tissue through heating. Excessive visible radiation can damage the eyes and skin (Department of Labor, OSHA *Safety and Health Topics*). However, in the discussion that follows, the term “radiation” is used to describe ionizing radiation.

E.3 Measuring Ionizing Radiation

To determine the possible effects of radiation on the health of the environment and the public, the radiation must be measured. More precisely, its potential to cause damage must be ascertained.

E.3.1 Activity

To determine radiation in the environment, the rate of radioactive decay or activity is measured. The rate of decay varies widely among various radioisotopes. For that reason, 1 gram of a radioactive substance may contain the same amount of activity as several tons of another material. This activity is expressed in a unit of measure known as a curie (Ci). More specifically, 1 Ci equals 3.7×10^{10} (37,000,000,000) atomic disintegrations per second (dps). In the International System of Units, 1 dps equals 1 becquerel (Bq).

E.3.2 Absorbed Dose

The total amount of energy absorbed per unit mass of the exposed material as a result of exposure to radiation is expressed in a unit of measure known as a rad. The effect of the absorbed energy (the biological damage that occurs) is important, not the actual amount. In the International System of Units, 100 rad equals 1 gray (Gy).

E.3.3 Effective Dose

The measure of potential biological damage to the body caused by exposure to and subsequent absorption of radiation is expressed in a unit of measure known as a rem. For radiation protection purposes, 1 rem of any type of radiation has the same damaging effect. Because a rem represents a fairly large dose, the measure is usually expressed as millirem (mrem), which is 1/1000 of a rem. In the International System of Units, 1 sievert (Sv) equals 100 rem; 1 millisievert (mSv) equals 100 mrem. The effective dose (ED) is the weighted sum of equivalent dose over specified tissues or organs. The ED is based on tissue-weighting factors for 12 specific tissues or organs plus a weight factor for the remaining organs and tissues. In addition, the ED is based on the recent lung model, gastrointestinal absorption fractions, and biokinetic models used for selected elements. Specific types of EDs are defined as follows:

- Committed ED – the weighted sum of the committed ED in specified tissues in the human body during the 50-year period following intake
- Collective ED – the product of the mean ED for a population and the number of persons in the population

E.4 Radiation Exposure Pathways

People can be exposed to radionuclides in the environment through a number of routes, as shown in Figure E.2. Potential routes for internal and external exposure are referred to as pathways. For example, radionuclides in air could be inhaled directly or could fall on grass in a pasture. If the grass were then consumed by cows, it would be possible for the radionuclides to impact the cow's milk, and people drinking the milk would be exposed to this radiation. Similarly, radionuclides in water could be ingested by fish, and fishermen or other consumers could then ingest the radionuclides in the fish tissue. People swimming in the water also would be exposed. Exposure to ionizing radiation varies significantly with geographic location, diet, drinking water source, and building construction.

Figure E.2. Examples of radiation pathways

E.5 Radiation Sources and Doses

Basically, radioactive decay, or activity, generates radiant energy. People absorb some of the energy to which they are exposed, either from external or internal radiation. The effect of this absorbed energy is responsible for an individual's dose. Whether radiation is natural or human-made, it has the same effect on people.

There are five broad categories for radiation exposure to the US population (NCRP 2009):

- exposure to ubiquitous background radiation, including radon in homes
- exposure to patients from medical procedures
- exposure from consumer products or activities involving radiation sources
- exposure from industrial, security, medical, educational, and research radiation sources
- exposure to workers that results from their occupations

Figure E.3 gives the percent contributions of various sources of exposure to the total collective dose for the US population in 2006. As shown, the major sources are radon and thoron (37 percent), computed tomography (24 percent), and nuclear medicine (12 percent) (NCRP 2009). Consumer, occupational, and industrial sources contribute about 2 percent to the total US collective dose.

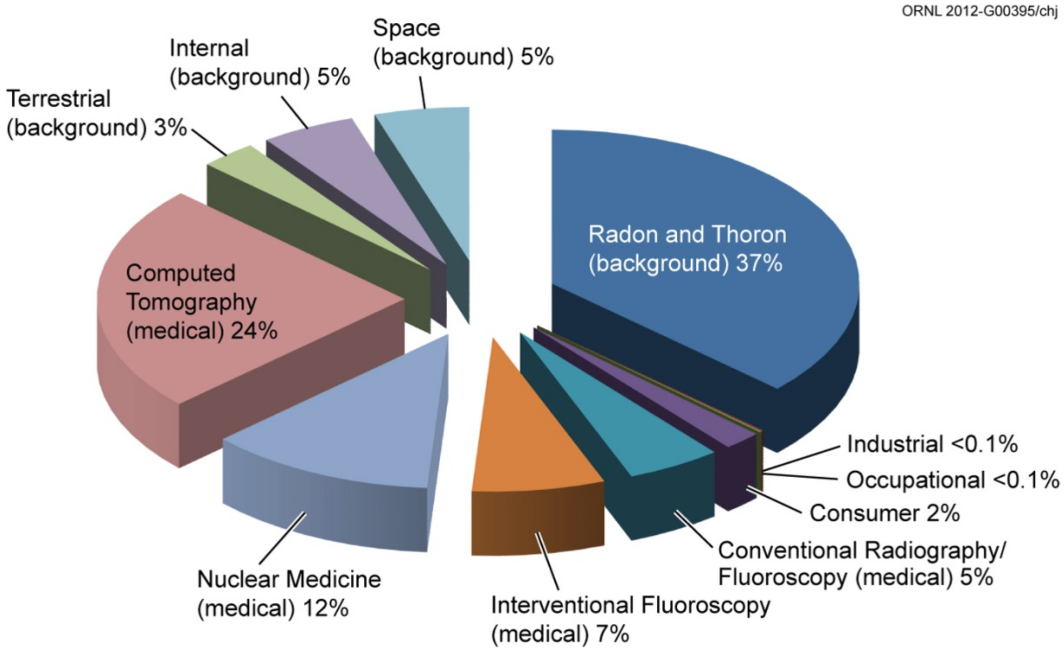

Figure E.3. All exposure categories for collective effective dose for 2006 (NCRP 2009)

E.5.1 Background Radiation

Naturally occurring radiation is the major source of radiation in the environment. Sources of background radiation exposure include the following:

- external exposure from space or cosmic radiation
- external exposure from terrestrial radiation
- internal exposure from inhalation of radon, thoron, and their progeny
- internal exposure from radionuclides in the body

E.5.1.1 External Exposures

Space or Cosmic Radiation

Energetically charged particles from outer space continuously hit the earth's atmosphere. These particles and the secondary particles and photons they create are called cosmic radiation. Because the atmosphere provides some shielding against cosmic radiation, the intensity of this radiation increases with altitude above sea level. For example, a person in Denver is exposed to more cosmic radiation than a person in New Orleans.

The average annual effective dose to people in the United States from cosmic radiation is about 33 mrem, or 0.33 mSv (NCRP 2009). Effective dose rates from cosmic radiation depend on geomagnetic latitude and elevation above sea level.

Terrestrial Radiation

Terrestrial radiation refers to radiation emitted from radioactive materials in the earth's rocks, soils, and minerals. Radon (Rn), radon progeny (the relatively short-lived decay products from the decay of the radon isotope ^{222}Rn), potassium (^{40}K), isotopes of thorium (Th), and isotopes of uranium (U) are the elements responsible for most terrestrial radiation.

The average annual dose from terrestrial gamma radiation is about 21 mrem (0.21 mSv) in the United States, but it varies geographically across the country (NCRP 2009). Typical reported values are about 23 mrem (0.23 mSv) on the Atlantic and Gulf coastal plains, about 90 mrem (0.9 mSv) on the eastern slopes of the Rocky Mountains, and about 46 mrem (0.46 mSv) elsewhere (EPA 2014).

E.5.1.2 Internal Exposures

Radionuclides in the environment enter the body with the air people breathe and the foods they eat. They also can enter through an open wound. Natural radionuclides that can be inhaled and ingested include isotopes of uranium and its progeny, especially radon (^{222}Rn) and its progeny, thoron (^{220}Rn) and its progeny, potassium (^{40}K), rubidium (^{87}Rb), and carbon (^{14}C). Radionuclides contained in the body are dominated by ^{40}K and polonium (^{210}Po); others include ^{87}Rb and ^{14}C (NCRP 1987).

Radon and Thoron and Decay Products

The major contributors to the annual effective dose from background radiation sources are radon and thoron and their short-lived decay products. As shown in Figure E.3, 37 percent of the dose from all exposure categories is from radon and thoron and their decay products, which contribute an average dose of about 228 mrem (2.28 mSv) per year (NCRP 2009). Radon is an inert gas and a small fraction is retained in the body; however, the dose to the lung comes from the short-lived radon decay products. Radon levels vary widely across the United States. Elevated levels are most commonly found in the Appalachians, the upper Midwest, and the Rocky Mountain states (NCRP 2009).

Other Internal Radiation Sources

Other sources of internal radiation include ^{40}K and ^{232}Th and the ^{238}U series. The primary source of ^{40}K in body tissues is food, primarily fruits and vegetables. The sources of radionuclides from ^{232}Th and ^{238}U series are food and water (NCRP 2009). The average dose from these other internal radionuclides is about 29 mrem (0.29 mSv) per year. This dose is attributed predominantly to the naturally occurring radioactive isotope of potassium, ^{40}K.

E.5.2 Human-Made Radiation

In addition to background radiation, there are human-made sources of radiation to which most people are exposed. Examples include consumer products, medical sources, industrial by-products, and fallout from atmospheric atomic bomb tests. No atmospheric testing of atomic weapons has occurred since 1980 (NCRP 1987).

E.5.2.1 Consumer Products

Some consumer products are sources of radiation. The radiation in these products, such as smoke detectors, radioluminous products (e.g., self-illuminating exit signs in commercial buildings), and airport x-ray baggage inspection systems, is essential to the performance of the device. In other products, such as tobacco products and building materials, the radiation occurs incidentally to the product's function (NCRP 1987, NCRP 2009).

The US average annual dose to an individual from consumer products and activities is about 13 mrem (0.13 mSv), ranging between 0.1 and 40 mrem (0.001 and 0.4 mSv). Cigarette smoking accounts for about 35 percent of this dose. Other important sources are building materials (27 percent), commercial air travel (26 percent), mining and agriculture (6 percent), miscellaneous consumer-oriented products (3 percent), combustion of fossil fuels (2 percent), highway and road construction materials (0.6 percent), and glass and ceramics (less than 0.003 percent). Television and video, sewage sludge and ash, and self-illuminating signs all contribute negligible doses (NCRP 2009).

E.5.2.2 Medical Sources

Radiation is an important tool of diagnostic medicine and treatment, which are the main sources of exposure to the public from human-made radiation. Exposure is deliberate and is directly beneficial to the patients exposed. In general, medical exposures from diagnostic or therapeutic x-rays result from beams directed to specific areas of the body. Thus, not all body organs are uniformly irradiated. Nuclear medicine examinations and treatments involve the internal administration of radioactive compounds, or radiopharmaceuticals, by injection, inhalation, consumption, or insertion. Even then, radionuclides are not distributed uniformly throughout the body. Radiation and radioactive materials also are used in preparing medical instruments, including sterilizing heat-sensitive products such as plastic heart valves.

Nuclear medicine examinations, which involve internal administration of radiopharmaceuticals, generally account for the largest portion of dose from human-made sources. However, the radionuclides used for specific tests are not uniformly distributed throughout the body. In these cases the concept of ED, which relates the significance of exposures of organs or body parts to the effect on the entire body, is useful in making comparisons. The average annual ED from medical examinations is roughly 300 mrem (3 mSv), including 147 mrem (1.47 mSv) from computed tomography scans, 77 mrem (0.77 mSv) from nuclear medicine procedures, 43 mrem (0.43 mSv) from interventional fluoroscopy, and 33 mrem (0.33 mSv) from conventional radiography and fluoroscopy (NCRP 2009). Not everyone receives such exams each year.

E.5.2.3 Other Sources

Other sources of radiation include emissions of radioactive materials from nuclear facilities such as uranium mines, fuel-processing plants, and nuclear power plants; transportation of radioactive materials; and emissions from mineral-extraction facilities. The dose to the general public from nuclear fuel cycle facilities, such as uranium mines, mills, fuel-processing plants, nuclear power plants, and transportation routes, has been estimated at less than 1 mrem (0.01 mSv) per year (NCRP 1987).

Small doses to individuals occur because of radioactive fallout from atmospheric atomic bomb tests, emissions of radioactive materials from nuclear facilities, emissions from certain mineral extraction facilities, and transportation of radioactive materials. The combination of these sources contributes less than 1 mrem (0.01 mSv) per year to an individual's average dose (NCRP 1987).

E.6 References

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Appendix F:
Chemicals

Appendix
F. Chemicals

This appendix presents basic information about chemicals. The information is intended as a basis for understanding the dose or relative toxicity assessment associated with possible releases from the Oak Ridge Reservation (ORR), and is not a comprehensive discussion of chemicals and their effects on the environment and biological systems.

F.1 Perspective on Chemicals

The lives of modern humans have been greatly improved by the development of chemicals such as pharmaceuticals, building materials, housewares, pesticides, and industrial chemicals. Through the use of chemicals we can increase food production, cure diseases, build more efficient houses, and send people to the moon. At the same time, we must be cautious to ensure that our own existence is not endangered by uncontrolled and over-expanded use of chemicals (Chan et al. 1982).

Just as all humans are exposed to radiation in their normal daily routines, humans are also exposed to chemicals. Some potentially hazardous chemicals exist in the natural environment. In many areas of the country, soils contain naturally elevated concentrations of metals such as selenium, arsenic, or molybdenum, which may be hazardous to humans or animals. Even some of the foods we eat contain natural toxins. Aflatoxins are found in chili peppers, corn, millet, peanuts, rice, sorghum, sunflower seeds, tree nuts, and wheat. Cyanide is found in apple seeds. However, exposure to many more hazardous chemicals results from the direct or indirect actions of humans. Building materials used in the construction of homes may contain chemicals such as formaldehyde (in some insulation materials), asbestos (formerly used in insulation and ceiling tiles), and lead (formerly used in paints and gasoline). Some chemicals are present as a result of the application of pesticides and fertilizers to soil. Other chemicals may have been transported long distances through the atmosphere from industrial sources before being deposited on soil or water.

F.2 Pathways of Chemicals from Oak Ridge Reservation to the Public

"Pathways" refers to the route or way in which a person can come in contact with a chemical substance. Chemicals released to the air may remain suspended for long periods, or they may be rapidly deposited on plants, soil, and water. Chemicals may also be released as liquid wastes, called "effluents," which can enter streams and rivers.

People are exposed to chemicals by inhalation (breathing air), ingestion (eating exposed plants and animals or drinking water), or direct contact (touching the soil or swimming in water). For example, fish that live in a river that receives effluents may take in some of the chemicals present in the water. People eating the fish and drinking water from the river would then be exposed to the chemicals. The public is not normally exposed to chemicals on ORR because access to the reservation is limited. However, chemicals released as a result of ORR operations can move through the environment to off-site locations, resulting in potential exposure of the public.

F.3 Definitions

F.3.1 Toxicity

Chemicals may have varying types of health effects. Chemical health effects are divided into two broad categories: adverse or systemic effects (noncarcinogens) and cancer (carcinogens). Sometimes a chemical can have both noncarcinogenic and carcinogenic effects. The toxic effect can be acute (a short-term, possible severe health effect) or chronic (a longer term, persistent health effect). Noncarcinogenic toxicity is often evident in a shorter length of time than a carcinogenic effect. The potential health effects of noncarcinogens range from skin irritation to death (or mortality). Carcinogens cause or increase the incidence of malignant neoplasms or cancers.

Toxicity refers to an adverse effect of a chemical on human health. Every day we ingest chemicals in food, water, and sometimes medications. Even those chemicals typically considered toxic are usually nontoxic or harmless below a certain concentration.

Concentration limits or advisories are set by government agencies for some chemicals that are known or thought to have adverse effects on human health. These concentration limits can be used to calculate chemical doses that would not harm even those individuals who may be particularly sensitive to the chemical.

F.3.2 Dose Terms for Noncarcinogens

F.3.2.1 Reference Dose

A reference dose is an estimate of a daily exposure level for the human population, including sensitive subpopulations. These reference doses are likely to be without appreciable risk of deleterious effects during a lifetime. Units are expressed as milligrams of chemical per kilogram of an adult’s body weight per day (mg/kg-day). Values for reference doses are derived from doses of chemicals that resulted in no adverse effect, or the lowest dose that showed an adverse effect on humans or laboratory animals.

Uncertainty factors are typically used in deriving reference doses. Uncertainty adjustments may be made if animal toxicity data are extrapolated to humans, to account for human sensitivity; extrapolated from subchronic to chronic no-observed-adverse-effect levels; extrapolated from lowest-observed-adverse-effect levels to no-observed-adverse-effect levels; and to account for data deficiencies. The use of uncertainty factors in deriving reference doses is thought to help protect sensitive human populations. The US Environmental Protection Agency (EPA) maintains the Integrated Risk Information System (IRIS) database, which contains verified reference doses and up-to-date health risk and EPA regulatory information for numerous chemicals.

F.3.2.2 Primary Maximum Contaminant Levels

For chemicals for which reference doses are not available in IRIS, Tennessee Water Quality Criteria for domestic water supply, which reflect maximum contaminant levels expressed in milligrams of chemical per liter of drinking water, are converted to reference dose values by multiplying by 2 liters (the average daily adult water intake) and dividing by 80 kg (the reference adult body weight). The result is a “derived” reference dose expressed in milligrams per kilogram per day (mg/kg-day).

F.3.3 Dose Term for Carcinogens

F.3.3.1 Slope Factor

A slope factor is a plausible upper-bound estimate of the probability of a response per unit intake of a chemical during a lifetime. The slope factor is used to estimate an upper-bound probability of an individual developing cancer as a result of a lifetime exposure to a particular level of a chemical. Units are expressed as risk per dose (in mg/kg-day).

The slope factor converts the estimated daily intake averaged over a lifetime exposure to the incremental risk of an individual developing cancer. Because it is unknown for most chemicals whether a threshold (a dose below which no adverse effect occurs) exists for carcinogens, units for carcinogens are set in terms of risk factors. Acceptable risk levels for carcinogens range from 10^{-4} (risk of developing cancer over a human lifetime is 1 in 10,000) to 10^{-6} (risk of developing cancer over a human lifetime is 1 in 1,000,000). In other words, a certain chemical concentration in food or water could cause a risk of one additional cancer for every 10,000 (10^{-4}) to 1,000,000 (10^{-6}) exposed persons, respectively.

F.4 Measuring Chemicals

Environmental samples are collected in areas surrounding ORR and are analyzed for those chemical constituents most likely to be released from ORR. Typically, chemical concentrations in liquids are expressed in terms of milligrams or micrograms of chemical per liter of water; concentrations in solids (soil and fish tissue) are expressed in terms of milligrams or micrograms of chemical per gram or kilogram of sample material.

The instruments used to measure chemical concentrations are sensitive; however, there are limits below which they cannot detect chemicals of interest. Concentrations detected below the reported analytical detection limits of the instruments are recorded by the laboratory as estimated values, which have a greater uncertainty than concentrations detected above the detection limits of the instruments. Health effect calculations that use these estimated values are indicated by the less-than symbol (<), which indicates that the value for a parameter was not quantifiable at the analytical detection limit.

F.5 Risk Assessment Methodology

F.5.1 Exposure Assessment

To evaluate an individual's exposure by way of a specific exposure pathway, the intake amount of the chemical must be determined. For example, chemical exposure by drinking water and eating fish from the Clinch River is assessed in the following manner: Clinch River surface water and fish samples are analyzed to estimate chemical contaminant concentrations. It is assumed that individuals drink about 2 liters (0.5 gal) of water per day directly from the river, which amounts to 730 liters (193 gal) per year, and that they eat 0.07 kg (roughly 0.2 lb) of fish per day from the river (27 kg or 60 lb per year). Estimated daily intakes or estimated doses to the public are calculated by multiplying measured (statistically significant) concentrations in water by 2 liters, or those in fish by 0.07 kg. This intake is first multiplied by the exposure duration (26 years) and exposure frequency (350 days per year) and then divided by an averaging time (26 years for noncarcinogens and 70 years for carcinogens) and 80 kg body weight. These assumptions are conservative, and in many cases they result in higher estimated intakes and doses than an individual would actually receive.

F.5.2 Dose Estimate

Once the chemical contaminant oral daily intake has been estimated, the dose is determined. For chemicals, the dose to humans is measured as milligrams per kilogram-day (mg/kg-day). In this case, "kilogram" refers to the body weight of an adult. When a chemical dose is calculated, the length of time an individual is exposed to a certain concentration is important. To assess off-site chemical doses, it is assumed that the exposure duration occurs over 30 years. Such exposures are called "chronic" in contrast to short-term exposures, which are called "acute."

F.5.3 Calculation Method

Current risk assessment methodologies use the term hazard quotient to evaluate noncarcinogenic health effects. Because intakes are calculated in milligrams per kilogram per day in the hazard quotient methodology, they are expressed in terms of dose. Hazard quotient values of less than 1 indicate an unlikely potential for adverse noncarcinogenic health effects, whereas hazard quotient values greater than 1 indicate a concern for adverse health effects or the need for further study.

Risk methods evaluating carcinogenic risk use slope factors instead of reference doses. To estimate the potential carcinogenic risk from ingestion of water and fish, the estimated dose or intake (I) is multiplied by the slope factor (risk per mg/kg-day). As mentioned earlier, acceptable risk levels for carcinogens range from 10–4 (risk of developing cancer over a human lifetime is 1 in 10,000) to 10–6 (risk of developing cancer over a human lifetime is 1 in 1,000,000). Carcinogenic risks greater than 10–4 indicate a concern for adverse health effects or the need for further study.

F.6 References

Chan, P.K., G.P. O'Hara, and A.W. Hayes, 1982. "Principles and Methods for Acute and Subchronic Toxicity." *Principles and Methods of Toxicology.* Raven Press, New York.

Memorandum: Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors, OSWER Directive 9200.1-120, U.S Environmental Protection Agency, February 6, 2014.

TDEC 2008. "General Water Quality Criteria." Chapter 1200-4-3 in *Rules of Tennessee Department of Environment and Conservation, Tennessee Water Quality Control Board, Division of Water Pollution Control*. June.

Appendix G:
Errata for Past ASERs

Appendix
G. Errata for Past ASERs

As this 2018 Oak Ridge Reservation Annual Site Environmental Report (ORR ASER) was being prepared, it was discovered that a unit conversion error in some previous ORR ASERs resulted in reporting incorrect radionuclide concentration data for hay and vegetables. The error began with the ASER issued for calendar year 2003. In the affected ASERs, the titles of tables that reported radionuclide concentrations in hay and vegetables indicated the concentrations shown in the body of the table were presented in pCi/kg. However, the results were instead shown in pCi/mg.

The following ASERs were affected by this error:

For hay: 2003–2007 and 2017 (data was not reported for hay in 2008−2016)

For vegetables: 2003–2016 (data was not reported for vegetables in 2017)

Correct versions of the affected tables are provided on the following pages. The concentration values in these replacement tables are reported in pCi/kg, as their titles indicate. Other than providing corrected concentration values, the corrected tables have the same numbers and titles and are as similar as possible to the tables in the original ASERs to facilitate comparisons.

It is important to note that dose calculations reported in the 2003–2017 ASERs were not affected by this unit conversion error. Dose calculations for all ASERs used unconverted hay and vegetable radionuclide concentrations, and were therefore reported correctly.

Table 7.6. Concentrations of radionuclides detected in vegetables, 2003 (pCi/kg)[a,b]

Location	Gross alpha	Gross beta	^{40}K	^{234}U	^{235}U	^{238}U
			Lettuce			
East of Y-12, #1	23	2,600	5,700	7.4	*c*	*c*
East of Y-12, Claxton	36	3,500	6,300	*c*	*c*	*c*
Northeast of Y-12, Scarboro #1	*c*	1,600	3,100	*c*	*c*	3.3
Northeast of Y-12, Scarboro #2	32	3,200	5,100	10	*c*	5.4
Southeast of ORNL	20	2,300	3,800	*c*	*c*	*c*
West of ETTP	*c*	2,200	4,400	4.4	*c*	*c*
			Tomato			
East of Y-12, #1	*c*	2,200	1,700	*c*	*c*	*c*
East of Y-12, Claxton	*c*	1,900	1,900	3.9	2.3	*c*
Northeast of Y-12, Scarboro #1	*c*	1,900	*c*	3.1	*c*	*c*
Northeast of Y-12, Scarboro #2	*c*	1,900	1,600	*c*	2.0	1.3
Southeast of ORNL	*c*	1,700	1,700	*c*	*c*	*c*
West of ETTP	*c*	2,100	1,800	*c*	*c*	*c*
			Turnip			
East of Y-12, #1	20	2,000	3,100	*c*	*c*	*c*
East of Y-12, Claxton	63	3,800	5,100	*c*	*c*	*c*
Northeast of Y-12, Scarboro #1	20	1,700	2,300	*c*	*c*	*c*
Northeast of Y-12, Scarboro #2	*c*	2,100	2,700	*c*	*c*	*c*
Southeast of ORNL	31	2,600	4,000	*c*	*c*	*c*
West of ETTP	24	2,300	3,100	*c*	*c*	*c*

[a]Detected radionuclides are detected above the minimum detectable activity.
[b]1 pCi = 3.7E-02 Bq.
[c]Value was not detected above the minimum detectable activity.

Table 7.6. Concentrations of radionuclides detected in vegetables, 2004 (pCi/kg)[a]

Location	Gross alpha	Gross beta	^{40}K	^{234}U	^{235}U	^{238}U
Lettuce						
East of Y-12, #1	23	2,200	2,500	*b*	*b*	3.9
East of Y-12, Claxton	*b*	3,400	4,000	6.9	*b*	3.7
Northeast of Y-12, Scarboro #1	53	2,700	3,600	9.8	2.8	6.3
Northeast of Y-12, Scarboro #2	*b*	2,500	2,800	8.1	*b*	5.4
Southeast of ORNL	29	2,100	3,100	8.8	2.7	*b*
West of ETTP	*b*	2,600	3,500	9.0	2.1	*b*
Tomato						
East of Y-12, #1	*b*	1,700	1,900	*b*	*b*	*b*
East of Y-12, Claxton	25	1,500	*b*	*b*	*b*	*b*
Northeast of Y-12, Scarboro #1	220	2,600	2,700	17	*b*	10
Northeast of Y-12, Scarboro #2	35	1,400	*b*	7.1	*b*	*b*
Southeast of ORNL	44	1,700	2,900	23	*b*	*b*
West of ETTP	*b*	1,500	2,500	9.6	*b*	*b*
Turnip						
East of Y-12, #1	33	2,500	*b*	*b*	*b*	6.5
East of Y-12, Claxton	*b*	2,200	2,200	*b*	*b*	*b*
Northeast of Y-12, Scarboro #1	34	2,500	2,000	*b*	*b*	*b*
Northeast of Y-12, Scarboro #2	150	2,900	3,200	*28*	*b*	19
Southeast of ORNL	62	2,800	3,200	*b*	*b*	*b*
West of ETTP	*b*	3,000	4,500	*b*	*b*	*b*

[a]Detected radionuclides are detected above the minimum detectable activity.
[b]Value was not detected above the minimum detectable activity.

Table 7.6. Concentrations of radionuclides detected in vegetables, 2005 (pCi/kg)[a]

Location	Gross alpha	Gross beta	^{40}K	^{234}U	^{235}U	^{238}U
			Lettuce			
East of Y-12, #1	*b*	2,700	4,300	8.6	3.2	*b*
East of Y-12, Claxton	46	2,400	4,700	7.6	*b*	4.0
Northeast of Y-12, Scarboro #1	49	2,100	3,800	9.4	*b*	11
Northeast of Y-12, Scarboro #2	140	2,300	6,500	12	4.5	7.3
Southeast of ORNL	140	3,300	4,400	8.8	5.9	9.2
West of ETTP	44	3,100	3,400	8.7	*b*	3.9
			Tomato			
East of Y-12, #1	70	1,900	2,600	8.0	*b*	*b*
East of Y-12, Claxton	50	1,300	1,500	*b*	*b*	*b*
Northeast of Y-12, Scarboro #1	*b*	1,500	2,900	*b*	*b*	*b*
Northeast of Y-12, Scarboro #2	*b*	1,400	*b*	6.3	*b*	7.1
Southeast of ORNL	21	1,400	*b*	*b*	*b*	23
West of ETTP	*b*	1,600	2,400	*b*	*b*	*b*
			Turnip			
East of Y-12, #1	*b*	1,400	2,600	*b*	*b*	*b*
East of Y-12, Claxton	*b*	1,300	2,300	*b*	*b*	*b*
Northeast of Y-12, Scarboro #1	*b*	1,600	2,900	*4.6*	*b*	*b*
Northeast of Y-12, Scarboro #2	*b*	2,000	5,200	*7.0*	*b*	*b*
Southeast of ORNL	*b*	2,100	3,800	*b*	*b*	*b*
West of ETTP	*b*	2,100	2,600	*b*	*b*	*b*

[a]Detected radionuclides are detected above the minimum detectable activity. 1 pCi = 3.7×10^{-2} Bq.
[b]Value was not detected above the minimum detectable activity.

Table 7.7. Concentrations of radionuclides detected in vegetables, 2006 (pCi/kg)[a]

Location	Gross alpha	Gross beta	^{7}Be	^{40}K	^{234}U	^{235}U	^{238}U
			Lettuce				
East of ORR (Claxton vicinity)	*b*	3,400	*b*	5,100	*b*	*b*	4.1
North of ETTP	32	2,100	*b*	3,700	*b*	*b*	12
North of ORR (Wartburg vicinity)	*b*	2,500	*b*	3,800	8.4	2.0	5.7
Northeast of Y-12, Scarboro #1	60	2,500	*b*	4,300	*b*	*b*	8.8
Northeast of Y-12, Scarboro #2	*b*	3,900	*b*	7,100	*b*	*b*	*b*
South of ORR (Eton Crossroad/ Lenoir City vicinity)	*130*	4,200	*b*	6,100	9.3	*b*	*11*
Southeast of ORNL	*b*	2,800	960	3,200	*b*	1.9	*b*
Southwest of ORR (Kingston vicinity)	160	4,400	*b*	5,800	13	1.8	14
			Tomato				
East of ORR (Claxton vicinity)	*b*	1,100	*b*	*b*	*b*	*b*	*b*
North of ETTP	73	1,800	*b*	3,500	*b*	*b*	*b*
North of ORR (Wartburg vicinity)	*110*	1,500	*b*	1,900	*b*	*b*	*b*
Northeast of Y-12, Scarboro #1	*b*	1,000	*b*	2,900	9.0	*b*	*b*
Northeast of Y-12, Scarboro #2	*b*	1,500	*b*	2,300	*b*	*b*	*b*
South of ORR (Eton Crossroad/ Lenoir City vicinity)	*b*	1,800	*b*	2,400	*b*	*b*	*b*
Southeast of ORNL	55	1,500	*b*	1,800	*b*	*b*	*b*
Southwest of ORR (Kingston vicinity)	*b*	1,500	*b*	2,800	*b*	*b*	*b*
			Turnip Roots				
East of ORR (Claxton vicinity)	*b*	1,800	*b*	4,200	*b*	*b*	*b*
North of ETTP	19	1,600	*b*	3,100	*b*	*b*	*b*
North of ORR (Wartburg vicinity)	*b*	2,000	*b*	5,000	3.8	*b*	*b*
Northeast of Y-12, Scarboro #1	*b*	1,200	*b*	1,800	*b*	*b*	*b*
Northeast of Y-12, Scarboro #2	25	1,800	*b*	3,700	8.5	*b*	5.2
South of ORR (Eton Crossroad/ Lenoir City vicinity)	32	2,100	*b*	2,600	*b*	*b*	*b*
Southeast of ORNL	23	2,200	*b*	3,700	*b*	*b*	*b*

Table 7.7. Concentrations of radionuclides detected in vegetables, 2006 (pCi/kg)[a] (Continued)

Location	Gross alpha	Gross beta	^{7}Be	^{40}K	^{234}U	^{235}U	^{238}U
Southwest of ORR (Kingston vicinity)	24	2,100	*b*	3,400	*b*	3.3	*b*

[a]Detected radionuclides are those detected at or above minimum detectable activity. 1 pCi = 3.7×10^{-2} Bq.
[b]Value was not detected above minimum detectable activity.

Table 6.7. Concentrations of radionuclides detected in vegetables, 2007 (pCi/kg)[a]

Location	Gross alpha	Gross beta	^{7}Be	^{40}K	^{234}U	^{235}U	^{238}U
			Lettuce				
East of ORR (Claxton vicinity)	91	2,500	*b*	4,800	*b*	*b*	*b*
North of ETTP	61	2,400	*b*	6,700	9.2	3.6	10
Northeast of Y-12, Scarboro #1	*b*	2,800	*b*	4,200	9.1	2.2	9.1
Northeast of Y-12, Scarboro #2	*b*	1,800	*b*	4,600	6.0	*b*	*b*
Southeast of ORNL	91	3,000	*b*	5,000	*b*	*b*	*b*
Southwest of ORNL	*b*	2,500	*b*	6,800	*b*	*b*	*b*
			Tomato				
East of ORR (Claxton vicinity)	*b*	1,500	*b*	2,000	*b*	*b*	*b*
North of ETTP	*b*	1,200	*b*	3,100	5.3	*b*	3.9
Northeast of Y-12, Scarboro #1	*b*	1,700	*b*	1,800	*b*	2.5	*b*
Northeast of Y-12, Scarboro #2	*b*	1,500	*b*	1,600	*b*	*b*	*b*
Southeast of ORNL	*b*	540	*b*	1,800	*b*	*b*	*b*
Southwest of ORNL	*b*	800	*b*	1,800	*b*	*b*	*b*
			Turnips				
East of ORR (Claxton vicinity)	*b*	1,800	*b*	1,900	*b*	*b*	*b*
North of ETTP	56	2,000	*b*	2,600	6.0	2.7	*b*
Northeast of Y-12, Scarboro #1	*b*	1,500	*b*	1,800	*b*	*b*	*b*
Northeast of Y-12, Scarboro #2	50	2,500	*b*	2,100	*b*	*b*	*b*
Southeast of ORNL	*b*	2,200	*b*	3,200	*b*	*b*	*b*
Southwest of ORNL	*b*	1,800	*b*	2,400	*b*	*b*	*b*

[a]Detected radionuclides are those detected at or above minimum detectable activity. 1 pCi = 3.7×10^{-2} Bq.
[b]Value was not detected above minimum detectable activity.

Table 6.6. Concentrations of radionuclides detected in vegetables, 2008 (pCi/kg)[a]

Location	Gross alpha	Gross beta	^{7}Be	^{40}K	^{234}U	^{235}U	^{238}U
Lettuce							
East of ORR (Claxton vicinity)	30	940	*b*	3,200	5.0	*b*	*b*
North of ETTP	*b*	4,700	*b*	7,900	5.7	*b*	*b*
Northeast of Y-12, Scarboro #1	23	1,400	*b*	4,700	*b*	*b*	*b*
Northeast of Y-12, Scarboro #2	30	2,000	*b*	4,600	*b*	*b*	*b*
Southeast of ORNL	79	2,500	340	4,900	*b*	*b*	*b*
Southwest of ORNL	140	3,000	*b*	5,800	*b*	*b*	*b*
Tomato							
East of ORR (Claxton vicinity)	48	1,300	*b*	2,400	*b*	*b*	*b*
North of ETTP	*b*	1,700	*b*	2,600	*b*	*b*	*b*
Northeast of Y-12, Scarboro #1	29	1,300	*b*	2,400	*b*	*b*	*b*
Northeast of Y-12, Scarboro #2	*b*	1,900	*b*	2,500	*b*	*b*	*b*
Southeast of ORNL	190	1,400	*b*	2,700	*b*	*b*	*b*
Southwest of ORNL	18	1,600	*b*	1,700	*b*	*b*	*b*
Turnips							
East of ORR (Claxton vicinity)	51	1,500	*b*	1,900	*b*	*b*	*b*
North of ETTP	41	1,900	*b*	3,500	*b*	1.6	*b*
Northeast of Y-12, Scarboro #1	100	2,200	*b*	3,000	*b*	*b*	*b*
Northeast of Y-12, Scarboro #2	92	1,900	*b*	2,500	*b*	*b*	*b*
Southeast of ORNL	69	1,500	*b*	2,400	*b*	*b*	*b*
Southwest of ORNL	85	2,000	*b*	2,400	*b*	*b*	*b*

[a]Detected radionuclides are those detected at or above minimum detectable activity. 1 pCi = 3.7×10^{-2} Bq.
[b]Value was not detected above minimum detectable activity.

Table 6.6. Concentrations of radionuclides detected in vegetables, 2009 (pCi/kg)[a]

Location	Gross alpha	Gross beta	^{7}Be	^{40}K	^{234}U	^{235}U	^{238}U
Lettuce							
East of ORR (Claxton vicinity)	40	2,900	1,100	4,800	7.3	*b*	9.2
North of ETTP	57	3,600	*b*	4,500	4.8	*b*	5.2
Northeast of Y-12, Scarboro #2	*b*	3,000	*b*	5,200	2.8	*b*	3.1
North of Y12	67	4,100	*b*	6,300	14	*b*	14
Southwest of ORNL, Lenoir City #1	71[c]	4,200	*b*	5,100	9.3	*b*	9.2
Southwest of ORNL, Lenoir City #2	80	3,400	*b*	5,500	*b*	*b*	*b*
Reference location, Maryville	38	2,900	*b*	3,800	3.7	*b*	*b*
Tomato							
East of ORR (Claxton vicinity)	400[d]	690	*b*	*b*	*b*	*b*	2.2
North of ETTP	260	570	*b*	*b*	4.4	*b*	*b*
Northeast of Y-12, Scarboro #2	*b*	470	*b*	2,500	*b*	2.3	*b*
North of Y12	210	730	*b*	1,500	4.8	*b*	*b*
Southwest of ORNL, Lenoir City #1	*b*	740	*b*	*b*	8.5	*b*	*b*
Southwest of ORNL, Lenoir City #2	15[e]	710	*b*	1,900	*b*	*b*	*b*
Reference location, Maryville	*b*	610	*b*	2,000	*b*	*b*	2.6
Turnips							
East of ORR (Claxton vicinity)	*b*	1,500	*b*	2,500	*b*	*b*	2.5
North of ETTP	22	1,700	*b*	2,600	*b*	*b*	*b*
Northeast of Y-12, Scarboro #2	200[f]	1,700	*b*	3,300	*b*	*b*	*b*
North of Y12	17	1,900	*b*	2,300	*b*	*b*	*b*
Southwest of ORNL, Lenoir City #1	110	2,200	*b*	2,800	*b*	*b*	*b*
Southwest of ORNL, Lenoir City #2	*b,g*	2,300	*b*	2,500	*b*	*b*	*b*
Reference location, Maryville	22[h]	2,000	*b*	*b*	*b*	*b*	*b*

[a]Detected radionuclides are those at or above minimum detectable activity. 1 pCi = 3.7 × 10^{-2} Bq.
[b]Value was not above minimum detectable activity.
[c]Additional analyses were conducted to identify alpha activity: $^{239/240}$Pu was detected at 6.1 pCi/kg; none of the following were above minimum detectable activity: ^{241}Am, ^{242}Cm, ^{244}Cm, ^{237}Np, ^{238}Pu, ^{228}Th, ^{230}Th, and ^{232}Th.
[d]Additional analyses were conducted to identify alpha activity, and none of the following were above minimum detectable activity: ^{241}Am, ^{242}Cm, ^{244}Cm, ^{237}Np, ^{238}Pu, $^{239/240}$Pu, ^{228}Th, and ^{230}Th, and ^{232}Th.
[e]Additional analyses were conducted to identify alpha activity: ^{241}Am was detected at 4.2 pCi/kg, and ^{242}Cm was detected at 13 pCi/kg. None of the following were above minimum detectable activity: ^{244}Cm, ^{237}Np, ^{238}Pu, $^{239/240}$Pu, ^{228}Th, and ^{230}Th, and ^{232}Th.
[f]Additional analyses were conducted to identify alpha activity; none of the following were above minimum detectable activity: ^{241}Am, ^{242}Cm, ^{244}Cm, ^{237}Np, ^{238}Pu, $^{239/240}$Pu, ^{228}Th, ^{230}Th, and ^{232}Th.
[g]Additional analyses were conducted to identify alpha activity: ^{232}Th was detected at 2.9 pCi/kg; none of the following were above minimum detectable activity: ^{241}Am, ^{242}Cm, ^{244}Cm, ^{237}Np, ^{238}Pu, $^{239/240}$Pu, ^{228}Th, and ^{230}Th.
[h]Additional analyses were conducted to identify alpha activity; none of the following were above minimum detectable activity: ^{241}Am, ^{242}Cm, ^{244}Cm, ^{237}Np, ^{238}Pu, $^{239/240}$Pu, ^{228}Th, ^{230}Th, and ^{232}Th.

Table 6.5. Concentrations of radionuclides detected in vegetables, 2010 (pCi/kg)[a]

Location	Gross alpha	Gross beta	^{7}Be	^{40}K	^{234}U	^{235}U	^{238}U
			Lettuce				
East of ORR (Claxton vicinity)	41	2,600	*b*	3,000	*b*	*b*	*b*
North of ETTP	34	4,000	*b*	4,600	8.7	*b*	5.6
Northeast of Y-12, Scarboro #2	*b*	2,600	*b*	4,800	22	*b*	28
Southwest of ORNL, Lenoir City #1	46[c]	4,500	*b*	5,300	*b*	*b*	*b*
Southwest of ORNL, Lenoir City #2	22	2,000	*b*	5,800	*b*	*b*	*b*
Reference location, Maryville	27	2,200	*b*	6,400	*b*	*b*	*b*
			Tomato				
East of ORR (Claxton vicinity)	*b*	800	*b*	*b*	27	*b*	*b*
North of ETTP	*b*	820	*b*	2,500	*b*	*b*	*b*
Northeast of Y-12, Scarboro #2	*b*	950	*b*	1,200	*b*	*b*	*b*
Southwest of ORNL, Lenoir City #1	*b*	640	*b*	2,000	*b*	*b*	*b*
Southwest of ORNL, Lenoir City #2	*b*[d]	1,100	*b*	1,300	4.1	*b*	*b*
Reference location, Maryville	26	450	*b*	1,700	*b*	*b*	*b*
			Turnips				
East of ORR (Claxton vicinity)	280	1,100	*b*	2,200	*b*	*b*	*b*
North of ETTP	32	1,600	*b*	2,600	*b*	*b*	*b*
Northeast of Y-12, Scarboro #2	190	1,800	*b*	3,200	*b*	*b*	*b*
Southwest of ORNL, Lenoir City #1	*b*	1,100	*b*	3,300	*b*	*b*	*b*
Southwest of ORNL, Lenoir City #2	*b*	1,400	*b*	2,600	*b*	*b*	*b*
Reference location, Maryville	31	990	*b*	*b*	*b*	*b*	*b*

[a]Detected radionuclides are those at or above minimum detectable activity. 1 pCi = 3.7×10^{-2} Bq.
[b]Value was not above minimum detectable activity.
[c]Additional analyses were conducted to identify alpha activity: ^{241}Am was detected at 3.4 pCi/kg and ^{232}Th was detected at 16 pCi/kg; none of the following were above minimum detectable activity: ^{242}Cm, ^{244}Cm, ^{237}Np, ^{238}Pu, $^{239/240}$Pu, ^{228}Th, and ^{230}Th.
[d]Additional analyses were conducted to identify alpha activity: ^{232}Th was detected at 17 pCi/kg; none of the following were above minimum detectable activity: ^{241}Am, ^{242}Cm, ^{244}Cm, ^{237}Np, ^{238}Pu, $^{239/240}$Pu, ^{228}Th, and ^{230}Th.

Table 6.5. Concentrations of radionuclides detected in vegetables, 2011 (pCi/kg)[a]

Location	Gross alpha	Gross beta	^{7}Be	^{40}K	^{234}U	^{235}U	^{238}U
Lettuce							
East of ORR (Claxton vicinity)	41	3,200	*b*	3,700	*b*	*b*	*b*
North of ETTP	120	4,600	*b*	5,300	*b*	*b*	*b*
Northeast of Y-12 Complex, Scarboro #2	41	3,000	*b*	4,100	*b*	*b*	*b*
Southwest of ORNL, Lenoir City #1	45	4,200	*b*	5,600	8.6	*b*	6.4
Southwest of ORNL, Lenoir City #2	65	4,700	*b*	5,400	*b*	*b*	*b*
Reference location, Maryville	170	3,300	*b*	3,500	*b*	*b*	*b*
Tomato							
East of ORR (Claxton vicinity)	*b*	840	*b*	*b*	*b*	*b*	*b*
North of ETTP	*b*	720	*b*	3,000	*b*	*b*	*b*
Northeast of Y-12 Complex, Scarboro #2	*b*	360	*b*	1,900	*b*	*b*	*b*
Southwest of ORNL, Lenoir City #1	120	830	*b*	*b*	*b*	*b*	*b*
Southwest of ORNL, Lenoir City #2	23	600	*b*	*b*	*b*	*b*	*b*
Reference location, Maryville	*b*	380	*b*	*b*	*b*	*b*	*b*
Turnips							
East of ORR (Claxton vicinity)	*b*	1,100	*b*	3,000	*b*	*b*	*b*
North of ETTP	*b*	900	*b*	*b*	*b*	*b*	*b*
Northeast of Y-12 Complex, Scarboro #2	*b*	860	*b*	1,900	*b*	*b*	*b*
Southwest of ORNL, Lenoir City #1	*b*	900	*b*	2,800	*b*	*b*	3.5
Southwest of ORNL, Lenoir City #2	17	790	*b*	*b*	*b*	*b*	*b*
Reference location, Maryville	*b*	620	*b*	*b*	*b*	*b*	*b*

[a]Detected radionuclides are those at or above minimum detectable activity. 1 pCi = 3.7×10^{-2} Bq.
[b]Value was not above minimum detectable activity.

Acronyms
ETTP = East Tennessee Technology Park
ORNL = Oak Ridge National Laboratory
ORR = Oak Ridge Reservation
Y-12 Complex = Y-12 National Security Complex

Table 6.5. Concentrations of radionuclides detected in vegetables, 2012 (pCi/kg)a

Location	Gross alpha	Gross beta	^{7}Be	^{40}K	^{234}U	^{235}U	^{238}U
			Lettuce				
East of Y-12 Complex (Claxton vicinity)	61	3,800	*b*	4,900	*b*	*b*	*b*
West of ETTP	*b*	3,900	*b*	4,900	*b*	*b*	*b*
North of Y-12 Complex	100	5,100	*b*	6,100	*b*	*b*	*b*
South of ORNL	*b*	2,300	*b*	4,800	*b*	*b*	*b*
Southwest of ORNL, Lenoir City	*b*	3,000	*b*	4,900	*b*	*b*	*b*
Reference location, Maryville	*b*	2,700	*b*	4,400	*b*	*b*	*b*
			Tomato				
East of Y-12 Complex, (Claxton vicinity)	*b*	320	*b*	1,300	*b*	*b*	*b*
West of ETTP	*b*	450	*b*	1,700	*b*	*b*	*b*
North of Y-12 Complex	*b*	530	*b*	*b*	2.6	*b*	*b*
South of ORNL	31	780	*b*	1,500	*b*	*b*	*b*
Southwest of ORNL, Lenoir City	*b*	850	*b*	*b*	*b*	*b*	*b*
Reference location, Maryville	*b*	400	*b*	1,400	*b*	*b*	*b*
			Turnips				
East of Y-12, Complex (Claxton vicinity)	*b*	1,600	*b*	2,400	*b*	*b*	*b*
West of ETTP	34	1,300	*b*	2,600	*b*	*b*	*b*
North of Y-12 Complex	36	1,500	*b*	1,800	*b*	*b*	*b*
South of ORNL	190	1,600	*b*	1,800	*b*	*b*	*b*
Southwest of ORNL, Lenoir City	*b*	1,800	*b*	4,800	*b*	*1.5*	*b*
Reference location, Maryville	*b*	1,300	*b*	2,500	*b*	*b*	*b*

[a]Detected radionuclides are those at or above minimum detectable activity. 1 pCi = 3.7 × 10^{-2} Bq.
[b]Value was not above minimum detectable activity.

Acronyms
ETTP = East Tennessee Technology Park
ORNL = Oak Ridge National Laboratory
Y-12 Complex = Y-12 National Security Complex

Table 6.5. Concentrations of radionuclides detected in vegetables, 2013 (pCi/kg)[a]

Location	Gross alpha	Gross beta	^{7}Be	^{40}K	^{234}U	^{235}U	^{238}U
			Lettuce				
East of Y-12 Complex (Claxton vicinity)	*b*	2,860	*b*	3,580	6.11	*b*	4.92
West of ETTP	*b*	3,380	*b*	3,590	*b*	*b*	*b*
North of Y-12 Complex	*b*	4,730	*b*	6,950	5.22	*b*	4.24
South of ORNL	*b*	3,100	*b*	4,570	*b*	*b*	3.77
Southwest of ORNL, Lenoir City	*b*	3,520	*b*	3,610	*b*	*b*	*b*
Reference location, Maryville	*b*	3,340	*b*	5,260	*b*	*b*	*b*
			Tomato				
East of Y-12 Complex, (Claxton vicinity)	*b*	1,310	*b*	2,480	*b*	0.836	*b*
West of ETTP	*b*	988	*b*	2,090	*b*	*b*	*b*
North of Y-12 Complex	*b*	1,120	*b*	2,720	*b*	*b*	*b*
South of ORNL	*b*	994	*b*	2,560	2.68	*b*	*b*
Southwest of ORNL, Lenoir City	*b*	418	*b*	*b*	*b*	*b*	*b*
Reference location, Maryville	*b*	606	*b*	*b*	*b*	*b*	*b*
			Turnips				
East of Y-12, Complex (Claxton vicinity)	*b*	2,200	*b*	3,080	*b*	*b*	*b*
West of ETTP	*b*	1,050	*b*	2,150	*b*	*b*	*b*
North of Y-12 Complex	*b*	2,260	*b*	5,150	*b*	1.11	*b*
South of ORNL	*b*	2,510	*b*	3,620	*b*	*b*	*b*
Southwest of ORNL, Lenoir City	35.9	1,640	*b*	3,020	*b*	*b*	*b*
Reference location, Maryville	*b*	1,500	*b*	2,210	*b*	*b*	*b*

[a]Detected radionuclides are those at or above minimum detectable activity. 1 pCi = 3.7×10^{-2} Bq.
[b]Value was not above minimum detectable activity.

Acronyms
ETTP = East Tennessee Technology Park
ORNL = Oak Ridge National Laboratory
Y-12 Complex = Y-12 National Security Complex

Table 6.5. Concentrations of radionuclides detected in vegetables, 2014 (pCi/kg)[a]

Location	Gross alpha	Gross beta	^{7}Be	^{40}K	^{234}U	^{235}U	^{238}U
			Lettuce				
East of Y-12, Claxton vicinity	*b*	3,530	*b*	4,020	7.54	*b*	6.51
West of ETTP	*b*	4,700	574	5,410	5.62	*b*	10.1
North of Y-12	*b*	3,120	*b*	4,130	3.44	*b*	3.76
South of ORNL	*b*	3,500	*b*	5,760	2.74	*b*	0.856
Southwest of ORNL, Lenoir City	*b*	2,130	*b*	3,840	*b*	0.879	1.49
Reference location, Maryville	*b*	3,280	*b*	4,550	*b*	*b*	*b*
			Tomato				
East of Y-12, Claxton vicinity	*b*	419	*b*	1,090	3.02	*b*	*b*
West of ETTP	*b*	812	*b*	1,870	2.34	*b*	*b*
North of Y-12	*b*	483	*b*	*b*	1.58	*b*	*b*
South of ORNL	*b*	1,090	*b*	1,530	2.15	1.26	*b*
Southwest of ORNL, Lenoir City	*b*	1,170	*b*	1,510	*b*	*b*	*b*
Reference location, Maryville	*b*	727	*b*	1,880	*b*	*b*	1.39
			Turnips				
East of Y-12, Claxton vicinity	*b*	2,520	*b*	2,920	*b*	*b*	*b*
West of ETTP	*b*	3,130	*b*	2,280	*b*	*b*	*b*
North of Y-12	*b*	3,440	*b*	2,970	*b*	*b*	*b*
South of ORNL	*b*	2,150	*b*	3,150	*b*	*b*	*b*
Southwest of ORNL, Lenoir City	*b*	2,030	*b*	2,320	*b*	*b*	*b*
Reference location, Maryville	*b*	2,610	*b*	4,280	*b*	*b*	*b*

[a]Detected radionuclides are those at or above minimum detectable activity. 1 pCi = 3.7×10^{-2} Bq.
[b]Value was not above minimum detectable activity.

Acronyms
ETTP = East Tennessee Technology Park
ORNL = Oak Ridge National Laboratory
Y-12 = Y-12 National Security Complex

Table 6.5. Concentrations of radionuclides detected in vegetables, 2015 (pCi/kg)[a]

Location	Gross alpha	Gross beta	^{7}Be	^{40}K	^{234}U	^{235}U	^{238}U
			Lettuce				
East of Y-12, Claxton vicinity	80.9	4,110	*b*	5,270	9.37	*b*	7.58
West of ETTP	*b*	3,740	*b*	5,210	*b*	*b*	2.45
North of Y-12	86.1	4,420	*b*	5,410	7.48	*b*	3.69
South of ORNL	*b*	3,720	*b*	3,850	5.50	*b*	4.11
Southwest of ORNL, Lenoir City	81.8	4,360	*b*	4,520	*b*	*b*	*b*
Reference location	*b*	4,710	*b*	6,310	*b*	*b*	*b*
			Tomato				
East of Y-12, Claxton vicinity	*b*	572	*b*	*b*	*b*	*b*	*b*
West of ETTP	*b*	3,330	*b*	1,820	*b*	*b*	*b*
North of Y-12	*b*	897	*b*	*b*	4.04	1.46	*b*
South of ORNL	26.7	935	*b*	1,520	*b*	1.30	*b*
Southwest of ORNL, Lenoir City	27.6	908	*b*	1,540	*b*	*b*	*b*
Reference location	*b*	460	*b*	*b*	3.07	1.60	*b*
			Turnips				
East of Y-12, Claxton vicinity	*b*	2,800	*b*	3,410	*b*	*b*	*b*
West of ETTP	*b*	2,160	*b*	2,050	*b*	*b*	1.75
North of Y-12	*b*	2,970	*b*	4,430	3.74	*b*	*b*
South of ORNL	*b*	2,070	*b*	1,800	6.36	*b*	*b*
Southwest of ORNL, Lenoir City	*b*	2,240	*b*	1,410	*b*	*b*	2.94
Reference location	*b*	3,530	*b*	3,600	1.76	*b*	*b*

[a]Detected radionuclides are those at or above minimum detectable activity. 1 pCi = 3.7×10^{-2} Bq.
[b]Value was not above minimum detectable activity.

Acronyms
ETTP = East Tennessee Technology Park
ORNL = Oak Ridge National Laboratory
Y-12 = Y-12 National Security Complex

Table 6.6. Concentrations of radionuclides detected in vegetables, 2016 (pCi/kg)[a]

Location	Gross alpha	Gross beta	^{7}Be	^{40}K	^{234}U	^{235}U	^{238}U
			Lettuce				
East of Y-12, Claxton vicinity	76.8	4,190	672	5,390	3.79	*b*	*b*
West of ETTP	*b*	5,370	*b*	7,350	*b*	*b*	*b*
North of Y-12	*b*	5,260	*b*	6,640	*b*	*b*	2.75
South of ORNL	*b*	4,230	*b*	5,200	*b*	1.80	*b*
Southwest of ORNL, Lenoir City	*b*	3,080	*b*	2,290	3.96	*b*	*b*
Reference location	*b*	1,390	*b*	1,250	3.44	*b*	*b*
			Tomato				
East of Y-12, Claxton vicinity	*b*	2,290	*b*	1,590	*b*	*b*	*b*
West of ETTP	*b*	1,300	*b*	1,780	*b*	*b*	*b*
North of Y-12	*b*	2,160	*b*	2,760	*b*	*b*	*b*
South of ORNL	*b*	2,190	*b*	2,030	*b*	*b*	*b*
Southwest of ORNL, Lenoir City	*b*	1,440	*b*	1,790	*b*	*b*	1.84
Reference location	*b*	1,500	*b*	1,530	2.81	2.2	*b*

[a] Detected radionuclides are those at or above minimum detectable activity. 1 pCi = 3.7×10^{-2} Bq.
[b] Value was less than or equal to minimum detectable activity.

Acronyms
ETTP = East Tennessee Technology Park
ORNL = Oak Ridge National Laboratory
Y-12 = Y-12 National Security Complex

Table 7.5. Concentrations of radionuclides detected in hay, 2003 (pCi/kg)[a,b]

Gross alpha	Gross beta	^{7}Be	^{40}K	$^{233/234}$U	^{238}U
		Area 1-2-3 composite			
92	2,300	3,200	5100	*c*	*c*
		Area 2-4-5 composite			
100	1,500	5,200	*c*	8.8	*c*
		Area 6			
140	1,500	3,700	3100	20	16
		Area 7 – Norris reference location			
130	2,300	5,700	*c*	12	*c*

[a]Detected radionuclides are detected above the minimum detectable activity.
[b]1 pCi = 3.7E-02 Bq.
[c]Value was not detected above the minimum detectable activity.

Table 7.5. Concentrations of radionuclides detected in hay, 2004 (pCi/kg)[a]

Gross alpha	Gross beta	^{7}Be	^{40}K	^{228}Ac	^{234}U	^{235}U	^{238}U
			Area 1-2-3 composite				
b	10,000	10,000	*b*	*b*	10	*b*	*b*
			Area 2-4-5 composite				
60	3,000	17,000	*b*	*b*	6.1	*b*	*b*
			Area 6				
430	3,200	12,000	*b*	*b*	52	6.2	53
			Area 7 – Norris reference location				
91	4,100	11,000	*b*	1,600	7.2	*b*	*b*

[a]Detected radionuclides are detected above the minimum detectable activity.
[b]Value was not detected above the minimum detectable activity.

Table 7.5. Concentrations of radionuclides detected in hay, 2005 (pCi/kg)[a]

Gross alpha	Gross beta	^{7}Be	^{40}K	^{234}U	^{235}U	^{238}U
			Area 1-2-3 composite			
b	11,000	*b*	17,000	*b*	*b*	*b*
			Area 2-4-5 composite			
83	9,900	*b*	28,000	8.0	*b*	5.7
			Area 6			
120	9,400	9,800	17,000	*b*	*b*	9.0
			Area 7 – Norris reference location			
b	9,200	*b*	23,000	*b*	*b*	2.1

[a]Detected radionuclides are detected above the minimum detectable activity. 1 pCi = 3.7 x 10^{-2} Bq.
[b]Value was not detected above the minimum detectable activity.

Table 7.6. Concentrations of radionuclides detected in hay, 2006 (pCi/kg)[a]

Gross alpha	Gross beta	^{7}Be	^{40}K	^{234}U	^{235}U	^{238}U
			Area 1-2-3 composite			
150	11,000	6,200	15,000	12	*b*	9.3
			Area 2-4-5 composite			
320	14,000	*b*	15,000	35	2.9	40
			Area 6			
b	11,000	*b*	17,000	9.5	*b*	7.3
			Area 7 – Norris reference location			
110	12,000	10,000	15,000	*b*	*b*	*b*

[a]Detected radionuclides are detected above the minimum detectable activity. 1 pCi = 3.7 x 10^{-2} Bq.
[b]Value was not detected above the minimum detectable activity.

Table 6.6. Concentrations of radionuclides detected in hay, 2007 (pCi/kg)[a]

Gross alpha	Gross beta	^{7}Be	^{40}K	^{234}U	^{235}U	^{238}U
			Area 1-2-3 composite			
b	14,000	*b*	22,000	*b*	*b*	5.1
			Area 2-4-5 composite			
190	10,000	*b*	20,000	4.6	*b*	8.7
			Area 6			
b	11,000	*b*	17,000	*b*	*b*	*b*
			Area 8 Fort Loudon Dam reference location			
130	11,000	*b*	11,000	3.4	*b*	4.2

[a]Detected radionuclides are detected above the minimum detectable activity. 1 pCi = 3.7 x 10^{-2} Bq.
[b]Value was not detected above the minimum detectable activity.

Table 7.7. Concentrations of radionuclides detected in hay, 2017 (pCi/kg)[a]

Gross alpha	Gross beta	^{7}Be	^{40}K	^{234}U	^{235}U	^{238}U	^{214}Pb
b	10,100	7,910	12,900	3.27	*b*	2.82	525

[a]Detected radionuclides are those detected above the minimum detectable activity. 1 pCi = 3.7×10^{-2} Bq.
[b]Value was not detected above the minimum detectable activity.

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